THE 1st ALL AFRICA POST HARVEST CONGRESS & EXHIBITION

Reducing food losses and waste: Sustainable solutions for Africa

Conference Proceedings

[Peer-reviewed Extended Abstracts]

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FOREWORD

Dear Reader,

We have the pleasure of presenting to you the **Congress Proceedings (Peer-reviewed Extended Abstracts)** of the 1st All Africa Postharvest Congress and Exhibition. The congress theme was **"Reducing Food Losses and Waste: Sustainable Solutions for Africa"**. The theme was unpacked into five subthemes based on five key sub-sectors in Agriculture that include:

1. Perishable food crop commodities (fruits, vegetables, roots & tubers, edible fungi)
2. Perishable livestock and fish food products (including milk, meat, eggs, fish)
3. Non-perishable food commodities (grains, including cereals and pulses, processed foods)
4. Capacity Development including training, research and extension programs
5. Gender, Youth, Policy and Governance issues affecting postharvest management

Over 200 abstracts were received in response to the call for papers for the congress. After the review process, a total of 160 abstracts were accepted for presentation during the congress. These abstracts were published in the congress **Book of Abstracts** which was availed in soft copy during the congress and on the congress website. Further to this, authors of the accepted abstracts were requested to submit extended abstracts with more details using guidelines prepared by the scientific committee of the congress.

This book contains 65 extended abstracts arranged into five sections as guided by the congress subthemes listed above. In the extended abstracts (1500 – 2000 words), the authors present more details of their research findings under the subtitles **Abstract, İntroduction, Materials & Methods/ Methodology, Results & Discussion, Conclusion & Recommendations, Key References**.

The published proceedings from authors around the world present a rich mix of basic science and applied research covering all the food value chains. During the peer review process, preference was given to papers that presented practical and innovative ideas for postharvest loss (PHL) reduction. It is my hope that the additional details provided by the authors will be useful for the readers who are seeking to find applicable solutions for PHL reduction in various food value chains.

We wish to thank and congratulate all the authors for preparing and submitting standard and extended abstracts for this inaugural congress.

We would like to wish you all an informative interaction with the congress proceedings.
Yours Sincerely,

Ambuko

Dr. Jane Ambuko
Chairperson, Local Organizing Committee
1st All Africa Postharvest Congress and Exhibition

Charles L. Wilson

Dr. Charles Wilson
Chairperson, Global Organizing Committee
1st All Africa Postharvest Congress and Exhibition

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Scientific Sub-committee

We would like to thank the team of scientists drawn from various institutions including universities, research and development organizations who were involved in the review of extended abstracts. The team was committed to the rigorous review process that was aimed at achieving quality and consistency of the document.

The scientists involved in the review of extended abstracts include the following:

Dr. Jane Ambuko (University of Nairobi)
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Dr. Charity Mutegi (International Institute of Tropical Agriculture, IITA)

PARTNERS AND SPONSORS

We would like to sincerely thank the University of Nairobi management for accepting onerous task of hosting this inaugural congress, the first of its kind in Kenya and Africa. The overall institutional support during the planning and hosting of the congress contributed immensely to the success. We highly appreciate the great support we received from the government of Kenya through the Ministry of Agriculture Livestock and Fisheries (MOALF).

The congress and subsequently the publication of these proceedings would not have been possible without the funding and support from our partners and sponsors. They include the Rockefeller Foundation (strategic partner); International Institute of Tropical Agriculture (IITA); SNV World; Horticulture Innovation Lab - USAID; Swiss Agency for Development and Cooperation; International Development and Research Center (IDRC); East Africa Trade and Investment Hub - USAID; Postharvest Education Foundation (PEF); Global Cold Chain Alliance (GCCA); Eastern Africa Grain Council (EAGC); Alliance for a Green Revolution in Africa (AGRA); Global Alliance for Improved Nutrition (GAIN); AgResults - Kenya, AgriProFocus-Kenya and Compatible Technology International (CTI), Food and Agriculture Organization (FAO).

We highly appreciate the support of the World Food Preservation Center (WFPC) in the organization of the congress and solicitation of abstracts from the international/global partners and experts in the postharvest management.

We sincerely thank the FAO, specifically the Save food program for the continued support to highlight/disseminate the congress outputs.

We thank everyone (individuals and institutions) who may not have been mentioned above but contributed towards the success of the congress and subsequently in the preparation of these proceedings.

Sub Theme 1

Perishable Food Crop Commodities (Fruits, Vegetables, Roots & Tubers, Edible Fungi)

1001 Postharvest Warm Water Treatment to Control Thrips in Export French Beans

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Abstract
French beans are the most important export crop after cut flowers in Kenya. Their productivity is significantly affected by several thrips species, especially the Western Flower Thrips (Frankliniella occidentalis). Normal postharvest processing of beans results in removal of adult and larval stages of thrips. But the egg stage, which is hidden in the plant tissue, makes deactivation very difficult. This study evaluates the effects of postharvest warm water treatments and post treatment storage conditions on the egg stage of thrips to increase quarantine security of French beans. Effects were investigated regarding the emergence of larvae and the survival of eggs by improved investigation methods. The treatment of French bean pods with warm water at 50°C for at least 5 min resulted in 100% mortality of thrips eggs. Four thrips species were investigated in total. Count of unhatched eggs was implemented after the observation of larval emergence. The treatment of French beans at 50°C did not affect the quality of bean pods related to their extent of surface yellowing. Treated and untreated beans kept under refrigeration at 5°C for a period of 5 days did not show larval emergence. However, once the beans were removed from refrigeration, larval emergence was observed from untreated bean samples. Thus, cold storage alone cannot ensure quarantine security. Warm water treatment at 50°C could be a future option to increase quarantine security against thrips infestation of French beans. This simple method can be used even by small scale farmers in Africa.

Keywords:
French beans, quarantine security, postharvest treatment, Western flower thrips

Introduction
The production of French beans plays an important role in the economy through the provision of food and the livelihood of the people in Africa, especially in Kenya (HCDA, 2010). French beans are an important protein source for people in Eastern Africa (Jones, 1999). The productivity of French beans is significantly affected by several thrips species. The Western Flower Thrips, Frankliniella occidentalis (Pergande), is the most important pest species affecting French bean production (Kasina et al., 2006). As a consequence, the EU and other export markets have implemented stringent quarantine restrictions for invasive pest species over the last couple of years (EU Legislation on MRLs). Integrated Plant Management (IPM) strategies for this pest have been developed and made available for farms in Eastern Africa (Muvea et al., 2014; Nyasani et al., 2015). However, postharvest treatment measures, which focus on egg stage which has the highest risk of spread, still needs to be developed, established and standardized. The egg stage of thrips is laid hidden within the bean tissue and presents the highest risk for spread of thrips into export markets. Normal postharvest processing of French beans results only in the removal of adult and larval stages. Hot water treatments were reported for the first time in 1922 to control decay of citrus fruit (Fawcett, 1922). In 2002, Hara et al. figured out that hot water dips of propagative material of anthurium at 49°C for 10 minutes can disinfect some anthurium cultivars of thrips before planting and without the application of insecticides. In the study from McLaren et al. (1997), a commercial scale hot water bath was tested for nectarines and peaches with good results. All adults and larvae were killed on nectarines at 50° for 2 minutes. For peaches a treatment for 1 minute was already enough to kill all life stages including eggs. The objective of this study was to evaluate simple postharvest warm water treatments on French beans and their impact on different thrips species. Hence the effects of different treatment parameters and post treatment storage conditions were tested. Besides Frankliniella occidentalis, other major thrips species namely Frankliniella schultzei, Megalurothrips sjostedti and Ceratothripoides brunneus were used in the experiments.

Material and Methods
Freshly harvested French bean pods (Phaseolus vulgaris L.) were surface disinfected to remove insects and fungal spores. The beans were then carefully washed with tap water and separated into plastic jars, whereby each jar has been filled with 5 bean pods. After this procedure, each jar was infested with 15 female adult thrips. The thrips were allowed 48 hours to lay eggs on the bean pods. Finally the adult thrips were totally removed from each bean pod, so that only the hidden eggs remained. These bean pods were subjected to three treatments and one set of control. The treatments were as follows;
1) control pods, non-treated beans kept at room temperature (25°C)
2) non-treated beans, kept under refrigeration at 5°C
3) warm water treated beans, kept at room temperature (25°C)
4) warm water treated beans, kept under refrigeration at 5°C

For Frankliniella occidentalis infested bean pods, the effect of warm water treatments were investigated at a temperature of 50°C and treatment time of 15, 10 and 5 minutes. For Frankliniella schultzei, the warm water treatment was undertaken at 50°C for 10 and 5 minutes. One hundred percent mortality of F. occidentalis and F. schultzei eggs was attained by 5 minutes in warm water treatment at 50°C, for Ceratothripoides brunneus and Megalurothrips sjostedti only a 5 minute warm water treatment at 50°C was adopted. The effects of warm water treatments and different post treatment storage conditions were investigated on the emergence of larvae and additionally the survival of eggs.
Once the beans were treated, groups of 5 pods were packed into plastic packages and covered with plastic foil. Observations on the larval emergence were executed each day over a period of up to 7 days post treatment. The observation was stopped when the number of larvae present did not increase anymore. The number of hatched larvae was observed visually and counted

cumulatively per package. The unhatched eggs were finally visualised and assessed by an improved staining procedure, based on Nyasani et al. (2012). For preparation of the staining procedure, standardized tissue parts with a length of 5 cm were sampled from the middle of each bean pod.

Beside the warm water effects to thrips, two other experiments were implemented to find out, whether the quality of the beans is affected by the warm water treatment and if cold storage on its own has an influence on thrips egg development. The effects of warm water on the bean pod quality was assessed during the experiment with Frankliniella schultzei. During this test sequence, the visual quality of bean pods was additionally scored for a period of 5 days post warm water treatment. Related to their extent of yellowing/spoilage compared to the non-treated bean samples, 5 categories were used to define different bean quality. The effects of cold storage to Frankliniella occidentalis oviposition were separately prepared. For this, infected bean pods were refrigerated at 5°C for a period of 24, 48, 72, 96, 120 hours without any warm water treatment. On post refrigeration, the beans were retained at room temperature (approx. 25 °C) for a duration of 6 days. During this period, the emergence of larvae was observed by daily visual checking and cumulative counting. After this 6 days observation period, the bean pod samples, again in the form of 5 cm sections, were prepared and the unhatched eggs were counted as outlinedabove.

Results and Discussion

Current studies in the literature which dealt with warm water treatments focused on the larval and adult life stages of thrips. This study was the first laboratory study on finding IPM strategies against pest insects (thrips) on French beans with focus on the egg life stage. Hara (2013) mentioned that hot water dips are more effective against cryptic insect pests than chemical pesticides because heat penetrates the plant tissue. Insecticidal dips only have surface contact and are less environment-friendly. These positive characteristics of warm water treatments were also recognizable in these experiments. Larval emergence was only detected at all investigated species in the non-treated controls, which were kept at room temperature. The warm water treatment conditions resulted in no larval emergence and 100% egg mortality. In addition and in comparison to the observation of living larvae, unhatched eggs inside the tissue of bean pods were counted by from the same bean samples. A fundamental requirement and condition for the scientific investigation is to find a suitable and reproducible procedure to count the absolute number of eggs inside the bean pod sections. So far there was no technique known to ensure reproducible egg identification. Only the intact, obviously deactivated eggs from all treatments were counted during the data capture. Because of the specialized staining procedure, it was possible to differentiate dead eggs with intact shape from destroyed and empty egg membranes, where larvae emerged out. As expected, the lowest numbers of unhatched eggs were found in the non-treated controls kept at room temperature, where almost 99% of larvae hatched out. Moreover, only simple storage at cold temperatures inside the fridge (5°C) was unsuitable to achieve the same results. Even an exposure time of 120 h at 5°C was not sufficient to kill the eggs inside the bean pods. After storage again at room temperature (25°C), larval hatching rates were the same as before. Considering that beans should be cooled after harvest preferably to 4-5°C to maintain quality and to lengthen shelf life (Engels, 2011), quarantine security thus cannot be ensured without any additional treatment. Concerning possible quality loss of the beans, the study found out that the French beans were not negatively affected by the warm water treatment at 50°C. Hara et al. (1996) reported that hot water has been observed to improve the quality of certain fruits like apples, citrus, mangos, strawberries and tomatoes. Therefore warm water treatment probably can also be interesting for the removal of Ceratothripoides brunneus (Tomato Thrips) from export tomatoes. Lurie (1998) observed that, if the combination of treatment temperature and exposure time is optimal, product quality of fruits and vegetables can even be significantly better than from an untreated ones. The reason for this is the inactivation of degradative enzymes so that the ripening process can be delayed. Warm water baths are relatively easy to use because of their short operation time and efficient heat transfer (Lurie, 1998). At the same time, the costs of typical hot water technology are significantly less than, for example, those from vapor heat treatment systems (Jordan, 1993) and for sure less than those for refrigeration. To ensure quarantine security in future zero-tolerance export markets, it will be important to focus more on non-chemical treatments like the investigated postharvest warm water baths.

Conclusion and Recommendations

Warm water treatments have the potential to be a future standard postharvest method within Integrated Pest Management (IPM) to ensure export quarantine security of French beans against pests like Frankliniella occidentalis and other thrips species. The study also shows that simple cold storage is not sufficient to kill thrips eggs inside the bean pods. The additionally quality experiment figured out, that there were no recognizable quality losses regarding surface yellowing as result of the warm water treatments. However, further studies are needed to find out the limits of effective treatment conditions and to figure out if the treatment is affecting the maximum residue levels of pesticides as well. And of course it will be interesting if the treatment is also effective on other species of thrips or other insect eggs. Furthermore, it has to be investigated if insect egg infection of other vegetables can be influenced in the same way. Postharvest warm water treatments would be a suitable non-chemical way to kill all thrips life stages inclusive of the eggs. Related to scalable technologies, warm water treatment is applicable for small up to large scale farmers to increase product quality and ensure quarantine security for minimally postharvest processed products like French beans.

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1002 Fresh-Cut Markets and Opportunities for Income and Nutrition Security

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Abstract
Fresh-cut processing, presents an additional opportunity to reduce loss, enhance nutrition security and increase sales of fruits and vegetable in Ghana. Vending of fresh-cut fruits began mainly with export rejects and/or excesses, with the aim of curbing losses by selling them locally. This processing method has, however, spread throughout urban centres and fruits and vegetables markets. The study aimed at highlighting opportunities for producers mainly small-scale farmers, vendors and consumers. Using the simple random sampling approach, a survey was conducted on 130 respondents, comprised of 40 producers, 60 consumers, 20 street vendors and 10 stall operators via focus group discussion, online questionnaires and one-on-one interviews. Results show that, fresh cut processing of fruits and vegetables has created market opportunities. Marketers surveyed, accrued positive and reasonable margins of 32% to 70% per annum with benefit-cost ratio ranging from 1 to 4. Fresh-cut okra and fruit salad provided the maximum sales benefits while sliced papaya and vegetable salad had the the minimum. Despite production challenges, producers accrued reasonable net profits ranging from 41% for papaya to 46% for cabbage per acre; with the increased sales observed, there is a potential supply opportunity for small-scale farmers in this sector. Furthermore, two-thirds of consumers surveyed, purchased fresh cuts due to their nutritional benefits and ready to eat attributes. Addressing hygienic issues especially in the case of fresh processing in the open-market will contribute to alleviating post-harvest losses, create employment opportunities and improve nutritional security of urban consumers.

Keywords:
Fruits, vegetables, fresh-cut, consumers, producers

Introduction
Production of fruits and vegetables, like many other produces by small scale farmers in Africa is mainly buyer-driven. However, the perishable nature of these produce presents a lot of challenges for the farmers who usually have inadequate or no technologies for storage when buyers are limited. In African countries including Ghana, the agro processing industry from cottage to the multinational level, has been found to play a key role in providing market access, employment opportunities and sustainable livelihoods for small-scale farmers; in addition to reducing postharvest losses and malnutrition (UNDP, 2012). Conventional fruits and vegetables processed products include, dried fruits and vegetables, juices, fruit wines and fried snacks. Another emerging agro-processing sector is the fresh-cut and fresh processing of fruits and vegetables, which has gained recognition due to worldwide consumers demand for healthy, fresh and convenient products with no additives (Huxley et al., 2004; Rico et al., 2007; Ayala-Zavala et al., 2010).

Fruits and vegetables are rich in vitamins, mineral and phytonutrients that helps to prevent cardiovascular diseases and cancer. Nonetheless, consumption of fruits and vegetables in the developing world, particularly African countries like Ghana have been found to be below the recommended dietary level, despite numerous educational activities (WHO, 2004; USDA, 2004). This was evident in a survey conducted in 52 countries where Ghana was indicated as the country with the lowest proportion of fruit and vegetable intake; 36.6% and 38% among men and women respectively (WHO, 2002). In another study on Ghana Demographic and Health Survey, only 28% of women and 21% of men consumed fruit daily, and about 24% of women and 30% of men consumed vegetables daily (Ghana Statistical Service, 2008). Studies by Meng et al. (2014) on expenditure on fruits and vegetables in Ghana, showed the urban location with well-educated and high-income population as a promising sector for consumption and enhanced sales. Opportunities to improve fruits and vegetable consumption may be through accessibility and convenience. In a report by Saavedra Gonzalez et al. (2016), the growing number of supermarket chains, high-end restaurants and hotels, using minimal (fresh-cut) processed product have been indicated to create an enormous opportunity for increased vegetable production and sales to feed an ever-increasing middle class. Processors of fresh cut and fresh processed products like Eden Tree Ghana Limited and multinational partnership companies like Blue Skies Ghana Limited are currently, supplying some products to the local market due to the increasing demand for these convenient fresh processed products. Typical minimally processed or cut products in Ghana include mostly coconut, papaya, pineapple, mango, and other local vegetables pre-cut upon request in the market like taro leaves (kontonmire) and okra. These products are usually sold by supermarkets, open markets and street vendors. The changes in the market trend, driving forces for purchasing fresh cut fruits and vegetables and opportunities in the production and sales by farmers in urban cities have not received much attention in literature especially in developing countries like Ghana. The aim of this study was to identify the production and marketing incentives of fresh fruits and vegetables cut or puree (smoothies) and the contribution to consumers' nutrition.

Materials and Methods
The study engaged 130 respondents comprised of producers, marketers and consumers of fruits and vegetables within Accra. As an exploratory study, a convenience sample of 60 consumers of fresh fruits and vegetables of various levels in Accra were randomly selected to participate in on-line survey (SurveyMonkey.com) and personal interviews. A semi-structured questionnaire was developed for focus group discussions and interviews (using an interview guide). The random and snowball sampling technique was used to solicit data from street vendors (20), stall operators (10) and small holder farmers (40). The fruits and vegetable value chain in Ghana was used as a tool to identify; (i) the roles, functions and linkages among the various actors and their influence on accessibility and consumption of fresh-cut and ready to eat (RTE) fruits and vegeta-

bles among urban dwellers; (ii) the opportunities and gaps that exists and (iii) develop the cost and earnings model for each actor, in addition to the survey results. Data was analyzed using SPSS (version 23) and Microsoft Excel. To determine the economic viability, we estimated the marketing margins, market efficiency and benefit-cost ratios for each product assessed.

Results and Discussions

The study showed that, males (90%) dominate the production sector while females (96%) dominate the marketing sector of fruits and vegetables. Similar results were reported by Levin et al. (1999) where women were more likely to engage in street food vending and petty trading than men among the household surveyed. Majority of the people involved in the production, marketing and consumption of fresh-cut fruits and vegetables were the economically active age-group (less than 40 years) but unfortunately had low levels of education (below high school) except for the consumers. This finding endorses the general assertion that the level of education among farmers as well as traders of agricultural foods continue to be low in Ghana and Africa (Weir, 1999; Naamwintome and Bagson, 2013).

The main constraints for the producers of fruits and vegetable were high cost of crop protection chemicals, organic and inorganic fertilizers, labour and irrigation. Amidst all these constraints they accrued positive and reasonable net-margins of 41% to 46% per season per crop with benefit-cost ratios of 1.35 – 2.46 (Table 1). With regards to marketing also, the margins were positive (32% - 70% per annum) with higher percentage representing supermarkets sales of fruit salads at GHS 21000

Table 1: Profitability of Producing an Acre of Some Selected Fruits and Vegetables

Crop	Yield (kg)	Sales (GHS)	Production Cost (GHS)	Net Margin (GHS)	Benefit-Cost Ratio
Cabbage	8000	12000	6500	5500	1.85
Lettuce	500	4000	2500	1500	1.60
Sweet pepper	7500	10200	7500	2700	1.36
Cucumber	8500	10000	6500	3500	1.54
Cauliflower	4500	8000	4500	3500	1.78
Okra	4560	6065	2465	3600	2.46
Mango	2000	3500	1500	2000	2.33
Pineapple	55404	14362	10609	3753	1.35
Coconut	5000	2500	1500	1000	1.67
Papaya	1000	850	500	350	1.70

NB: All tree crops were assumed to be at their peak season of production

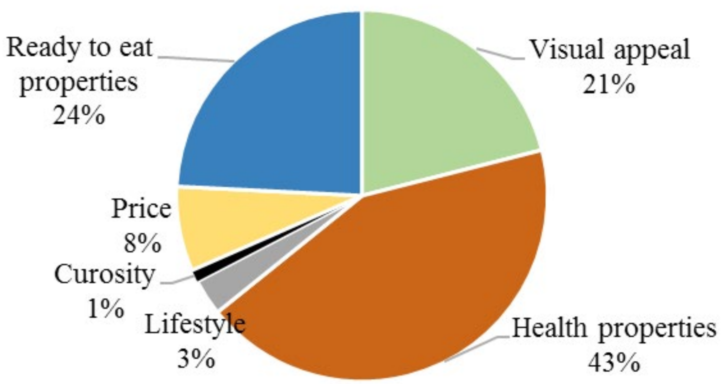
Table 2: Profitability of Marketing Some Selected Fruits and Vegetables per annum

Crop	Open-market Retailers			Supermarket Retailers		
	Market Margin (GHS)	Market Efficiency	Benefit Cost Ratio	Market Margin (GHS)	Market Efficiency	Benefit Cost Ratio
Sliced papaya	2300	0.46	1.46	9400	0.75	1.75
Sliced pineapple	2800	0.62	1.62	8400	0.62	1.62
Sliced mango	2500	0.56	1.56	14250	2.11	3.11
Coconut	5000	1.00	2.00	-	-	-
Fruit salad	5500	1.22	2.22	21000	2.33	3.33
Fruit smoothies	-	-	-	5000	0.50	1.50
Vegetable salad	-	-	-	2000	0.25	1.25
Fresh-cut okra	6000	3	4.00	5000	0.33	1.33
Taro leaves	4000	0.67	1.67	15000	1.00	2.00

(-) As shown in the table represent products which were not found at the open market or supermarket

The key drivers for fresh-cut fruits and vegetables purchases were health properties (indicated by 43% and 36% of consumers for fruits and vegetable products respectively) (Figure 1a and 1b). This was followed by ready-to-eat properties (indicated by 19% and 24% of consumers for vegetables and fruits products respectively) and visual appeal (indicated by 16% and 21% of consumers for vegetables and fruits products respectively). Though noteworthy, purchasing factors related to lifestyle, price and curiosity were of less importance

(a) Factors Influencing Purchase of Fresh-cut Fruits and Smoothies



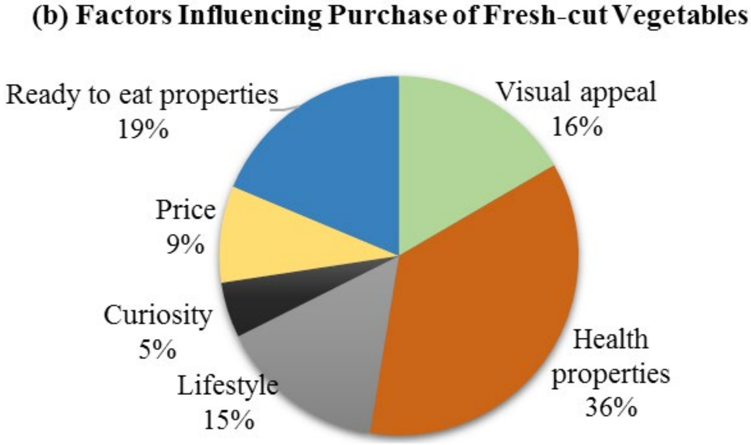


Figure 1: Factors influencing the purchases of fresh-cut fruits and vegetable in Accra, Ghana

Conclusions and Recommendations

Fresh processing of fruits and vegetables offers great potential for increased consumption of fruits and vegetables in the urban areas where consumption of fresh products is lacking in consumer diets. It may also contribute to reducing losses and in turn increasing sales of producers who are mainly small-scale farmers. Fresh-cut fruits and vegetables marketing in Accra was found to be lucrative and economically empowering especially to the active economic age group. More so, investors who are looking for profitable business opportunities in agriculture could consider the fresh-cut industry and even enjoy economies of scale by operating on large scale. Some consumers highlighted the issue of hygiene as a deterrent, therefore improving hygiene of operations like sanitizing equipment used, cold processing and cold storage to minimize microbial contamination especially among the street vendors and open market sellers may contribute to increased consumption. Fresh-cut could contribute to the curbing of the issue related to quarantine and insect infestation of fruits, for example the case of fruit fly and stone weevils in mangoes since the product is already cut into slices or cubes exposing all the internal parts prior to export. Hence such cases could be controlled at source (country of origin) prior to exporting provided issues related to microbial contamination are also well addressed.

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1003 Effect of Different Peeling Methods on the Quality Characteristic of Livingstone Potato Flours

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Abstract
This study evaluated the quality characteristics of Livingstone flours produced using different peeling methods: Lye peeling (LP); Knife peeling (KP) and Abrasion peeling (AP). The percent of peel loss and flour yield were determined using standard methods. The proximate composition, phytochemical content and functional properties were also evaluated. The results showed that KP had the highest peel loss (37.47%), while AP and LP had lower values 23.36 and 23.23%, respectively. In terms of flour yield, AP exhibited the highest percentage (31.71%), followed by LP (31.34%) and KP showed the least value (23.75%). The Livingstone flours showed no significant (P>0.05) differences in their fat (0.01-0.02%) and protein (0.34-0.35%) contents. The crude fibre, moisture, ash and carbohydrate contents of the flours ranged from 4.66-5.03%; 16.01-14.95%; 4.62-4.82% and 74.14-76.26%, respectively. The LP treated flour had the lowest Bulk density (0.85%), oil absorption capacity (OAC) 1.60% and solubility (11.60) however, the flour exhibited the highest tannin content (0.90%) when compared to the KP and AP treated samples. This result showed that LP with the least peel losses and highest flour yield compared to the AP and KP treated flours may possess the highest potential for the reduction of postharvest loses during its utilization for pre-processing of Livingstone tubers.

Keyword: Functional-chemical properties, livingstone potato, peeling yield and loss

Introduction
Livingstone potato (Plectranthus esculentus) tuber which is commonly cultivated in Africa belongs to the family of Lamiacea and it encompasses many aromatic plants (Allemann and Hammes, 2006). They are erect perennial, herbaceous plants that may grow up to 60 cm tall with yellow flowers and lumpy edible tubers at the base of the stem (Temple et al., 1991, Ukpabi et al., 2011). It is one of the lesser known tropical crops in Nigeria and other Sub-Sahara African countries (Ukpabi et al., 2011). It is eaten raw as snack after peeling and washing or boiled and eaten as porridge. This plant is also being used as a functional food due to its perceived therapeutic value in alleviating stomach upset and pain (folklore medicine). Over the years this plant has remained underutilized due to the difficulty involved in peeling of the tubers which are finger-like shaped (about 5 cm). The growers of livingstone potato tubers, mostly rural women, use abrasion method of peeling that involves rubbing of the tubers between two palms to create friction that enhances peeling [Personal observation]. This method is often used immediately after harvest during the rainy season when the skin has not strongly stacked to the flesh of the tubers. Alternatively, the unpeeled tubers are cooked with potash to ease peeling and then consumed [Personal observation]. Due to the difficulty in peeling, often times, the farmers abandon the harvested tubers thus leading to huge postharvest losses. Presently there is dearth of information regarding the processing, quality characteristics and uses of this crop. The objectives of this study were therefore to evaluate the effect of different peeling methods and time on the quality characteristics of livingstone potato flour through the determine their physico-chemical and functional properties as well as phytochemical profile of the flours.

Materials and Methods
About 15 kg of the fresh livingstone tubers were obtained from the Minor Root Crop Programme of the National Root Crops Research Institute (NRCRI), Umudike. The tubers were then sorted and cleaned to remove defected ones and extraneous materials. The tubers were then divided into 3 lots and subjected to treatments of three different peeling methods: Knife peeling (KP), Lye Peeling (LP) and Abrasion peeling (AP). One (1) kg of the tubers was peeled using kitchen knife. The average peeling time was recorded and the percentage peel loss determined using the difference in weight before and after peeling; Lye peeling was performed by soaking 1kg of the tubers in 5% lye for 5min, after which they were washed vigorously with water to remove the peels. The peeling time was also noted and peel loss determined. The choice of the lye concentration used was based on previous pilot work which used varying concentrations: 1, 3, 5, 7 and 9 % lye at corresponding soaking times of 1, 3, 5, 7 and 10 min, respectively; Abrasion peeling was carried out by rubbing the tubers in between two palms to create friction which helped removed the peels under running water. Similarly, the peel time and losses were also determined like in the previous experiments which were performed in triplicates. Quality parameters including peel loss, flour yield (Onwuka, 2005, AOAC, 2016) and functional properties: bulk density, water/oil absorption capacity, solubility in water and gelation capacity (Onwuka, 2005, Okezie and Bello, 1988) were determined. Phyto-chemicals including tannins, saponins, flavonoids and alkaloids were screened using a previous method adopted by (Abba et al., 2009). Data obtained was analyzed using Statistical Analysis System (SAS) Software Version 8.

Results and Discussion
The results of this study showed that KP ranked highest in peel losses and time (37.47% & 145 min/kg) which was significantly ($p<0.05$) different from that of AP (23.36% & 23.66 min/kg) and LP (23.23% & 15min/kg), respectively (Table 1). The flour yield for KP, AP and LP were 23.75; 31.34 and 31.71%, respectively, showing a positive correlation to the peel losses recorded in this study (table 2). The peeling methods did not have any significant ($p>0.05$) effect on the functional properties of livingstone flours. The functional properties of the flours ranged from 0.85-0.87 g/m3 (bulk density), 2.16-2.30 g/mL (Water absorption capac-

ity), 1.60-2.16 g/mL (oil absorption capacity) and 73.66-76.66 °C (Gelation temperature) (Figure 1). The tannin content for LP (0.63 %) was significantly ($p<0.05$) different from that of KP (0.85 %) and AP (0.90%). A similar trend was observed for saponins and flavonoids with LP having values of 0.23 & 0.21%, KP (0.37 & 0.29 %) and AP (0.38 & 0.31%), respectively. It was observed that the percentage concentration of phenols and alkaloids for LP (0.09 & 0.53 %) were significantly reduced compared to KP (0.15 & 0.73 %) and AP (0.12 & 0.61%) processing methods (Table 3). The result indicates that it is possible to optimize the utilization of livingstone potato for new product development, if the above processing methods are adopted.

Tables and Figures

Tables 1: Effect of peeling methods and time on the flour yield and peel loss of fresh Livingstone Potato (Plectranthus esculentus) tuber.

Flour	Flour yield (%)	Peel loss (%)	Peeling (min/kg)	Time
LP	31.34a ± 0.51	23.23b ± 0.84	15c ± 1.01	
KP	23.75b ± 0.31	37.47a±0.16	145b ±1.07	
AP	31.71a ± 0.82	23.36b±2.82	23.66a ±1.01	
LS	**	**	***	
LSD	1.257	1.564	1.16	

Values are means of triplicate determinations ± Std and different letters within each column are significantly ($p<0.05$) different.

Table 2: Effect of peeling methods and time on the secondary metabolite content of Livingstone potato (Plectranthus esculentus) flours

Flour	Bulk Density (g/m3)	Water Absorption Capacity (g/mL)	Oil Absorption Capacity (g/mL)	Solubility in Water (%)	Gelation Temp(°C)
LP	0.85a ± 0.02	2.16a ± 0.76	1.60b ± 0.10	11.60a ±1.07	74.33a ± 2.87
KP	0.86a ± 0.02	2.26a ± 0.68	2.10a ± 0.02	13.04a ± 0.02	73.66a ± 0.58
AP	0.87a ± 0.04	2.30a ± 0.35	2.16a ± 0.06	12.85a ± 0.79	76.66a ± 2.08
LS	NS	NS	**	NS	**
LSD	0.99	0.903	0.194	0.133	1.401

Values are means of triplicate determinations ± Std and different letters within each column are significantly ($p<0.05$) different

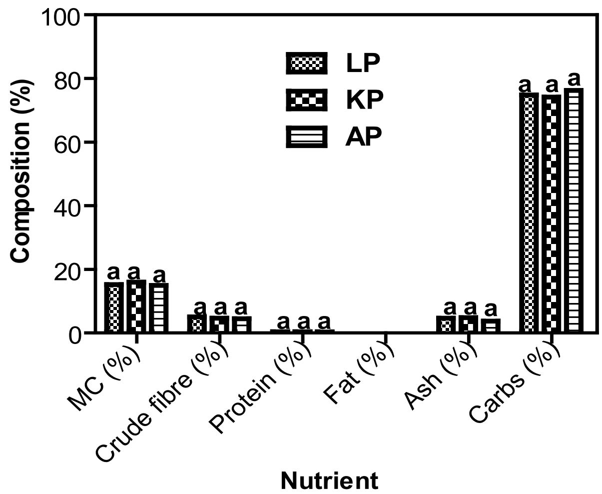

Figure 1: Effect of peeling methods and time on the proximate composition of Livingstone potato (Plectranthus esculentus) flours. Bars with different letters are significantly ($p<0.05$) different.

Table 3: Effect of peeling methods and time on the secondary metabolite content of Livingstone potato (Plectranthus esculentus) **flours**

Flour	Tannin (%)	Saponin (%)	Flavonoid (%)	Phenol (%)	Alkaloid (%)
AP	0.90a ± 0.02	0.38a ± 0.03	0.31a ± 0.01	0.12a ± 0.01	0.61a ± 0.02
KP	0.85b ± 0.02	0.37a ± 0.01	0.29a ± 0.01	0.15a ± 0.04	0.73b ± 0.01
LP	0.63c ± 0.03	0.23b ± 0.03	0.21b ± 0.01	0.09b ± 1.39	0.53c ± 0.01
LS	***	***	***	***	***
LSD	0.277	0.059	0.122	1.140	0.140

Values are means of triplicate determinations ± Std and different letters within each column are significantly ($p<0.05$) different.

Conclusion and Recommendations

This study has shown that LP and AP significantly minimized peel losses thereby enhancing the flour yield of the tubers when compared to the KP method of peeling. Thus post-harvest losses of livingstone potato could be reduced, if modified LP and AP methods of pre-processing are adopted. Apart from continued search for a suitable and efficient peeling method, it is recommended that agronomic improved varieties of livingstone potato (Plectranthus esculentus) be developed that will possess easily removable skins to address the problem of difficulty in peeling, enhance processing and promote its utilization for novel new product development.

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1004 Assessment of Postharvest Losses in Chilli Pepper (Capsicum annuum cv. Legon 18) in the Kwahu North District, Ghana

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Abstract
This study assessed the contribution of pre-production, production and postharvest handling activities on postharvest losses in the export of chilli pepper variety (Legon 18) in the Kwahu North District of Ghana. The commodity system assessment methodology (CSAM) was used. Fifty farmers were purposively sampled from seven communities based on the acreage of pepper produced. A semi-structured questionnaire covering pre-production, production and postharvest components of the CSAM were administered. The data were analysed using descriptive statistics. The total postharvest loss for the 50 farmers was quantified as a percentage of the ratio of damaged produce to harvested produce. Most (80%) of the farmers attributed lack of extension services as the key pre-production factor affecting postharvest losses of their produce. The major production factors significant to loss of farmers produce were: poor weed control (22.6%), inappropriate irrigation (16.2%), high plant density & poor planting patterns (18.6% each) and, field sanitation (18.6%). Although the farmers applied postharvest practices (sorting, 84%; curing, 25%; packaging, 24%; boiling, 13%), they perceived inadequate technical knowledge of these practices as a leading cause of postharvest losses. The study suggests that the farmers are not oblivious of the impact of their activities and management decisions on postharvest losses. It is recommended that the major pre-production, production and postharvest factors affecting postharvest losses should be quantified. Further, more technical knowledge (good agronomic and postharvest practices) should be given to the farmers and their labour force.

Keywords:
Chill pepper, cultivar (Legon 18), commodity system assessment, Farmers, Postharvest loss.

Introduction
The economic value of postharvest losses of fruits and vegetables ranges between 30-40% in Sub-Saharan African countries including Ghana. This is attributable to the deterioration of crop or produce quality (5-90%) at the farm (4.8-81%), wholesale (5.4-90%) and retail (7-79%) levels; as well as management decisions (5-40%) from pre-production through to the marketing of the produce (Affognon et al. 2015). Most postharvest losses are due to poor handling, mechanical damage (54%) and inadequate knowledge on the maintenance of produce quality along the produce value chain (Kitinoja and Kader, 2015). About 20-50 % of vegetables produced in Ghana are lost after harvest due to pre-production, production, harvest and postharvest management, and marketing decisions (Gonzalez et al. 2016).

This study was on chilli pepper (Capsicum annuum L. cv Legon 18) an important export vegetable crop in Ghana. Legon 18 is a hybrid chilli pepper bred to suit the climatic and soil conditions in Ghana (MiDA 2010). It is popular for both local consumption and export to Europe including Germany; (77%); United Kingdom, (15%) and Switzerland (8%) due to its good taste and longer shelf life (MiDA 2010). It is a vegetable with a significant foreign exchange earning capacity and a reliable source of income for small-holder producers or out growers (Nkansah et al. 2011). The selection of chilli pepper cultivar Legon 18 for the study is due to the existing climatic and soil conditions for production, presence of well-organised growers, and policy support from Millennium Development Authority (MiDA) in agribusiness and infrastructure programs as well as trade and investment incentives for export businesses in some pepper producing areas such as the Kwahu North District.

Despite its relatively longer shelf life, postharvest losses are inevitable as most producers and exporters do not use cold chain transportation or storage to maintain the quality of the harvested produce (MiDA 2010). This study provides descriptive first-hand information on the contribution of pre-production, production and postharvest handling activities of producers on postharvest losses in Chilli pepper cultivar Legon 18 by employing the commodity system assessment methodology (CSAM) (La Gra et al. 2016).

The specific objectives of the study were: 1) to examine the contribution of pre-production, production and postharvest activities to postharvest losses in chilli pepper cultivar (Legon 18) and 2) to estimate the magnitude of postharvest loss of chilli pepper cultivar (Legon 18) by producers in the Kwahu North District.

Materials and Methods
This study used the CSAM to assess the postharvest losses of chilli pepper cultivar (Legon 18) in the Kwahu North District in 2012. With the help of Agricultural Extension Officers from the Ministry of Food and Agriculture (MoFA), 50 producers were purposively sampled from seven major Legon 18 chilli pepper producing communities; Ekye-Amanfrom, Kwame-Dwamena, Amankwakrom, Dortopong, Sodziekope, Mem Kyemfre and Brumben. A semi-structured questionnaire covering issues on the pre-production, production and postharvest handling components of the CSAM were administered. Issues considered in the survey questionnaire were: i) Preproduction: relative importance of the crop, government policies, relevant institutions, facilitating services, producer/shipper organizations, environmental conditions, availability of planting materials; ii) Production: farmers' crop management practices, pests and diseases control, pre-harvest treatments and production cost and iii) Postharvest: harvest, grading, sorting and inspection, postharvest treatments, packaging, cooling, storage and transport.

The survey data were subjected to descriptive statistical analysis in the Statistical Package for Social Sciences (version 17.0). The total postharvest loss (PL) for the producers was calculated as a percentage of the ratio of the number of harvested sacks damaged (ND) and the total number of sacks harvested (NH) by producers surveyed;.

$$PL = {ND}/{NH} * 100\% \quad \text{……equation 1}$$

Results and Discussion

Preproduction: Producers ranked the importance of the crop based on high profitability (30%), high demand (26%), low capital input (16%), fast growth (10%) and favourable environment (8%), less susceptibility to pests and diseases (5%) and seed availability (5%) (Table 1). The high profitability of chilli pepper cultivar (Legon 18) is debunked as Nkansah et al, (2011) reported that the cultivar attracted lower prices than other varieties that are not readily available in Ghana. Twenty percent (20%) of producers benefited from extension services while 80% of the producers did not and suffered extensive postharvest losses. The beneficial farmers are mostly members of the MiDA agricultural project (MiDA, 2010). Producers obtained their seeds from; own seed (30%), friends (10%) and market (60%). This observation indicates that most of the seeds for planting were from certified source and therefore may not adversely affect yield and quality of the fruits.

Production: The cultural practices that influenced postharvest losses were; poor weed control (22.6%), inappropriate irrigation (16.2%), high plant density (18.6%) and poor planting patterns (18.6%), field sanitation (18.6%) and poor fertilizer application (5.4%) (Table 2). These results show that producers are aware of the standard cultural practices that are necessary for increased fruit yield and quality (Osei-Kwarteng et al. 2017). It is also clear that poor weed control and other planting practices may lead to resource competition and the prevalence of diseases that affect yield and quality of the fruits. Producers used baskets (82%), bowls (16%) and sacks (2%) in carting produce. Maturity at harvest was either at the full ripe stage (86%) or green mature stage (14%) and harvesting was usually done in the morning, though few producers harvested in the evening (8%).

Postharvest Handling: Eighty four percent (84%) of the producers sorted produce as either damaged or undamaged for better value. The postharvest treatments used were blanching (27%), cleaning (25%), curing or drying (20%) and treating with chemicals (2%). Harvested produce are packaged in polyethylene bags (Fig.1) and stored in storage rooms (60%) at ambient temperature, kitchen (26%) and in huts (12%) mostly with poor ventilation. Few producers (10%) stored produce for less than a month while 40% of producers could store produce for more than 5 months. Produce were transported to market places either by road (56%) or by river (Canoes and Pontoon; 44%) without any cooling facilities. To ensure reduced postharvest losses, standard postharvest practices, and good storage and transport facilities must be provided to minimise physical damage to the produce and enable easy movement from farm-gate to sale points (Osei-Kwarteng et al. 2017). Total postharvest loss estimated for the producers surveyed was 16.3%.

Table 1: Some of the reasons for producing chilli pepper in Kwahu North District

Reasons for producing pepper	Frequency	Percentages
High demand	39	26
Low capital input	23	16
Fast growth	15	10
Government support	0	0
High profit	45	30
Favourable environment	12	8
Less susceptibility to pest and disease	7	5
Available seeds	7	5
Total	**148**	**100**

Table 2: Postharvest practices that affects produce quality in the Kwahu North District

Postharvest practices	Frequency	Percentages
Curing/drying	42	28
Boiling	20	13
Packaging	36	24
Storage	33	22
Transportation	20	13
Total	**148**	**100**

Figure 1: Dried chilli pepper (Legon 18) packaged in clear polyethylene bags for storage

Conclusion and recommendations

Postharvest losses of chilli pepper (Legon 18) in the Kwahu North District of Ghana is influenced by low extension services from MoFA, use of producers own seeds; poor production practices including weed infestation, inadequate irrigation, and poor field sanitation; and inadequate knowledge of postharvest handling activities and treatments (curing , blanching and cleaning). A postharvest loss of 16.3% of harvested produce was estimated in spite of the MiDA interventions to 20% of the producers in the area, suggesting that producers may experience more postharvest losses without any interventions. We recommend an interdisciplinary quantitative assessment of postharvest loss along the commodity value chain with the inclusion of all actors (Retailers, marketers, transporters, and consumers). This will enable an in depth identification of the causes of postharvest loss and a reliable quantification of the cumulative postharvest losses for effective and appropriate postharvest loss interventions.

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1005 Processing Methods and Nutritional Quality of Dried Amaranth (Amaranthus spp. L) Leaves: A Review

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Abstract
Postharvest losses of vegetables are major challenge for the vegetable industry. Postharvest losses of leafy vegetables are as high as 20-50% of production. Various stakeholders have adopted different approaches for the reduction of postharvest losses as the most feasible option for improving food and nutritional security. Vegetable amaranths are popular in African and Asian countries where leaves are mostly bundled fresh and drying is encouraged to prolong the postharvest shelf life. Amaranths have excellent nutritional value because of their high essential micronutrients such as beta-carotene, iron, calcium, vitamin C and folic acid. They also have lysine, an essential amino acid in the range of 6 g 100 g-1 DW protein, which is similar to the recommended FAO/WHO standards and is often lacking in human diets. The review highlights drying methods for vegetable amaranths and their effect on the nutritional quality. Literature was sourced from journal articles, reports, books, online library, and extension fact sheets from Universities websites. Dried leaves are preserved to prevent microorganism infestations and to concentrate nutrients for later use. Amaranths are preserved by sun, shade, solar, cabinet, oven, freeze, infrared and vacuum drying methods. Nutrient retention in solar dried leaves is higher than sun and oven dried leaves. We recommend the use of solar drying of amaranth leaves. Drying should be advocated for an all year round supply of nutrient rich amaranth leaves particularly in developing countries to curb both qualitative and quantitative postharvest losses.

Keywords:
Amaranths, drying methods, malnutrition, nutritional value, postharvest losses.

Introduction
In developing countries, postharvest losses of leafy vegetables are as high as 20-50% of production (Acedo, 2010). Postharvest losses in vegetable amaranth are even much higher (79-89.5%; Affognon et al. 2015).These losses contribute to food insecurity, poverty and economic ineptitude in developing countries (Acedo, 2010). Leafy vegetables such as amaranth can ameliorate food insecurity, poverty and malnutrition problems in developing countries due to their high nutritional value (Achigan-Dako et al. 2014). Amaranths (Amaranthus spp. L) have excellent nutritional value because they contain essential micronutrients such as beta-carotene, iron, calcium, vitamin C and folic acid (Achigan-Dako et al. 2014). The nutrient content of five species of amaranths (Amaranthus blitum, A. cruentus, A. dubius, A. tricolor and A. viridis) were reviewed as ranging from; Protein (3.2-4.6 g/100gFW), Vitamin A (1.7-5.7mg/100gFW), Vitamin C (36-78 mg/100gFW), Calcium (270-582mg/100gFW), Iron (2.4-8.9mg/100gFW) and Zinc (0.7-1.5mg/100gFW) (Table 1; Achigan-Dako et al. 2014). A challenge to the utilisation of amaranth leaves is their highly perishable nature due to the high water content and short shelf-life which prevents the long term storage of harvested produce.

Dried leafy vegetables are rich in protein, total phenolics compounds, natural antioxidants, vitamins, minerals and fiber (Achigan-Dako et al. 2014; Kiremire et al., 2010). However, like any other processing method, drying has an effect on the biological activity of the chemical composition of the dried products (Kiremire et al., 2010). Therefore, the study aimed to review drying methods of vegetable amaranths and their effects on the nutritional composition of the dried leaves and to appraise the best drying method based on the nutrient content after drying. Specifically, the review was to highlight the commonly used drying methods for vegetable amaranths and the nutritional quality of dried vegetable amaranth leaves.

Methodology
Literature was sourced from journal articles via several databases (Web of Science, Science Direct, Directory of Online Journals, PubMed etc.) reports, books, online library (TIB Uni Hannover), and other extension facts sheet from Universities websites online.

Results and Discussion
Drying methods
The drying methods reported for amaranths include; sun, shade, solar, oven (Ukegbu and Okereke, 2013; Kiremire et al., 2010), cabinet tray, freeze, infrared and vacuum drying (Sopian et al., 2005). Sun, solar and oven drying are the commonly used commercial and household methods but the most practiced is sun drying (Kiremire et al., 2010).The attributes of sun, shade, oven, solar (Ukegbu and Okereke, 2013; Kiremire et al., 2010), cabinet (tray), vacuum, freeze and far infrared (Sopian et al. 2010) drying methods are reduced microbial load and moisture content (Table 1).

Drying methods and Nutritional Value
Sun dried leaves had decreased Vitamin C, ß-carotene, and phosphorus content while the calcium, sodium and dietary fibre content increased (Table 2; Kiremire et al., 2010). Nutrient retention (20.5-93.8%) in solar dried leaves was generally higher than sun dried leaves (Kiremire et al. 2010). Further, Kiremire et al. (2010) also compared the effects of sun, solar and oven drying on amaranth leaves and recommended solar dried leaves because they had a higher nutrient retention (20.5-93.8%). Freeze drying of leaves also decreased the total carotene and ß-carotene content in blanched (18.60% & 18.91%) and unblanched (4.99% & 10.46%) as well as vitamin C in blanched (30.67%) and unblanched (13.21%) samples. Far infrared dried leaves also showed a decrease in total carotene and ß-carotene content for blanched (24.86% & 29.3%) and unblanched (34.90% & 37.94%) samples (Sopian et al., 2010).

Table 1: Nutrient content in the leaves of five Amaranthus species (100 g fresh weight of edible proportion basis)

Species	Protein (g)	Vitamin A (mg)	Vitamin C (mg)	Ca (mg)	Fe (mg)	Zn (mg)
Amaranthus blitum	3.5	1.7	42	270	2.0	-
Amaranthus cruentus	3.2	1.8	36	305	3.8	0.7
Amaranthus dubius	3.5	3.1	78	582	3.4	1.5
Amaranthus tricolor	3.9	1.8	62	358	2.4	0.8
Amaranthus viridis	4.6	5.7	64	410	8.9	-

Source: Achigan-Dako et al. 2014.

Table 2: Nutrient retention of Amaranthus hybridus dried by different methods

Drying methods	Vitamin C(%)	ß-carotene (%)	Phosphorus (%)	Calcium (%)	Sodium (%)	Dietary fibre
Oven dried	73.7	21.6	94.0	94.7	81.1	72.0
Solar dried	31.0	23.6	91.6	91.8	68.8	79.2
Sun dried	22.4	8.3	88.8	95.6	86.1	91.5

Source: Kiremire et al., 2010

Conclusion and recommendation

It is clear that drying methods affect the nutritional value of dried amaranth leaves and nutrient retention is dependent on the drying method employed. Solar drying is recommended for drying amaranths because with the exception of reduced crude protein content, it had significantly ($P < 0.05$) higher nutrient, mineral and vitamin A and C contents than sun dried samples. Moreover solar drying is more hygienic with reduced microbial load compared to sun drying (Ubeku and Okerekere 2013).

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1006 Low Cost Evaporative Coolers as an Alternative Storage to Mechanical Refrigerators for Tomato Storage

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Abstract

Tomato (Lycopersicon esculentum Mill) is a widely consumed fresh vegetable in the world. However it's highly perishable nature limits its postharvest life. Temperature and relative humidity management to extend shelf life and maintain postharvest quality of perishables are the main challenges in tropical countries like Ethiopia. Therefore management of these factors is a crucial task to extend shelf life and maintain quality of tomatoes. The current study conducted was with the objective of determining the effect of different storage methods and ripening stages on shelf life and postharvest quality parameters of tomatoes. A two-factor factorial CRD design experiment was laid out with the two factors being storage methods (Zero Energy Cooling Chambers, pot in pot storage, desert cooler and the control), and two ripening stages (breaker and light red stage) each with three replications. Average daily temperature, relative humidity, shelf life, deterioration and weight loss percentage, titratable acidity, total soluble solid, fruit firmness, Lycopene, ß-carotene, Chlorophyll A and B were evaluated as response variables. Results of the study showed that retaining of tomato postharvest quality and shelf life were much better inside evaporative coolers (24 days) as compared to room temperature (11 days). In general weight loss and deterioration percentage, TSS, Lycopene and ß-carotene content increased with the storage period, but were faster on tomatoes stored at room temperature. TTA, fruit firmness, Chlorophyll A and B content decreased with the storage times which were faster on tomatoes stored at room temperature. It can be concluded that evaporative coolers give an alternative option to mechanical refrigeration aimed at temperature and relative humidity management to prolonging postharvest shelf life and maintain quality of tomato fruits.

Keywords:

Evaporative coolers, quality, relative humidity, shelf life, temperature Introduction

Tomato is recognized as one of the most important commercial and dietary vegetable crop in the world (Bauer et al., 2004). The introduction of cultivated tomato into Ethiopian agriculture dates back to the period between 1935 and 1940 (Workneh, 2010). The annual production of tomato in Ethiopia is 4593 hectares which yields about 89702 tons (FAOSTAT, 2010). It is a popular and widely grown vegetable crop in Ethiopia, ranking 8th in terms of annual national production (workneh et al., 2011). However it's highly perishable nature limits the postharvest life of the fruit vegetable. Improper harvesting time (maturity), ripening conditions and lack of suitable storage facilities contribute to high postharvest losses in tomato. In addition, glut during the peak harvesting period results in high postharvest losses and a large portion of yield being sold at very low prices. Sometimes the postharvest loss of the fruit reaches 100% if there is no market. Temperature and relative humidity management to extend shelf life and maintain postharvest quality of perishables are the main problems in tropical countries like Ethiopia. So therefore management of these factors is crucial tasks to extend shelf life and maintain quality of the fruit. Mechanical refrigerators are the best option for storage, however it is unaffordable for farmers and small retailers to buy and run in developing countries. In addition, they require electric energy to operate where it is impossible to get electricity in most parts of the country. Therefore development of cheap, mechanically operated storage methods is important tasks to overcome these problems. The objective of this study was to determine the effect of different low cost evaporative cooler storages and ripening stages on shelf life and postharvest quality of tomato fruits.

Materials and Methods

Fruits with uniform size, ripening stage, free from damage and fungal infection brought from Melkassa Agricultural Research Centre (MARC). A completely randomized design (CRD) experiment was laid out with two factors; factor one being storage methods (Zero Energy Cooling Chambers, pot in pot storage, desert cooler and storage at ambient room conditions), and factor two being two ripening stages (breaker and light red stage) each with three replications. Average daily temperature and relative humidity were regularly recorded two times per day (in the morning and in the afternoon) using hand held Hygrometer (PWT -101, UK). Shelf life, deterioration and weight loss percentage were determined according to Monerzumma et al., (2009). TSS content of the fruit was determined by using refractometer (Bellingham + Stanley 45-2, UK) and pH using standardized pH meter (CP-505). Lycopene, ß-carotene, and Chlorophyll A & B contents of the fruit were analyzed according to method describe by Nippon, (1992). The collected data were subjected to Analysis of Variance using SAS 9.2 statistical software. Fisher's least significance difference was used to establish the multiple comparisons of mean values.

Results and Discussion

Results of the study showed that retaining of tomato postharvest quality and shelf life were much better inside the evaporative coolers as compared to storage at room temperature. Harvesting at early ripening stage also extends the shelf life of the fruit compared to late ripe harvest. Reduction of inside storage temperature and increment in relative humidity was recorded throughout the storage period. Heat moves from higher temperature of air, brick and eucalyptus stick walls to lower temperature of the moistened sand and jute sack due to convection and conduction, respectively. During this conversion process the inside storage temperature decreases below wet-bulb temperature (Islam, 2012). Temperature decreased to 21.370C, 20.030C, and 21.02 0C for ZECC, pot in pot storage and desert cooler storages respectively; while the average room temperature was 26.430C throughout the storage period. Relative humidity increased to 87.86%, 88.47%, and 84.74% for ZECC, pot in pot storage and the desert cooler storages respectively while the room relative humidity was 54.22%. Fruits rate of respiration is highly affected by the storage temperature and relative humidity (Okole and Sanni, 2012).

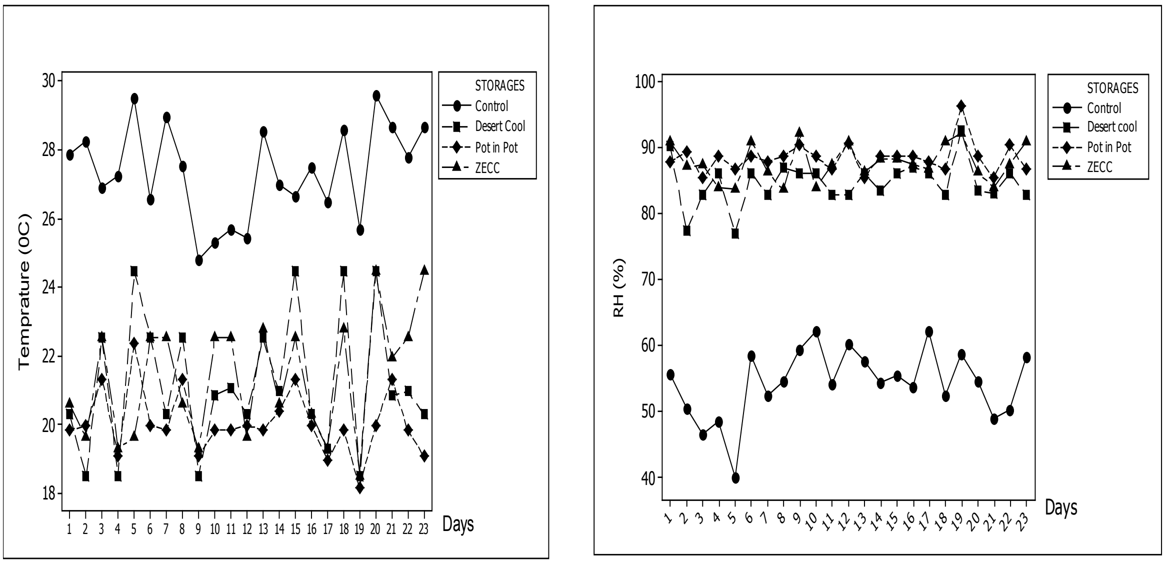

Fig.1. Daily temperature relative humidity (%) of ZECC, pot in pot, desert cooler and control for 23 days

Tomatoes were preserved for 19 days under ZECC, 24 days under pot in pot storage and 23 days under desert cooler, while only 14 days at room temperature all harvested at breaker ripening stage. Tomato fruits harvested at light red ripening stage retained 14 days stored inside ZECC, 21 days inside pot in pot storage, 21 days at desert cooler, while it was only 11 days at room temperature. Parvez and Tustuo, (2012) reported ZECC extended the shelf life of tomatoes up to 17 days while it was only 7 days at room temperature storage. Getinet et al., (2008) also reported evaporative coolers increase the shelf life of perishables through temperature and relative humidity management. Decay started early on the 6th day for fruits stored at ambient temperature but was delayed to the 11th day for fruits stored inside the evaporative coolers. Storage of tomato at low temperature and high relative humidity decrease early deterioration percentage Moneruzzaman et al. (2009). Weight loss of the fruits increased progressively during the storage. Minimum weight loss was recorded for tomatoes stored inside Pot in pot storage (2.58%) and maximum weight loss was recorded for fruits stored at room temperature (15.45%) both harvested at breaker stage after 10 days of storage. Cold stored fruits had a low weight loss due to temperature effects on vapor pressure difference and increased water retention. In addition, higher respiration rate also resulted in higher transpiration of water from the fruit surface which led to increase in percentage of weight loss. Generally, weight loss and deterioration percentage, total soluble solid, lycopene and ß-carotene content increased with increment of storage time, but were early and fastest on tomatoes stored at room temperature. Highest firmness was retained for tomatoes stored inside pot in pot storage (5.598N) and least firmness was recorded for ambient storage (3.585N) both harvested at light red stage after 10 days of storage period. Fruit firmness is an important quality attribute that influences consumer's acceptance and determine the shelf life of most perishables. When fruits become less firm which comes due to high moisture loss and enzymatic activitity leading to softening. Titratable acidity, fruit firmness, Chlorophyll A and B content decreased with the increment of storage times which were also fastest from tomatoes stored at room temperature.

Conclusion and Recommendations

The evaporative coolers maintained better quality in the physico-chemical characteristics of tomato fruit. Decay percentage was fastest for tomatoes stored at room temperature as compared to the evaporative coolers. Firmness of the tomatoes was better until the final day of the storage inside the evaporative coolers as compared to the ambient storage. Weight loss was highest for tomatoes stored at room temperature and was lowest for tomatoes stored inside the evaporative coolers. In general weight loss percentage, deterioration percentage, Total soluble solid, lycopene and ß-carotene content increased with the storage period, but were faster in tomatoes stored at room temperature as compared to the evaporative coolers. Titratable acidity, fruit firmness, Chlorophyll A and B content decreased with the storage times which were faster on tomatoes stored at room temperature. Tomatoes harvested at light red ripening stage had a shorter shelf life as compared to those harvested at breaker ripening stage. Therefore it could be concluded that evaporative coolers give an alternative approach to mechanical refrigeration for prolonging postharvest shelf life and maintaining quality of tomato fruits. Zero energy cooling chambers need a bigger space as compared to other evaporative coolers, and even at the smaller size it is probably too large for one family's needs. So its application is better for on-farm storage. Pot in pot storage method requires a small space relatively and it can be used in individuals household to extend the shelf life of their produce. But for on farm storage, it is difficult to design very big pots since the pots could easily be broken. The designed passive cooler is appropriate for retailers at market place; where it can withstand breakage in busy market places. However, the above conclusion was derived from results of study conducted within one time. So, further studies repeatedly in different months and locations should be conducted in order to give confirmative results.

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1007 Post Harvest Loss Reduction in Fruits: Is Proper Identification Methods of Maturity Indices a Solution?

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Abstract
A decrease in quantity or quality of food at whatever stage of food processing value chain is considered food waste. The African continent contributes the largest percentage to food waste especially to perishable products such as the fruits and vegetables. The timing and stage of maturity of a fruit at harvest is crucial in its storage and marketability life and quality. The proper timing to attain maximum nutrient composition without losing the other desired attributes should be the ultimate target. Fruit consumers rely on the visual appearance, texture and firmness, sensory analysis as the main attributes for assurance of nutritional and food safety. The common maturity indices such as skin colour, shape of fruit, aroma, size, firmness are easier to be established through physical assessment but others are impossible to be done without use of specialized equipments. In Kenya, most fruit harvesting timing is determined purely through this physical assessment leaving out other vital indices which are of essence such as sugars, acidity, oil content, dry matter content, juice content and concentration levels of other soluble solids. The protocols for maturity stage are either destructive or non destructive (optical, vibrational, electrical, nuclear magnetic resonance and gas analysis techniques). Some of these protocols such as: brix hydrometer or refractometer for sugars, diffuse reflectance method for soluble solids, protein, fat and carbohydrate determination, fourier analysis, the delayed light emission and the Electonic aroma detection (e-nose) are unavailable in Kenya. Unlike the developed countries where such protocols are in place, the reliance on sensory analysis leads to high amount of nutrients loss as the fruit progresses from maturation to ripening due to improper timing of harvesting. Some products are obtained by the consumers when the nutrient content is low while in other cases the need for preserving the nutrients has led to lower physical attributes thus rejection by the end consumer resulting in more food waste.

Key words:
Fruits, food security, postharvest losses, quality assurance

Introduction
The ever expanding human population is facing a risk of failing to feed itself. FAO –World Bank, 2010 and Prusky, 2011 gave an estimated loss of 1.3 billion tons of food per year which represents an estimated one third of total global food production. The actual losses are far higher if the qualitative value loss is included. Despite high resource input in increasing food production and marketing, little work is being done to minimize the post harvest losses. Kader (2005) and WFLO (2010) showed that an estimated 95% of the research investments during the past 30 years were focused on increasing productivity with only 5% focusing on food losses prevention. Focusing on the food production may not fully solve the challenge of food insecurity and a priority in reduction of food losses in the entire food value chain should be set. More emphasis should be placed at reducing post harvest losses. The objective of this paper was to identify different methods and techniques that eliminates wastages and increase the utilization of fruits.

Materials and methods
The paper relied on secondary data. An extensive literature review was carried out to establish the different techniques. The most applicable in the African context were picked through comparison with the available literature.

Results and discussion
Post harvest losses Estimates
The biggest hindrance to post harvest losses reduction is the lack of clear knowledge of the real magnitudes of losses, which makes it impossible to measure progress against any loss reduction targets. Uncertain estimates of post harvest losses, coupled with imprecise understanding of the points in value chains where the losses occur as well as the socio-economic factors for the losses could end in policy errors and sub-optimal choices of mitigation approaches (Dranski et al., 2010). Some of the socio economic causes of food loss include religious and cultural beliefs, lack of proper storage facilities for surplus and lack of sufficient information on the food loss issues among others.

Maturity indices
The knowledge of the maturation process contributes to the establishment of the ideal time to harvest. Different crops have different maturity indices depending on the type of crop and the edible part (Figure 1). For most fruit crops, the following are the major maturity indices that are used to determine the harvesting time. They include: fruit color, size , smell, spontaneous opening, firmness, total soluble solids, respiration, dry matter content, titratable acidity, nutrient content and sensory scores (Reboredo-Rodriguez et al., 2014). The above maturity indices are applied discriminately depending on the target market, consumer preferences and type of fruit. Correct identification and harvesting of crops at the right maturity stage is vital in achieving the sensory and nutritional uality market demand, enable proper utilization either fresh market or processed, enhance adequate shelf-life attainance while facilitating marketing through the right standards thus spurring productivity (Kader, 1996).

The maturity indices poses a challenge in the harvesting of fruit crops as each value chain actor have specific need in terms of point of harvest. The physiological maturity can be defined as the stage of development where most growth has occurred while horticultural maturity can be defined as the developmental stage at which the plant part possesses the necessary characteristics for use by consumers and provide good eating quality (Lee et al, 1983).

Techniques for maturity indices

Several techniques are used worldwide on the proper identification of maturity indices. They range from use of human sensory organs (touch, smell, taste, color) to use of complicated equipments and procedures. Some the techniques available in the world are unavailable in Kenya thus limiting reduction of post harvest losses. The techniques are divided into two: destructive techniques and non-destructive techniques. Destructive techniques includes: dry matter assessment by use of thermo-ventilated oven, nutrient analysis by use of titratable acidity, use of taste and probing. Non-destructive techniques include use of optical such as: delayed light emission, light reflectance, light transmittance, diffuse reflectance, hyperspectral imaging, laser light backscattering imaging, magnetic resonance imaging, X-ray computed tomography, near-infrared spectroscopy and Raman spectroscopy; vibrational and electrical techniques such as electronic nose (e-nose).

Several studies have reported that color change of fruits is a good indicator to assist in identifying the harvest stage of several species. Digital quantification of colors lines by monochrome scale enables to distinguish areas subject to color variations. In this context, the greatest variation of means in relation to maturity stages allows one to classify fruits with greater repeatability. The biggest challenge associated with the use of color is demonstrated in the case of avocados. In avocado plants, horticultural maturity is not accompanied by changes in external appearance (Brasil, 1992; Ferreira, 2000; Dranski, 2010). Moreover, mature avocado fruit do not ripen on the tree, but soften several days after being picked. Thus, it is difficult to judge in advance whether a fruit is mature enough to ripen satisfactorily. Since acceptable eating quality depends on flavor, aroma, color, and texture, a taste panel analysis of ripe fruit is the only true test of horticultural maturity which can only be conducted after full ripening. This results in need for a different technique. The use of Munsell color chart, or refractance values provide a means to identify the fruits with epicarp presenting the colorimetric characteristics with maximum accumulation of dry biomass, water content and seeds with physiological maturity status.

The use of total soluble solids and sugars does have its limitations including: TSS may not be an accurate indicator of sugar content or sweetness (Baldwin et al., 1998), increased sugars and acid levels without manipulating volatile profile may not improve flavor (Baldwin et al., 2008) and the extent to which human senses can perceive changes in chemical constituents varies (Maul et al., 2000). Studies have also shown lack of correlation between instrumental analysis and human sensory perception. The uses of such parameters are dependent on the available resources hence limiting its utilization in small scale production. The e-nose or electronic nose is used to improve accuracy in identification of mature fruits through use of smell or gas emitted from ripe fruits. The e-nose uses sensor arrays composed of 10 metal oxide semiconductor (MOS) type chemical sensors: W1C (aromatic) W5S (broad range) W3C (aromatic) W6S (hydrogen) W5C (aromatic–aliphatics) W1S (broad-methane) W1W (sulphurorganic) W2S (broad-alcohol) W2W (sulphur-chlorinate) W3S (methane-aliphatics). The technique can be used to separate different maturity level of different cultivars thus enabling wider use (Benedetti et al., 2008).

Maturation stage	Epicarp color	Visual characterization	Munsell chart*
1		Green fruit	7,5 GY 6/6
2		Fruit at the beginning of yellow pigmentation	2,5 GY 5/10
3		Predominantly yellow fruit	5 Y 8/10
4		Fruit at the beginning of brown pigmentation	5 Y 8/8
5		Mature fruit	7 YR 4/2
6		Dry fruit at the beginning of dehiscence	5 YR 3/2

Figure 1: Color of physic nut fruits (Jatropha curcas L.) at different maturation stages. * Munsell color charts for plants tissues.
Adopted from Draski (2010)

Conclusion and recommendations

The utilization of maturity indices offers the proper alternative in fruit production for reducing post harvest losses. The use of modern and more precise techniques and equipments provide a cutting edge advantage to the agriculture community. Lack of such equipments and techniques limits the ability to achieve high food storage ability and food security. An investment into such techniques by the relevant authorities will help curb the increasing food wastage and thus contribute towards food security and livelihood improvement.

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Postharvest Losses in Fruits: Dissecting Possible Role and Implications of Pre-Harvest NPK Nutritional Status of Fruits

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Abstract
Postharvest losses (PHL) and food waste is a key pathway to food and nutrition security problems, especially in developing countries. Mineral nutrition is an important pre-harvest aspect that affects the post-harvest quality in fruits and vegetables. However; their quality and quantity is greatly influenced by mineral plant nutrition such as nitrogen (N), Phosphorous (P) and potassium (K) which influence the quality of horticultural crops, particularly in physiological disorders. The main aim of this paper was to present a review on the influence of N,P and K mineral status on postharvest quality in various fruits and vegetables. Desktop literature review using different journal papers and books was done to identify the effect of mineral plant nutrition in relation to postharvest quality development and maintenance. Excess N may result in reduced firmness and enhanced susceptibility to mechanical damage and postharvest decay hence reduced shelf life in tomatoes. Different N forms influence calcium (Ca) uptake availability, a deficiency which may induce a range of postharvest disorders in many fruits and vegetables. Insufficient levels of K may increase the possibility of yellow shoulder and blotchy ripening in fruits. Deficiencies in N and/or P supply have been found to increase acidity and ascorbic acid in citrus fruits. Post-harvest status of fruits and vegetables at and after harvest to some extend depends on some pre-harvest plant mineral management and practices carried out during production.

Key words:
Fruits, nitrogen, phosphorous, potassium, postharvest.

Introduction
One of the biggest challenges for agricultural research and development is how to address and overcome food and nutrition insecurity. While substantial research is focused toward increasing food production to meet this target, reducing food loss and waste, is one significant and complementary factor that is often forgotten. Post-harvest loss (PHL) and food waste is a great and increasingly urgent problem resulting to food and nutritional insecurity particularly in developing countries (Rockefeller, 2015). Fruits and vegetables are an important element of human nutrition. They are not only rich sources of vitamins and mineral elements important for alleviation of hidden hunger but have also been reported to contain immense bioactive phytochemicals and anti-oxidants associated with health benefits. World Health Organization Panel on Diet, Nutrition and Prevention of Chronic Diseases recommend an individual intake of at least 0.3 – 0.4 kg of fruits and vegetables daily. In addition, these horticultural products serve as a source of income and employment for most rural and peri-urban producers. Irrespective of the numerous benefits derived from these crops, postharvest losses make their production unprofitable as a result of low returns to growers, processors, and traders along the value chain. The economy is negatively affected as well in terms of foreign exchange earnings particularly in the third world countries. Most fruits and vegetables are vulnerable to post-harvest loss due to their high water content, soft texture and high respiration rate. Postharvest losses can either be quantitative or qualitative, which have a negative impact on various parameters like consumer acceptability, nutritional content, and income return to the producers.

Many PHLs are dependent not only on post-harvest handling and treatment technologies but also on various pre-harvest features. Among the factors, mineral nutrition is a vital aspect for plant growth and development. Mineral nutrients can also influence quantity and quality of crop produce at and after harvest. Nitrogen (N), along with phosphorous (P) and potassium (K) primary macro-elements have been observed to notably affect the post-harvest value of horticultural products in a number of ways, particularly in physiological fruit disorders. Specifically, postharvest quality disorders of fruits and vegetables more often than not result from nutritional imbalances (deficiency or excess) of these minerals elements. According to Hewett (2006), excess N results in reduced firmness and enhanced susceptibility to postharvest decay in tomatoes. Elevated levels of N may increase the possibility of yellow shoulder and internal whitening while adequate K may reduce the problem in harvested Solanum lycopersicum. Different N forms influence calcium (Ca) uptake availability, a deficiency which may induce a range of postharvest disorders in many fruits and vegetables such as blossom end rot (BER) and reduced firmness (Borgognone et al., 2013).

Fruits and vegetables that are nutrient stressed and of poor quality before harvesting can never be improved in quality by any postharvest treatment methods. This indicates that the postharvest quality of the farm produce cannot be improved by any postharvest methods but can only be maintained. This paper presents an overview on the roles of pre-harvest NPK mineral nutrition in relation to postharvest quality and shelf life in fruits and fruit vegetables.

Effect of NPK mineral nutrition on post-harvest quality
Post-harvest qualities in fruits and vegetable fruits can be influenced by both deficiency and excess availability of nitrogen nutrition. For instance, above optimal levels is associated with excess water content and reduced shelf life while insufficiency of N results to inappropriate ripening traits such as blotching and scabs. High nitrogen supply can impair some important quality traits of fruits, such as total soluble solids and sugars (Kader, 2000).

Of great importance also are different N forms which modulate availability and uptake of other plant elements such as calcium which significantly influences postharvest quality in fruits and vegetables. Nitrogen in ammonium form inhibits calcium uptake by plant roots resulting to a range of physiological disorders in harvested fruits. Some of these are bitter pit in apples, blossom end rot in tomatoes and capsicums, soft nose in mangoes and tip burn in strawberries and lettuce (Hewett, 2006). Calcium deficiency under sole ammonium nutrition can induce loss of membrane integrity, which results to reduced fruit firmness during ripening increasing possibility of mechanical damage during harvesting, transportation and storage. Calcium deficit increases susceptibility to post harvest grey mould (Botrytis cinera) as a result of decreased membrane firmness, increased emission of ethylene and leakage of exudates to the fruit surface in strawberry and tomato production. In addition ammonium N form results in smaller orange fruits; however, it can result in improved tomato fruit flavours. Occurrence of flat fruits has been observed to increase with increasing ammonium concentration in the plant media. Non-specific cation exchange under ammonium N can also result to potassium deficiency associated with blotchy ripening in tomatoes (Brust, 2009). Nitrogen forms also affect the postharvest nutritional value of farm produce. Unlike nitrate N, ammonium N leads to reduced contents of calcium and magnesium mineral elements in tomatoes. Nitrate N reduces the nutritional value by high accumulation of anti-nutrients such as oxalates.

Potassium nutrient affects post-harvest quality specifically during ripening. Insufficient supply of potassium can result to ripening problems known by various names; blotchy ripening, yellow shoulder, grey wall and internal whitening in tomatoes (Brust, 2009). Adequate supply of the same improves fruit colour while enhancing the titratable acidity of tomato fruits especially for processing. Deficient provision of potassium has been associated with small sized citrus and tomato fruits at maturity (Kays 1999).

Phosphorus imbalance is also of postharvest concern. Excess phosphorous results in poor cranberry color development. Deficiency of phosphorus in fruit concentrations is associated with biochemical browning reactions in fruit flesh at harvest and storage, signs of a shorter market life and lower consumer quality, a condition aggravated by nitrogen deficiency. Moreover, low levels of P induce susceptibility of stone fruits to chilling injury during cold storage. Inadequacies in N and/or P supply have been found to increase acidity and ascorbic acid in citrus fruits. Low levels of N,P and K in the plant media results in reduced size and weight in fresh fruits and vegetables.

Conclusion and Recommendations

Plant mineral nutrition greatly influences the post-harvest status in fruits and vegetables. Optimizing plant growth and minimizing post-harvest disorders and quality deterioration is possible through manipulation of NPK mineral nutrition. Thus understanding the effects of pre-harvest NPK nutrient availability is very important in order to produce high quality fruits at harvest. There is need for extensive and exploratory research on mineral nutrition management influence on post-harvest quantity and quality in fruits and vegetables.

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1008 Influence of Different Edible Coatings and Storage Media on Quality and Shelf Life of Cucumber (Cucumis sativus L) fruits

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Abstract

Cucumber fruit is highly perishable after harvesting due to its extremely high metabolic activities. An experiment was conducted at the Laboratory of the Department of Horticulture, Federal University of Agriculture, Abeokuta (FUNAAB) in Nigeria to determine the effects of different edible coatings and storage media on the quality and shelf life of cucumber fruits. Physiological dark green immature cucumber fruits ('Marketmore') were harvested from the Organic Skill plot in FUNAAB and treated with different edible coatings namely; Shea butter, coconut oil and honey while those without edible coating served as control. Treated fruit samples were stored in evaporative cooling structure-ECS (21-23oC and 89-90% RH) for 21 days and open shelf (27-29oC and 74-75% RH) for 10 days. Results revealed that Shea butter coated fruits had significantly ($p \leq 0.05$) reduced weight loss, colour and firmness retention, higher amount of vitamin C content and better visual quality when compared with other fruits coated with coconut oil, honey and those without coating stored in the ECS or open shelf. The ECS delayed colour change and retained firmness in fruit samples when compared with samples stored in open shelf. Shea butter coated fruits stored in open shelf or ECS had acceptable sensory quality parameters such as appearance, taste, texture and overall acceptability when compared with other treated fruits. Thus, the use of Shea butter as an edible coating and ECS as a storage medium for cucumber fruits extended shelf life and maintained quality.

Keyword:

Cucumber, edible coatings, postharvest quality, storage

Introduction

Cucumber (Cucumis sativus L) is an important fruit vegetable which serves as a good source of vitamins and minerals. It is soft, succulent and eaten in salads or sliced into stew.
Edible coatings are an environmentally friendly technology that are applied on many products to control moisture transfer, gas exchange or oxidation processes (Dhall, 2013). The practice of using edible coatings on fruits has been in existence for a longtime in the industry. Edible coatings when applied on harvested fruits prevent shrinkage resulting from water loss and create a modified internal atmosphere around the fruit. Water loss can be controlled by altering the fruit surface or by proper control of storage conditions (Bahnasawy and Khatar, 2014).

The environmental conditions under which cucumber fruit is stored have a significant effect on its shelf life and postharvest quality. Evaporative cooling structure is a locally fabricated low temperature storage structure that has proved to be useful in storage of some fruits and vegetables. Cucumber fruit is usually harvested at physiologically immature state thus making it highly perishable. This leads to extremely high metabolic activities predisposing the fruits to high water loss resulting in rapid deterioration. Furthermore, improper handling, poor storage and preservation techniques increase postharvest losses of cucumber fruits in tropical countries like Nigeria. In view of these challenges, this study was conducted to determine the effects of different edible coatings on the quality and shelf life of cucumber fruits stored in the evaporative cooling structure and open shelf.

Materials and Methods

Source of plant materials

The experiment was conducted at the Laboratory of the Department of Horticulture, Federal University of Agriculture, Abeokuta (FUNAAB) to determine the effects of different edible coatings on the quality and shelf life of cucumber fruits. Cucumber ('Marketmore') was planted between April-June 2015 at the Organic skill plot situated at FUNAAB in South western, Nigeria. The fruits were harvested at physiological dark green immature stage. Fruits of uniform sizes, free from defects and physical damages such as cuts, pests and diseases were selected.

Sample preparation

Cucumber fruit samples were properly washed with distilled water to remove dirt that can hinder proper coatings and air dried at room temperature in the laboratory. They were randomly divided into four lots of two batches and treated with different edible coatings namely, shea butter, coconut oil and honey while those without edible coating served as control in each batch. The edible coating was applied thinly on the samples with the use of a soft brush. The coated fruit samples were stored in evaporative coolant structure-ECS, pot-in-pot design (21-23oC and 89-90% RH) for 21 days and open shelf (27-29oC and 74-75% RH) for 10 days. Fruits were analyzed for qualitative parameters before application of edible coatings at pre-storage and after application of edible coatings at 7 days after storage in the open shelf and ECS.

Experimental design

The experiment was arranged in a completely randomized design and replicated three times

Data collection

Weight loss was determined by dividing the fruit weight change during storage by the original fruit weight using the following equation:

FW (%) = 100 x (FW1– FW2)/FW1

Where FW1 is the weight on the first day and FW2 weight of fruit at the time of sampling.

Fruit firmness of individual fruits was measured using a hand held penetrometer. Color change and visual quality was observed using a Produce Quality Rating Scales and Color Charts (Kader and Cantwell, 2005). Total soluble sugar (TSS) was determined by placing juice from fresh samples on the reading surface of a hand-held Brix Refractometer (MF032ATC). Titratable acidity (TA) was estimated by titrating with 0.1N NaOH solution to pH 8.1 and it was calculated as percent citric acid. Determination of vitamin C was done according to titration method described in AOAC (2004). Potassium and Iron were determined according to the standard methods of AOAC (2004). A panel of 20 trained students from the Department of Horticulture, FUNAAB evaluated sensory attributes such as fruit appearance, taste, texture and overall acceptability at 4 and 12 days after storage in open shelf and ECS respectively. Scores were allotted on a 9 point hedonic scale.

Data Analysis

Data obtained were subjected to analysis of variance (ANOVA) using GenStat Discovery Statistical package (GenStat, 2011) and means were separated using least significant difference at 5% level of probability.

Results

Results revealed that cucumber fruits coated with shea butter stored in either ECS or open shelf had a significantly ($p<0.05$) reduced weight loss (6.2% or 12.7%) respectively when compared with fruit samples coated with honey, coconut oil and those without edible coatings. Also, weight loss in cucumber fruits stored in both the ECS and open shelf increased with days in storage. However, weight loss of fruit samples was significantly reduced in fruits stored in the ECS. The vitamin C contents (2.87mg/100g or 2.64mg/100g) of cucumber fruits stored in either ECS or open shelf respectively, coated with shea butter was higher when compared with cucumber fruits coated with honey, coconut oil and those without coating at 7 days after storage. However, TSS was significantly reduced in cucumber fruits coated with Shea butter (Table 1). Furthermore, TA was higher ($p<0.05$) in fruits coated with Shea butter. Generally, the TA in cucumber fruits reduced with increasing TSS in storage. The iron contents of fruits at pre storage were similar with fruits coated with Shea butter at 7DAS in open shelf when compared with other coated and uncoated fruits. Visual quality, colour and firmness retention were also higher ($p<0.05$) in fruits coated with Shea butter at 14 and 7 days after storage in the ECS and open shelf respectively while the least values were obtained in cucumber fruits without coatings (Table 2). Shea butter coated fruits had higher scores in acceptable sensory quality parameters such as appearance, better taste, texture and overall acceptability.

Table 1: Quality of cucumber fruits as influenced by edible coatings

Treatment	Weight loss (%)		Colour Change	Firmness (N)		Total Soluble Solids	Vitamin C mg/100g		Iron mg/100g		Potassium mg/100g		
OS	ECS	OS	ECS	OS	ECS	OS	ECS	OS	EC	OS	ECS	OS	ECS
Pre storage 1.46	*	*	5	5	54.3	53.1	3.56	3.38	2.22	2.65	0.0042	0.0032	1.49
Coconut oil 1.35	18.5	9.3	4	4	50.5	50.2	4.02	4.47	2.12	2.44	0.0012	0.0027	1.22
Honey 23.2	12.7	3	4	49.4	47.2	4.12	4.40	2.01	2.62	0.0032	0.0031	1.13	1.41
Shea butter 1.40	12.7	6.2	5	5	52.3	51.5	3.10	3.22	2.45	2.87	0.0045	0.0034	1.45
No coating 1.47	25.1	11.8	3	4	51.4	49.3	4.26	3.93	2.11	2.69	0.0023	0.0029	1.23
Lsd (p<0.05) ns	4.3	3.2	*	*	2.1	2.0	1.05	1.02	0.04	0.07	0.0005	ns	ns

Note: *Not determined

ECS-Evaporative cooling structure, OS- Open shelf.

Colour Change: 5-dark green, 4-light green, 3- greenish yellow, 2-yellowsish green, 1-yellow

Table 2: Sensory evaluation of cucumber fruits as influenced by edible coatings

Treatment	Appearance		Taste	Texture		Overall acceptability				
Open shelf		ECS	Open shelf		ECS	Open shelf		ECS	Open shelf	ECS
Coconut oil	6.3	8.2	7.0	7.6	6.5	6.5	5.5	6.5		
Honey 3.2	7.2	3.4	5.4	2.1	3.4	3.4	3.2			
Shea butter	8.4	8.6	7.1	7.8	7.7	7.2	7.6	8.2		
No coating	5.2	6.6	5.9	4.2	3.5	4.5	3.1	4.1		
Lsd (p<0.05)	1.2	1.6	1.6	2.1	2.5	2.2	1.5	1.7		

Note: ECS-Evaporative cooling structure. Hedonic Scale: 1-dislike extremely, 2- disliked very much, 3-disliked moderately, 4- disliked mildly, 5-neither disliked nor liked, 6-liked slightly, 7- liked moderately, 8- liked very mush, 9-liked extremely

Discussion

Cucumber fruits coated with honey, coconut oil and those without edible coating had higher TSS content with change in colour from green to yellow. This observation is due to the conversion of starch in the fruits into sugars with the expression of carotenoids. However, cucumber fruits coated with shea butter had the acceptable dark green colour. Consumers of cucumber fruits prefer a firm and dark green fruit with no wrinkled ends. Furthermore, retardation of colour changes in shea butter coated fruits may be due to high CO2 and or low O2 levels in the internal atmosphere of the fruits (Moalemiyan and Ramaswamy, 2012).

Generally, low storage temperature promotes longer postharvest life and quality of fresh produce. The ECS maintained quality, delayed color change and retained firmness because this storage method operates like a cool storage. Moistening of the ECS during the experiment helped to maintain the moisture content of the fruits and also ensured moderate average temperature ((21-23oC) and high relative humidity (89-90%). The optimum relative humidity for most fruits is 85-90%. However, cucumber fruits stored in the open shelf had lower quality probably due to the exposure of the fruits to the atmosphere which encouraged interplay of various agents of deterioration. Firmness of cucumber fruits decreased with storage over time in both the open shelf and ECS possibly due to textural change as a result of enzymatic degradation of the components responsible for structural rigidity of the fruit, which are primarily the insoluble pectin and proto-pectin. Texture is however an extremely important attribute in cucumber as consumers prefers the skin to be firm and crisp.

Conclusion and Recommendation

Shea butter used as an edible coating for cucumber fruits extended the shelf life and maintained quality of fruit stored in either the ECS or open shelf when compared with coconut oil and honey and those without coatings. The ECS as storage medium performed better than open shelf because it created a moderate temperature and high relative humidity that suppressed metabolic activity and physiological reactions in the fruits.

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1009 Selection of Appropriate Chilli Drying Technologies Using Analytical Hierarchy Process: A Case of Northern Uganda

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Abstract
Kawanda Agricultural Research Institute estimates crop post-harvest losses at 5-15% for cereals and legumes, 20-25% for roots and tubers and over 35% for fruit and vegetables. Specific to NECPA Chilli farmers, the loss is up to 35% because of the use of rudimentary technologies for drying. This study was conducted with the aim of selecting appropriate drying technology to reduce the post -harvest losses. Analytical Hierarchy Process Methodology was used. The survey in the study involved stakeholders who rated the technologies depending on cost of the technology, time it took to dry and cleanliness of the product. Results indicated that 91% of farmers interviewed used open air drying method (plastic carpet-2%, papyrus mats-58%, sun tables-5%, black polythene sheet-10%, cow-dung smeared floor-9%, tarpaulins-12%, Iron sheets-4%) leaving only 9% using improved Ultra violet solar dryer (the UV polythene sheet dryer). The major loss of over 30% to chilli farmers is because of the use of open air drying methods. The Ultra Violet Solar dryer was found to be the most appropriate post-harvest technology for the Chilli farmers.

Keywords:
Analytical Hierarchy Process, chilli, open air drying, post -harvest handling, U.V polythene sheet solar dryer.

Introduction
In Uganda, 73% of households depend on agriculture for food and income (Kawanda research Institute 2010) and the use of traditional post-harvest handling methods account for the loss of 5-15% for cereals and legumes, 20-25% for root and tubers and over 35% for fruit and vegetables (Kawanda research Institute 2010). More specifically, post- harvest processing by drying of chilli is a challenge among the chilli growing community in Northern Uganda. Drying of chilli takes more than five days and yet during the peak period, harvesting is done on a daily basis (Cocker, 2000; Palled.et.al 2012; Madhlopa et.al 2002). This is making farmers to lose a lot of crop produce which directly leads to a low income gain from the sale of the crop because it takes a longer period for the farmers to achieve 7.5-8% moisture content (Dulawat.et.al, 2012; Kulanthaisami.et.al.2009). Uganda targets a middle income status by 2020. To achieve this expectation of poverty reduction through agricultural growth, both production and management of produce need to be improved, hence, research in Post-Harvest Handling (PHH) methods is paramount.

Objectives of the study
The purpose of the study was to select and recommend appropriate post-harvest handling technologies for use by chilli farmers in Northern Uganda so as to improve the quality of the product and income of the farmers.

Materials Methods
The study adopted a case study design and qualitative methods of data collection (Yin, 2009). This included surveys among, Key Informant Interviews (KIIs), Focus Group Discussions and Document review. The study population was the chilli farmers who are working with North East Chilli Producers Association, local government extension workers and leaders in Northern Uganda. Analytical Hierarchy Process (AHP) Methodology (Saaty, 2008) was used to select the best technology based on the following criteria: cost of drying technology, drying period, and the quality of the final product. Based on that methodology, the available drying technologies were rated by stakeholders and sensitivity analysis was done. The random index, which is the consistency index of a randomly generated pairwise comparison matrix, was found to be -0.171 according to (Saaty 1998)

Results and Discussion
About, 91%, of the farmers interviewed used the open air drying method (plastic carpets, papyrus mats, sun tables, black polythene sheet, cow dung smeared floors, iron sheets and tarpaulins). Only 9% of the farmers used UV solar dryer.As a result, the existing post-harvest technologies used by most chilli farmers are rudimentary, locally sourced and have little significance in ensuring quality of the end product. For the three most common techniques used; plastic carpets, black polythene sheet and papyrus mats, 31.4% on average, of the dried chilli was sorted out as non-market worthy poor quality chilli. This agrees with the findings from Kawanda Research Station, (2010) that estimated post-harvest losses for fruits and vegetables (the category where chilli falls) was over 35%.

In this study the U.V polythene sheet solar dryer is the recommended technology for drying chilli in Northern Uganda because it gives clean chilli with a minimum post-harvest loss of 2.4 %. The recommended dryer is highly effective since it gives the cleanest final product in the shortest time possible. However, this technology is not widely used by chilli farmers in Northern Uganda because it is not easy to use (it requires training), it is expensive to acquire and it is not readily available on the local market. The majority of the farmers (58%) use papyrus mats for open sun drying of their chilli. Other technologies that farmers use for drying chilli are tarpaulins (12%), black polythene sheets (10%) ,cow dung smeared floors (9%) and plastic carpets, sun table and iron sheets (accounting for not more than 5%).

Factors Affecting the Use of Technologies

Factors influencing these rudimentary post-harvest handling techniques include lack of exposure, low purchasing power due to poverty and luck of skills. This is typical of the farmers in Uganda since farming is a preserve of the rural, uneducated, unskilled and poor population. The study found out that reasons such as; availability of materials, ease of use and being cheap were key reasons for the farmers' choice of post handling method. These as well agrees match the findings of Madhlopa et al., (2002) on the reason why farmers prefer open air drying; i.e. it is the simplest and cheapest method of conserving foodstuffs. The supply of the chilli during the pick period is limited and this is because many buyers are chasing after the crop and they keep on increasing the prices and not bothering about proper post-harvest practices. They buy all types whether dirty or clean and at the same price (Cocker, 2000). This encourages farmers not to stick to proper post-harvest handling and on the other hand discourages the farmers who are genuinely doing proper post-harvest handling because in the long run there is no price differentiation.

Effectiveness of the Technologies Currently Being Used

Post-harvest handling techniques relied on by a majority of farmers are largely non effective. For the three most common techniques used; plastic carpets, black polythene sheet and papyrus mats, 31.4% on average, of the dried chilli was sorted out as non-market worthy poor quality chilli. This agrees with the findings from Kawanda research station that estimates post-harvest losses for fruits and vegetables (the category where chilli falls) at over 35%. This means that farmers earn little from their agricultural efforts since they lose an average 35% of their expected income due to poor post handling methods. There is therefore need to improve traditional drying, solar dryers, which have the potential of substantially reducing the moisture content of the food should be introduced and availed to the farmers.

Effective Technologies for Post-Harvest Handling of Chilli

The Solar tunnel Dryer made of UV stabilized polythene sheet dries products better in terms of quality and drying time of final product as compared to open sun dried products (Kulanthaisami et.al. 2009) . Reduction of moisture content to the desired level is the most important function of solar drying and this involves two processes, low temperature heating and exhaust of moist hot air (Kulanthaisami et.al. 2009). The reduction of moisture content to the required level is very important because the most common cause of rot in chilli in northern Uganda is the presence of excess moisture in the dry chilli. This has rendered farmers to lose more than half of their crop produce and thus reduced income at the end. Unlike the open air drying methods, the UV polythene sheet can easily be made to achieve both low temperature heating and exhaust of moist hot air.

Drying using the UV polythene sheet does not result in products losing their colour as also confirmed by Dulawat in Palak India (Dulawat.et.al, 2012). This is one of the most important factors considered by the buyers of Chilli in Northern Uganda. Mixed colored product will have to be sorted until a uniform red coloured product is achieved. Using open air drying, farmers leave their crop indoors for days if it's the rainy season, and with chilli, one day is enough for it to rot thus darkening occurs. This leads to loss for the farmers because they have to sort out the rotten ones. During sunny days, the UV Polythene Sheet Solar Dryer takes 4-8 days to dry the chilli depending on the quantity of the chilli put in the shelf. This agrees with the work of Palled.et.al (2012) in India, who reported that by using the solar dryer made of UV polythene sheet made in a tunnel shape, the drying was achieved within 60 drying hours (8-9 sunny days) (Palled.et.al, 2012). This gives the solar dryer a greater advantage over open drying methods which take longer time. However this technology is not widely embraced in northern Uganda among the chilli farmers because it is expensive to acquire, the materials are not easily available in the local markets and the expertise for making the dryer is not readily available.

Conclusion and recommendations

The UV polythene sheet solar dryer is effective in drying in that it results in quality chilli with a percentage loss of <5% in after sorting dried product. The solar dryer also takes less time of 5 days to dry the crop as compared to the open air drying methods which take 7-8 days. However, in Northern Uganda, only 9% of the chilli farmers still used this technology because of high cost of the technology and there was no price fragmentation of the products. In marketing, chilli dried using the solar dryer was paid the same price as that dried in open air. This did not give the farmers motivation to buy the dryer but rather continued to use the open air drying methods like papyrus for drying chilli because they were cheap and easy to use despite not being very effective because the loss incurred after sorting was >30%. This loss when compared in terms of money is a lot for a poor farmer to incur. However, there are ways to popularize and avail the UV solar dryer technology to the farmers for improved quality of the chilli and these include but not limited to; putting these farmers in groups and helping them acquire these dryer in a group rather than have it bought individually, have the different stakeholders like NECPA that can buy this solar dryer material and give to the farmers on a credit basis and the farmers pay later after the sale of the crop. However, to achieve this more should be done by lobbying the government for higher prices for the chilli dried using the solar dryer so that farmers are encouraged to acquire the dryer. The marketing system should be revised so that both farmers and buyers move at the same pace in terms of information flow so as to maintain the markets.

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10010 Determination of Maturity Indices of Three Mango Varieties Produced in Embu County of Kenya

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Abstract
Harvest maturity significantly affects the overall quality and shelf life of fruits such as mango. Subjective indices often used by producers are unreliable and cannot be used to accurately predict the right maturity for the target market or use. The objective of this study was to determine maturity indices of 'Tommy Atkins', 'Van dyke' and 'Kent' mango varieties produced in a medium altitude agro-ecological zone, Embu County of Kenya. Mango trees were tagged at 50% flowering and the number of days to the earliest maturity stage established for each variety as stage 1. Subsequent stages (2, 3 and 4) took 7-10 days apart. For each maturity stage and variety, the indices of maturity based on physical, physiological and biochemical parameters were established. The number of days from 50% flowering to physiological maturity was established as 97, 100 and 114 for 'Tommy Atkins', 'Van dyke' and 'Kent' respectively. Fruits' flesh firmness decreased gradually with maturity from 40.54 N (stage 1) to 6.84 N (stage 4). Ethylene production and respiratory activity increased with maturity. The ratio of total soluble solids to total titratable acidity increased from a mean value of 25.57 (stage 1) to 109.9 (stage 4). The study revealed that despite similarity in visual (subjective) parameters, the three varieties differed significantly in other maturity indices. A combination of flesh color, firmness and computational maturity indices to ascertain harvest maturity for mango fruits can be complemented by the subjective indices used by farmers.

Key words: Mango, maturity indices, postharvest

Introduction
Mango (Mangifera indica L.) is a climacteric fruit and is grown in most tropical countries and some subtropical ones. Poor harvest scheduling and lack of proper knowledge on fruit maturity which results in farmers harvesting immature or over mature fruits is considered to be one of the major problems contributing to post harvest losses in mango (Gitonga et al., 2009). The subjective maturity indices commonly used by farmers are affected by factors such as production location, variety and cultural practices (Salengke and Mursalim, 2013). Most objective indices used to establish maturity of mangoes are based on computational, physical, physiological and biochemical parameters. Days after full bloom provides a better maturity index compared to other computational methods, provided number of days used has been derived in the area it is being used as an index. Physical parameters used include peel/flesh color, peel/flesh firmness, specific gravity and size; while physiological parameters include respiration and ethylene evolution rates. The rate of respiration increases gradually as the fruits advance in maturity. The change in respiratory activity follows a distinct pattern and is dependent on the variety and production conditions (Ouma, 2015). Maturity in mango can also be established using biochemical indices which include total soluble solids and total titratable acidity. Thus this study reveals significant variation in objective maturity indices of 'Tommy Atkins', 'Van dyke' and 'Kent' mango varieties produced in a medium altitude agro-ecological zone of Kenya.

Materials and Methods

Samples
Three commercial mango varieties namely, 'Tommy Atkins',' Van dyke' and 'Kent' were randomly harvested from small scale farmers in Embu county of Kenya. The number of days from 50% flowering to physiological maturity, based on flesh color was established for each variety as stage 1. Subsequent stages (2, 3 and 4) took 7-10 days apart. The fruits were separately harvested based on maturity stage and variety. For each maturity stage and variety, a random sample of ten fruits was used to analyse the initial maturity indices based on physical parameters (size, peel/flesh firmness, peel/flesh colour), physiological parameters (respiration rate and ethylene evolution rate) and biochemical parameters (total soluble solids (TSS) and total titratable acidity (TTA) maturity indices.

Physical parameters
The length of the three fruits randomly selected from each of the 3 varieties at the different stages was determined using a caliper (Model Mitutoyo, Japan) and the mean size was expressed in centimeters. Peel and flesh firmness was determined using a penetrometer (Model CR-100D, Sun Scientific Co. Ltd, Japan) fitted with a 5 mm probe. The color of both the flesh and skin were measured using the Minolta color difference meter (Model CR-200, Osaka, Japan).

Physiological parameters
Ethylene evolution and respiration rates were determined using gas chromatographs (Models GC-8A and GC-9A, Shimadzu Corp., Kyoto, Japan). Rate of carbon dioxide production was expressed as ml/kg/hr at standard atmospheric pressure while ethylene production was expressed as µl/kg/hr

Biochemical parameters

The total soluble solid (TSS) was determined using an Atago hand refractometer (Model 500, Atago, and Tokyo, Japan) and expressed as degrees brix (°B), while total titratable acidity (TTA) was determined by titration with 0.1N NaOH in presence of phenophthalein indicator (1% in 95% ethanol)

Statistical analysis

Data obtained was presented as mean computed in triplicates and was statistically analyzed using Genstat statistical package 13th edition. Means were separated using Fisher's protected Least Significance Difference (LSD) at P $\leq$ 0.05.

Results

Tommy Atkins and Kent varieties were generally larger compared to Van dyke variety. A decreasing trend for both skin and flesh firmness for the 3 varieties was observed as maturity progressed. Kent variety had significantly (p $\leq$ 0.05) higher peel firmness compared to Tommy Atkins and Van dyke while Tommy Atkins had the softest flesh among the 3 varieties (p $\leq$ 0.05). The hue angle on the skin fluctuated depending on the variety but not stage of maturity. Flesh color changed from warm green to yellow green then to cool yellow as maturity progressed. The respiration rate and ethylene evolution increased with maturity in all the fruits. Ethylene production was significantly (p $\leq$ 0.05) affected by the interaction between variety and stage of maturity. Kent variety had the lowest respiration rate at maturity stages 2 and 3. As maturity progressed, TSS increased in all the varieties. The levels of TSS was significantly different (p $\leq$ 0.05) among the varieties at maturity stages 2 and 3. As maturity progressed, TTA decreased in all the fruits. At maturity stages 2 and 3, the levels of TTA was significantly different (p $\leq$ 0.05) among the varieties.

Table 1. Days after flowering to maturity stages 1 to stage 4 for 'Van dyke', 'Tommy Atkins' and 'Kent' mango varieties

Stages	Van dyke	Tommy Atkins	Kent
1	100	97	114
2	110	107	121
3	119	115	164
4	129	124	173

Table 2. Maturity indices; o Brix ratio, hue angle flesh (°), peel and flesh firmness (N) of 'Van Dyke', 'Tommy Atkins' and 'Kent' mango fruits varieties harvested at four stages of maturity; stages 1, 2, 3 and 4

Maturity Stage	Variety	°Brix ratio	Hue angle flesh (°)	Peel firmness (Newtons)	Flesh firmness (Newtons)
1	Van dyke	25.57a	105.3b	48.14a	33.92a
	Tommy Atkins	33.14b	100.0a	46.43a	34.77a
	Kent	33.88b	98.1a	53.81b	40.54b
	LSD	4.9118	2.5445	4.0412	3.3466
	CV%	7.0	1.1	3.6	4.1
2	Van dyke	47.34a	96.31c	41.71a	30.21a
	Tommy Atkins	69.97b	91.48b	41.14a	28.58a
	Kent	81.98c	85.96a	43.61a	33.59a
	LSD	5.6525	1.1311	Ns	ns
	CV%	3.8	0.5	3.4	6.6
3	Van dyke	69.27a	90.68b	33.23a	24.75c
	Tommy Atkins	92.62b	82.32a	31.88a	15.69a
	Kent	99.39c	80.19a	36.58b	20.35b
	LSD	3.1765	7.58	2.8080	1.4668
	CV%	1.6	4.0	3.7	3.2
4	Van dyke	94.3a	76.63c	28.15a	13.88c
	Tommy Atkins	106.1b	72.48b	27.28a	6.84a
	Kent	109.9b	69.34a	27.07a	10.82b
	LSD	8.4127	2.6087	Ns	1.5062
	CV%	3.6	1.6	3.9	6.3
	Significance V	**	*	*	*
	S	**	**	**	**
	(V*S*)	**	*	**	**

Means within each column followed by a different letter differ significantly at (p $\leq$ 0.05) while similar letter (s) in a column do not differ significantly at (p $\leq$ 0.05).

ns -non significance at 5% level, *Significance V=Variety and S=Stage.

Discussion

Number of days from full bloom to physiological maturity varies among cultivars and locations and therefore should be limited to a particular geographical area (Debbie, 2012). Previous studies have shown that 'Apple' mango variety attained maturity 111 and 107 days after full bloom (DAFB) while 'Ngowe' mango variety, 97 and 91 DAFB for Embu and Makueni counties of Kenya, respectively (Ouma, 2015). The present study verifies varietal differences in reaching physiological maturity even at similar production area. Litz (2009) showed that mango fruit size depends on the accumulation of water and dry matter in the various compartments during fruit growth. Differences in ground color between immature and mature green mangoes can be subtle since it is environment and cultivar dependent (Jha et al. 2007). Assessment of harvest maturity by skin color changes usually depends on judgment by harvester. The firmness of the skin and flesh is strongly dependent on the maturity stage. Firmness is a measure of hardness of the mango fruit and it plays a crucial role in postharvest activities like stacking, packaging, transportation and perishability arising from mechanical damages. The firmer the flesh of the fruit, the more suitable they are for processed mango products. Ethylene evolution rate and respiratory rate increased as maturity progressed in 'Van dyke', 'Tommy Atkins' and 'Kent' varieties. However these rates varied with the different varieties. Respiration rate and ethylene evolution follow a distinct pattern in climacteric fruits. Ethylene evolution and respiratory activity begins to rise gradually as climacteric fruits mature and begins to ripen (Litz, 2009). Total Soluble Solids (TSS) increased as maturity progressed while Total Titratable Acidity (TTA) decreased as maturity progressed and this led to an increase in the TSS:TTA ratio. Kent variety was established to have more TSS:TTA ratio compared to Van dyke and Tommy Atkins varieties. Hydrolysis of polysaccharides, especially starch, could have led to the observed increase.

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10011 The Effect of Harvest Maturity on the Quality Attributes of Solar-Dried Mango Products of Selected Mango Varieties

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Abstract
Processing of perishable fruits into shelf-stable products is considered as one effective strategy towards reduction of the high postharvest losses. The quality of processed mango products is affected by many factors including variety and stage of maturity. The main objective was to determine the effect of harvest maturity on the quality attributes of dried products of three mango varieties; 'Van dyke', 'Kent' and 'Tommy Atkins'. The earliest maturity stage, based on yellowing around the seed, was established for each variety as stage 1. Subsequent stages (2, 3, 4 and tree ripe) took 7-10 days apart. The fruits were harvested at maturity stages 3, 4 and tree ripe and arranged as batches for each maturity stage and variety. A random sample of ten fruits from each batch was peeled and cut into 2-3 mm thick chips which were laid out on trays and loaded into a solar drier. The trays were removed once the slices had achieved 10% moisture content. The dried and fresh mango slices were analyzed for Vitamin C, ß- carotene, fructose, glucose, sucrose, potassium, calcium, magnesium, moisture content and firmness. The results showed that dried products had lower levels of ascorbic acid content and higher sugar levels compared to fresh products. Kent variety had the highest vitamin C level of 24.073 mg/100g of the dried slices at tree ripe stage. The results showed that quality of dried products determines consumer acceptance and consequently feasibility of processing as a strategy to reduce postharvest losses in fruits.

Key words:
Mango, maturity stage, nutritional qualities, solar drying

Introduction
Mango fruit is an important fruit crop and its quality as well as the postharvest life of the fruit is influenced by the stage of maturity at harvest. Harvesting at the right maturity is a significant phase which determines the shelf life, aroma as well as acceptability by the consumer. Depending with the marketing demand along the mango value chain, fruits can be harvested at any maturity stage. Fruits meant for export or far flung markets are harvested more often at premature stage to ensure longer shelf life and marketing period. Such fruits may attain the desired physical attributes but have inferior sensory and nutritional qualities (Sivakumar, 2011). Processing mango fruits into shelf-stable products such as dried products has been on the increase due to postharvest losses incurred as a result of perishability of the fruits. The quality of such products is significantly affected by the maturity stage and the variety of the fruits used. The final quality of processed fruit products is determined by the quality at the start of processing (Kader, 2005). Nutritional qualities such as Vitamins, ß-carotene, minerals and sugars change as the fruits mature and they are also affected by drying. Direct exposure of products to the sun lowers quality factors like ascorbic acid. Indirect utilisation of the solar energy could improve the quality of the final dried product. Solar dried products are cost-effective solution to food preservation in hot climate as they reduce storage and transportation costs as well as associated problems due to climatic effects (Whitfield, 2000). .

Materials and Methods
Three mango varieties, namely 'Van dyke', 'Tommy atkins' and 'Kent', were harvested from Embu County at three different maturity stages (3, 4 and tree ripe) based on the flesh color as the index of maturity and arranged as batches based on maturity stage and variety. Ten fruits were randomly sampled out from each batch and were peeled and cut into 2-3 mm thick chips. The chips were then arranged on trays and loaded into a small scale greenhouse solar dryer. The drying conditions in the solar drier were; average temperature of 45°C, relative humidity ranged between 21.8 - 63.5% depending on the moisture content of the slices and the prevailing temperature. The average air speed was 4m/s. The ambient temperature conditions ranged between 17 - 30°C.The trays were removed once the sampled mango slices had achieved 10% moisture content. The dried mango slices were analyzed for ascorbic acid content,ß-carotene, sugars (fructose, glucose and sucrose), minerals (potassium, calcium and magnesium) moisture content and firmness. Data obtained was presented as mean computed in triplicates and was statistically analyzed using Genstat statistical package 13th edition.

Results and Discussion

Ascorbic acid (Vitamin C)
Ascorbic acid content reduced after drying the slice from maturity stage 3 to maturity stage 4. Ascorbic acid content of the dried slices reduced from 56.13 mg/100g (maturity stage 3) to 19.51 mg/100g (tree ripe stage). Tommy atkins variety had the lowest amount of ascorbic acid content on the dried slices at tree ripe stage compared to Van dyke and Kent varieties. These results concur with those of Ahmet et al., (2010) who reported that increasing drying air temperature causes more loss of vitamin C in the dried Kiwi fruits. Drying concentrates those nutrients that are not heat or light labile and ascorbic acid is the main casualty, often being reduced to a mere trace.

Beta - carotene

Drying of the slices had significant (p ≤ 0.05) effect on the ß-carotene content on the fresh samples. ß-carotene content increased with maturity after drying the slices. Tommy atkins variety had the highest ß- carotene levels of the dried slices during maturity stage 4 and tree ripe stage while Van dyke variety had the lowest ß- carotene levels of the dried slices during maturity stage 4 and tree ripe stage. ß-carotene is responsible for the orange pigment in most fruits and vegetables (Ellie, et al; 2010). As the samples were dried, lightness (L) and hue angle (h°) of the samples reduced and the shift of color from cool yellow to orange could have led to the increase of the ß-carotene content.

Changes in minerals

Drying of the slices had significant (p ≤ 0.05) effect on the minerals (potassium, calcium and magnesium) of the fresh samples. All the minerals decreased gradually as maturity progressed after drying the slices. Potassium content reduced from 108.57 mg/100g to 88.4 mg/100g at tree ripe stage, after drying the slices. Calcium content reduced from 4.46 mg/100g to 2.967 mg/100g at maturity stage 4 after drying the slices. Magnesium content reduced from 8.102 mg/100g to 4.2 mg/100g at maturity stage 4 and 6.233 mg/100g to 3.08 mg/100g at tree ripe stage, after drying. Kent variety had the highest magnesium content of the dried slices which ranged from 8.267 mg/100g (maturity stage 3) to 5.7 mg/100g (tree ripe stage). The mineral contents of the dried samples varied among the varieties and the maturity stages. The reduction of the mineral levels after drying could be due to exposure to high temperatures in the polythene greenhouse which led to high moisture loss from the samples.

Changes in sugars

Drying of the slices significantly (p ≤ 0.05) affected the amount of sugar content on the slices. Sugar contents increased after drying the slices and as maturity progressed. Fructose contents increased after drying the slices from 3.227 mg/100g to 5.46 mg/100g at tree ripe stage. Glucose contents increased after drying the slices from 1.92 mg/100g to 3.42 mg/100g at tree ripe stage while at maturity stage 4, sucrose contents increased from 2.016 mg/100g to 4.28 mg/100g after drying the slices. Kent variety had the highest amount of sucrose content of the dried slices which ranged between 4.13 mg/100g to 5.02 mg/100g. Drying concentrated the amount of sugars in the mango slices. Vaughan (2003) reported that drying concentrated sucrose, fructose and glucose contents in fruits.

Firmness

Drying affected the firmness of the slices. The firmness of the dried slices reduced as maturity progressed. Firmness increased after drying the slices from 6.03N to 31.17 N at tree ripe stage. Firmness of the dried slices reduced from 42.33N (maturity stage 3) to 26.20 N (tree ripe stage). Kent variety was most firm at tree ripe stage (31.17N). The firmness of the fruit is strongly depended on the maturity stage. The decrease in firmness with maturity is attributed to steady solubilization of protopectin in the cell wall to form pectins (Tridjaja et al., 2000).

Moisture content

As maturity of the fruits progressed, the moisture content of the dried slices increased. The levels increased from 10.33% to 15.28% depending with maturity stage and variety. As the fruits mature, various biochemical changes occur and this leads to more water and dry matter accumulating with maturity. Moisture content level is however depended with varieties and the method of drying (Bige et al; 2016).

Table 1: Vitamin C content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3 ,4 and tree ripe

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	79.323a	51.883b	43.543b	33.547b	32.667b	21.373b
Tommy atkins	65.269c	45.846c	35.876c	27.636c	26.100c	19.513c
Kent	76.773b	56.133a	49.735a	38.703a	36.733a	24.073a
LSD	2.448	1.176	0.91	1.269	3.1	0.0207
Levels of Significance (V*S)	*	*	*	*	*	*
CV%	1.0	1.0	0.6	1.7	4.3	3.8

Means within each column followed by a different letter differ significantly at (p ≤ 0.05) while means with a similar letter in a column do not differ significantly at (p ≤ 0.05). ns -non significance at 5% level, *Levels of significance V=Variety and S=Stage.

Table 2: Beta Carotene content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	2.477c	11.283c	5.670b	16.17c	15.31c	20.27c
Tommy atkins	2.965b	11.36b	5.539b	18.15a	16.28b	25.08a
Kent	3.372a	12.22a	6.136a	17.173b	18.09a	23.36b
LSD	0.3023	0.0621	0.4712	0.1191	0.432	1.039
Levels of Significance						
(V*S)	*	*	*	*	*	*
CV%	5.2	0.3	2.2	0.3	6.4	2.0

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$). ns - non significance at 5% level, * Levels of significance V=Variety and S=Stage.

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10012 Incidences of Post Harvest Insect Pests in Shea Fruits During Storage

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Abstract
Insect pests can damage and affect the quality of the shea fruit in storage and this could threaten food security, self sufficiency and incomes. The study area, Niger State, Nigeria, was divided into zones (A - C) for effective coverage of storage warehouses. Selected warehouses were visited, observations conducted on processing and storage methods and shea fruits collected for laboratory analysis. Direct observations of infrastructural facilities were also conducted. Laboratory analysis were conducted on shea fruits for identification and quantification of storage insect pests from October 2014 to September 2015 at Nigerian Institute for Oil Palm Research (NIFOR), with temperatures fluctuating between 260C – 340C and relative humidity from 52% - 92%. As storage time increased, mites, chalcid ants, and weevils (Curculionidae) were observed. The fruits were observed to be mainly attacked by mites and beetles. October (25) and November (21) 2014 had the highest number of mites with fruits severely attacked, and with subsequent decrease in the number of mites observed. Shea fruits should be picked immediately as it matures, as fruits left in the fields for long periods become infested. During collection, it should be ensured that the fruits are not exposed to insect pests before they are properly bagged and removed. All infested fruits should be removed and separated immediately. Particular attention should be paid to cracks and gaps where insects may hide on the fruits. The fruits should be properly dried before storage to prevent germination and fungi attack.

Key words:
Management practices, mites, shea fruit, storage insect pests

Introduction
The shea tree, Vitellaria paradoxa (Gaertn) averagely produces its first fruit when it is 20 years old and reaches its full production when the tree is about 45 years old. It produces nuts for up to 200 years after reaching maturity. The shea fruit plays a significant role in human nutrition by supplying vitamins, minerals and dietary fibre. The tree can be found growing naturally in the southern region of the Sahel and the northern regions of the Guinea zone. It thrives in savanna areas due to low rainfall (GTZ, 1986). The fruit is ellipsoidal in shape and has a white scar at one side. The main size of the nut is about 35mm long x 25mm wide x 23mm thick. There is a kernel inside the nut which fits properly into the shell and is about 32mm large, 23mm wide x 21mm thick in size. It has a uniform shell of about 1mm thick (Olaniyan and Oje, 1999). The fruit comprises an outer fleshy mesocarp enclosing a nut. The nut is thin-shelled and enclosed with oil bearing kernel (Babatunde and olaoye, 1997). The nut is processed to produce shea butter, which is a very important vegetable oil in West Africa. The high allantoic content in the butter also makes it a useful base for local pharmaceutical preparations. The butter is also used to make soap and in the construction industry. It is applied on the walls of houses to prevent them from being washed away during the rainy season. Shea butter can also be used to form a cocoa butter substitute (Fleury, 2000). According to Olaniyan and Oje (1999), the cake from which the oil is extracted is used in livestock feed production.

Insect pests can damage and affect the quality of the shea fruit in storage. In many developing countries including Nigeria, it is estimated that 40-45% of crops are lost to pests, diseases and inadequate storage before they reach the market. The study was carried out to evaluate the population dynamics of insect pests associated with the shea fruit and possible management strategies.

Materials and Methods
Shea fruits were collected from Bida, Niger State and taken to the entomology laboratory located in the Nigerian Institute for Oil Palm Research (NIFOR). They were placed in a black polyethylene bag and kept in a metal cage where observations were conducted for storage pests on a monthly basis for 12 months (October 2014-November 2015) with temperatures fluctuating between 260C – 340C with a mean of 29.510C and relative humidity from 52% - 92% with a mean of 77.06%. On a monthly basis, 10 fruits were removed and observed under a Wild Heerbrugg M 3B Binocular Microscope equipped with a standard ocular micrometer. In addition, a Samsung camera S760, 7.2 Mega pixels was utilized to take images.

Niger State was divided into zones (A - C) and four farmers (adequate considering low numbers of farmers) were visited representing different communities for effective coverage of storage warehouses. Selected warehouses were visited, observations made and shea fruits collected for laboratory analysis.

Results and Discussion
A total of 126 mites were recorded during the period under review (Table 1). October (25) and November (21) 2014 had the highest number of mites while no mites were recorded in September 2015. It was observed that the numbers of mites recorded were reducing with the length of storage. Other insect pests were also recorded (Table 2).

Table 1: Number of mites recorded in the fruits

Month	Mites recorded	Mean standard deviation
October	25	2.5
November	21	2.1
December	18	1.8
January	14	1.4
February	10	1.0
March	10	1.0
April	10	1.0
May	9	0.9
June	8	0.8
July	8	0.8
August	3	0.3
September	0	0
Grand Total	**126**	**1.26**

Table 2: Number of insect pests recorded in the fruits

Month	No of Shea Fruits	Insect species recorded	Number recorded	Stage of development
February	10	Chalcid ants	9	Adult – 4 Larva – 4 Pupa – 1
March	10	Weevils (Curculionidae)	7	Larva – 4 Pupa – 3

As storage time increased, the nuts began to shrink. This is due to reduced moisture levels. After 7 months, effects of insect boring begin to emerge in the nuts. Outer shell coverings showed signs of de-scaling. After 10 months, scale covering of the nuts started breaking off thereby exposing the bare nuts. After 11 months, some of the nuts started physical disintegration into dust. After 12 months, the nuts became very dry and further disintegrated with no observed insect pest. It was observed that the mites were the most common pests encountered. The chalcid ants were only sighted in February 2015 while the weevils (Curculionidae) were observed in March 2015.

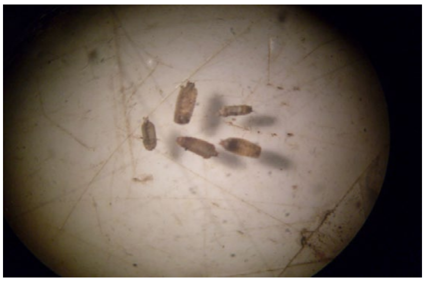

Plate 1: Weevils (Curculionidae)

Plate 2: Chalcid ant

Plates 1 and 2 show weevils and chalcid ants.

General Observations in the warehouses inspected include the following: The warehouses were not properly sealed with continuous openings between the roof and block wall leading to lizards, rodents and insects having access to the stored kernels; Dry kernel bags were placed on the bare floor of the stores; The dry shea kernels were not sorted into grades; The walls of the stores were not plastered; and the doors and windows were not sealed with nets to prevent entry of insects.

Conclusion and Recommendations

Measures to be taken to improve the storage of shea fruits include: The shea fruits should be picked immediately as it matures, as fruits left in the fields for long periods become infested; During collection, it should be ensured that the fruits are not exposed to insect pests before they are properly bagged and removed; All infested shea fruits should be removed and separated immediately with particular attention paid to cracks and gaps where insects may hide; The fruits should be properly dried before storage to prevent germination and fungal attack; Stores should be sited from any potential source of infestation with windows and doors sealed with insect proof gauze, and bags placed on wooden layers to prevent dampness rising from the ground; Stores must be airy, cool and dry while walls, roof and floor should be both water tight and rat proof; Temperature variations should be minimal to discourage condensation of water which promotes fungus development; Always keep the store and the surroundings clean with disinfectants and fumigation applied periodically; Periodic inspection (weekly to fortnightly) and removal of infested fruits is important, with particular attention paid to cracks and bag seams when looking for insects; and Infection with fungi can be detected by the moldy smell, which is noticeable even before any visual changes to the fruits can be seen.

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10013 Field Testing of a Multipurpose Solar Dryer for Small Farmholders

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Abstract

Drying crops is one of the most feasible low-cost means of reducing post-harvest losses and aflatoxin contamination. Open sun-drying on the bare ground, concrete, tarred road or on a tarp is still the most common means of drying crops for small-holder and medium farmers. However, this method is not efficient and results in poor product quality and phytosanitary conditions, and handling losses. A multipurpose solar dryer was developed as part of a project through Purdue's USAID funded Post-harvest Handling and Food Processing Innovation Lab. The multipurpose crop dryer is applicable to drying cereal grains, oilseeds, tubers, vegetables and cash crops like cocoa and coffee. It consists of a 1.8 m3 drying chamber that holds about 9 drying trays. The design enables setting various drying modes using a feedback control system to set temperature. It was tested for drying shelled corn (maize) on the field in the fall of 2016 in West Lafayette, Indiana, USA, in Velingara, Senegal and in Kakamega, Kenya with simultaneous tests conducted to compare with drying maize on drying trays and drying maize on a tarp. The results were different for the different locations. Shelled maize dried at a faster rate in the solar dryer and drying tray than drying on a tarp in West Lafayette. However, all the three different drying systems had similar drying rates in Kakamega, Kenya and Velingara, Senegal. Maize in Velingara dried from 20-23% to 13% within 6-8 hours (about 10 percent points removal), which took up to 6 days in Kakamega from an initial moisture of 28% (15 percentage point removal), and 2 to 3 days in West Lafayette from an initial moisture of 28-31% (15-18 percentage point removal). The faster drying rates in Velingara compared with Kakamega and West Lafayette was due to the lower moistures, high temperatures and low relative humidity (RH). Overall, the confined drying chamber presented a drying environment with better phytosanitary requirement and temperatures in the solar dryer chamber peaked at 10oC or more above the ambient for all locations.

Key words:

post-harvest technology, shelled maize, smallholder, solar dryer

Introduction

Reducing post-harvest losses (PHL) and mycotoxins of the major staple food crops in sub-Saharan Africa will put most countries in the path to meet the UN Millennium Development Goals (MDG) of reducing hunger and poverty by half from 1990 levels by 2015 (UN, 2010). For cereal grains, the value of quantitative PHL in the continent is estimated at more than US$4 billion annually (ADB, 2010). The lack of affordable and efficient drying technologies available to smallholder farmers is one of the major constraints faced along the grain value chain in the humid tropics. Drying provides farmers the option of storing grains longer for sale later when prices are more favorable (Loewer et al., 1994). The use of open-air drying on a hard surface such as a tarred road, concrete surface, a tarp or bare ground is still the primary means used by smallholder farmers in drying grains. Because harvest activities in the major season are characterized by intermittent rainfall, there are challenges of using open-air drying to achieve safe storage. Additionally, with the average farm size of smallholders in developing countries in Africa being 2 ha growing several crops, any drying technology for smallholder farmers should be applicable to drying several crops. The objective of this study was to evaluate the performance of a multipurpose solar dryer designed for smallholder farmers under field conditions in three locations: West Lafayette-USA, Velingara-Senegal and Kakamega-Kenya. This paper presents results of tests using a multipurpose solar dryer for drying maize conducted in comparison with drying in open-air on a drying tray and tarp in the aforementioned locations.

Materials and methods

The multipurpose solar dryer design

The multipurpose solar dryer has 0.64 m3 of drying volume, capable of holding 9 stacked trays (5 trays stacked at the back and 4 trays stacked at the front). The multipurpose solar chamber dryer uses thermal collectors located on top to capture solar radiation, which is transferred primarily by convection and radiation into the drying chamber below. Heat distribution is enabled by 8 small fans (2 in front and 6 on the floor) powered by a 12V deep-cycle battery. The battery is recharged continuously during the day using a 100W photovoltaic cells mounted on the top and angled appropriately to capture incident solar radiation. A charge controller regulates the charging of the battery. Depending on the prevailing solar load, the solar dryer chamber temperatures can rise from 10oC up to 45oC above the ambient. During the design and prototyping phase, CFD simulation was used to determine the number and location of fans that pull heat from the collectors (8 fans), or the 2 fans at the back that cool the chamber by pulling air from the ambient.

Field testing of the solar dryer

The multipurpose solar dryer was tested on the field in the fall of 2016 (September to November, 2016) in three locations with different agro-ecological conditions: West Lafayette-USA, Velingara-Senegal and Kakamega-Kenya. The purpose was to test the field performance of the solar dryer under various environmental conditions. A protocol was developed and implemented across the various sites. Maize harvested at 35% to 25% range based on availability and local conditions was used for the tests. Simultaneous comparisons of the drying performance using a tarp and the drying tray was conducted alongside the solar dryer tests (Fig. 1). Temperature and RH sensors were installed in the solar dryer chamber, while maize being dried using the various methods were sampled hourly to determine the drying rate. Three drying modes of operation based on preliminary tests were implemented, however, only one drying run was conducted for every drying mode.

Figure 1. Comparative test of multipurpose solar dryer (left), drying tray in open-air (center), and tarp in open-air (right).

Results and Discussion

Only the first mode of operation (Mode 1) and half load tests are reported in this paper. Mode 1 has only the 6 bottom fans turned on and the two fans at the back sealed. For half load tests, maize sample weighing 4.5 kg (~9 lb.) was placed in each tray, both inside the dryer and outside. To match the total sample inside the dryer, approximately 36 kg of maize was spread on the tarp in the same layer thickness as the trays. Results from each of the three sites with half load and Mode 1 operation are briefly discussed.

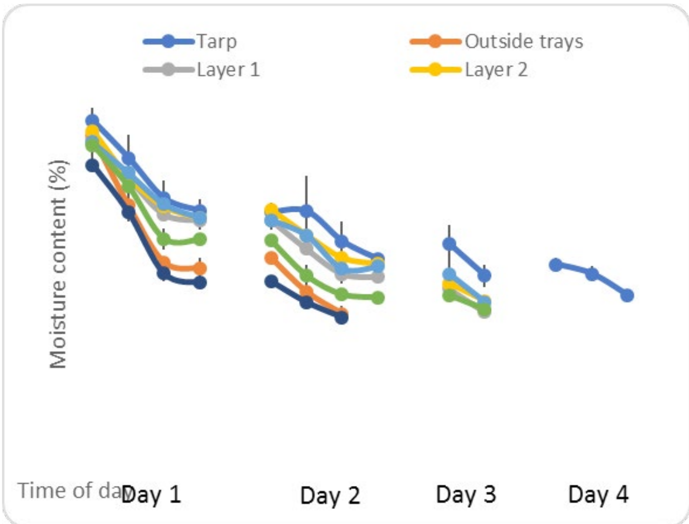

Figure 2. Variation in moisture content for half load mode 1 in West-Lafayette, USA.

The initial moisture of the maize samples in West Lafayette ranged between 28-31%. By the middle of the second day (18 hours), layer 5 (bottom most) inside the dryer and the outside trays had dried down to 12-13% (Fig. 2). The other layers inside the dryer needed another four hours of drying on the third day. Maize in the tarp took 4 days to complete drying. The chamber temperature peaked at 40oC, while the ambient temperature was about 30oC. The RH of the chamber was as low as 10%, while the ambient RH was 15%. In Kakamega, approximately 45 kg of maize was placed in the solar dryer (5 kg per tray) as well as on the tarp and 5 kg in the open-air tray for half load test (only one tray used for open-air). The initial moisture of the maize was approximately 28%. The initial 10-point moisture drop down to approximately 18% occurred in all drying systems on the first day of drying (Fig. 3). However, the rate of drying was negligible from day 3-5 due to high ambient humidity during the mornings and afternoons. Some amount of rewetting was observed in the samples overnight as well. Maize in the bottom most layer inside the dryer, the open-air tray and the tarp was found to dry down to below 13% only slightly faster than the other dryer trays on the sixth day of drying. The peak temperatures in the solar dryer chamber ranged from 37°C to 42°C while the ambient temperature was 28°C to 30°C.

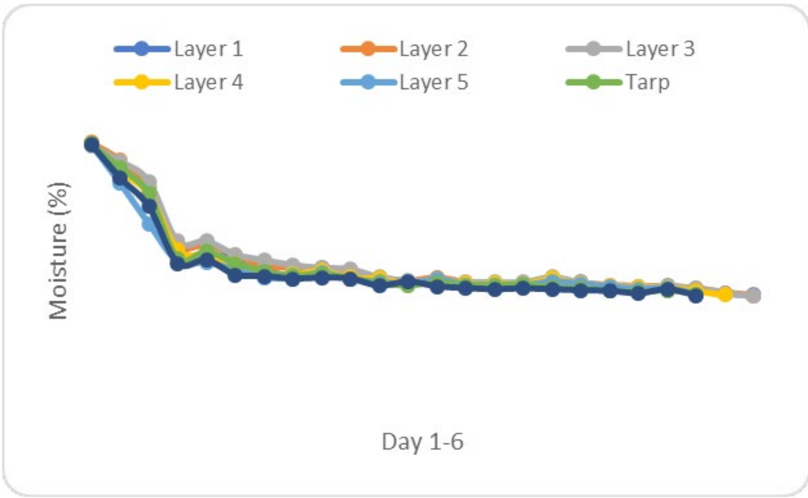

Figure 3. Variation in moisture content for half load mode 1 at Kakamega, Kenya.

Maize drying tests with half load (i.e. approximately 5 kg per tray and 35 kg on tarp) were performed on three consecutive days in Velingara, Senegal. On each day, maize at initial moisture of 20-23% was dried down to 13% or below within six to eight hours. As seen in Figure 4, the rate of drying was almost the same for all drying systems. The low initial moisture content, high ambient temperature (>35°C) and low relative humidity can be attributed to faster and uniform drying as compared to tests in West Lafayette and Kakamega. The peak temperatures in the solar dryer chamber during the 3 days ranged from 41°C to 45°C.

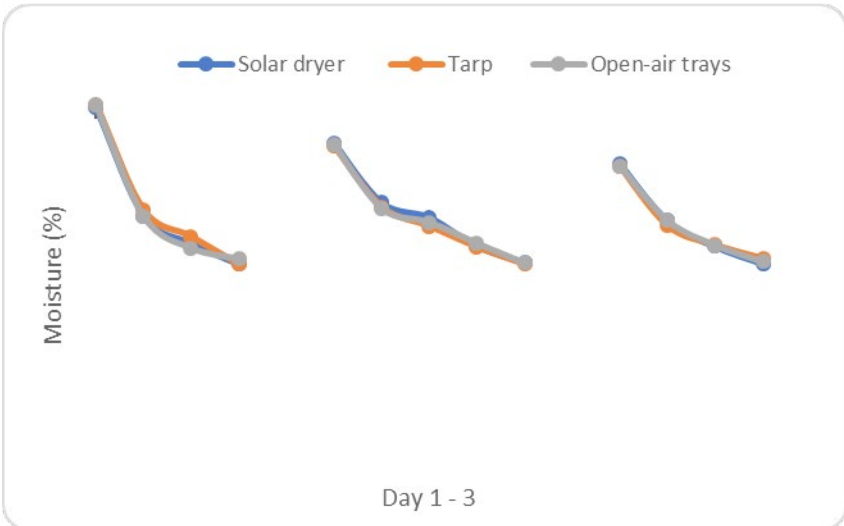

Figure 4. Variation in moisture content for half load mode 1 tests at Velingara, Senegal.

Conclusion and Recommendations

While maize dried in all three systems were thicker than one-kernel layer, just as in thin-layer drying, factors such as the air temperature, initial moisture content, air velocity, and relative humidity affected the drying rate (Pathak et al., 1991). The tests conducted in West Lafayette, USA showed that the solar dryer and drying tray performed better with respect to having a faster drying rate than drying maize on a tarp. They also provide a better sanitary environment for drying. However, for Kakamega, Kenya and Velingara, Senegal, all three drying systems had the same drying rates. Velingara had the best solar conditions for drying maize, achieving 7 to 10 percent points in six to eight hours; however drying was from a lower initial moisture of 20-13%. Overall, the multipurpose solar dryer with an enclosed chamber had a better phytosanitary quality, and addresses a major shortfall in the current methods used for crop drying by smallholder farmers. Improvements on the multipurpose solar dryer would be made with respect to integrating an automatic temperature, RH and aeration control of the drying chamber to optimize crop drying rates. Additionally, plans are underway to commercialize the solar drying technology by offering both the drying tray (low-end) and multipurpose solar dryer (high-end) as two optional drying technologies for a smallholder farmer. Taking advantage of the economics of scale in manufacturing would be key to successfully achieving an affordable product to the smallholder farmer.

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10014 Innovative Technologies for Cassava Processing: Viable Option for Growth of Small and Medium Enterprises in Nigeria

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Abstract

Cassava (Manihot Esculenta, Crantz.) is a versatile crop widely grown in Nigeria. Processing of the crop is dominated by cottage-level processors scattered all over the rural and semi-urban areas. They depend largely on labour-intensive manual processing methods. Consequently, cassava loss and poor quality of products such as gari and cassava flour are major challenges. Recent research works were carried out to completely mechanize cassava processing for the production of gari (dried and gelatinized cassava flour). Innovative cassava processing machines are designed, fabricated and tested based on a proper study of the knowledge, attitude and practices (KAP) of small scale cassava processors. Existing technologies hitherto available to the cassava processors are carefully studied and their inadequacies are used as design considerations in the development of new technologies, namely, peeling machine, washing machine, hammer mill, horizontal press, rotary sifter, rotary fryer and rotary grader. Quantitative and qualitative data show that the machines are efficient, cost-effective and capable of increasing the quality and quantity of gari that is produced. The target end users of the cassava processing machines are the small and medium scale enterprises (SMEs) in Nigeria. Full adoption and optimal utilization of the machines by SMEs will contribute significantly to the rapid growth of SMEs and the technologies are now being adopted by some SMEs in Nigeria.

Keywords:

Agro-industrial growth cassava processing, technologies

Introduction

Nigeria is the largest producer of cassava (Manihot esculenta, Crantz.) in the world (Babatunde, 2012). Gari (a granular and gelatinized product) is the most popular staple food produced from cassava, providing a cheap source of carbohydrate for over 500 million people around the world (Oluwole et al., 2004). Given the growing population in Nigeria, the demand for gari is increasing (CTA, 2007) and this has encouraged increased production of cassava and also created greater opportunities for small and medium enterprises (SMEs) who are engaged in its postharvest processing. Majority of cassava processors in Nigeria use the traditional manual methods. Despite research efforts, there is a dearth of appropriate and efficient technologies to fully mechanize and industrialize cassava processing operations. The aim of this work is to present some innovative cassava processing technologies that were specifically developed to upgrade existing cassava processing techniques to industrial standards. The objectives of this paper is to present findings on the assessment of existing cassava processing machines and the development of new and innovative machines for processing of freshly harvested cassava into gari at industrial scale.

Materials and Methods

Traditional practices of selected cassava processors in S/West Nigeria and shortcomings of existing cassava processing techniques were identified using the participatory rural appraisal (PRA) technique (Webber, 1995). New design criteria were used to develop innovative and improved technologies to upgrade existing cassava processing techniques to industrial scale. Performances of the innovative cassava processing machines developed were evaluated in comparison with existing ones. The Taguchi statistical method and analysis of variance (ANOVA) were used for the performance evaluations according to Sanni et al. (2015).

Results and Discussion

The setting of a typical cassava processing centre in South-west Nigeria was generally unorganized and dirty, and the handlers were mostly uneducated women who had little or no appreciation for clean and hygienic food processing environment. Figure 1 shows the existing cassava processing techniques. Most cassava processing centres practiced the manual traditional methods, but the improved technologies were available in a few locations. Table 1 shows the shortcomings of the existing methods. Peeled cassava was washed in small water basins and most rural based processors sourced water from streams. Fermentation of grated cassava mash was achieved anaerobically in perforated polyethylene bags left on the ground for 48 to 72 hours before pressing. After roasting of gari, cooling was achieved by spreading the dried meal on mats placed outdoor on the ground. The improved technologies were better than the traditional methods but they were yet to be fully adopted by cassava processors. Both techniques of cassava processing were not adequate for industrial production of gari and therefore required some upgrading.

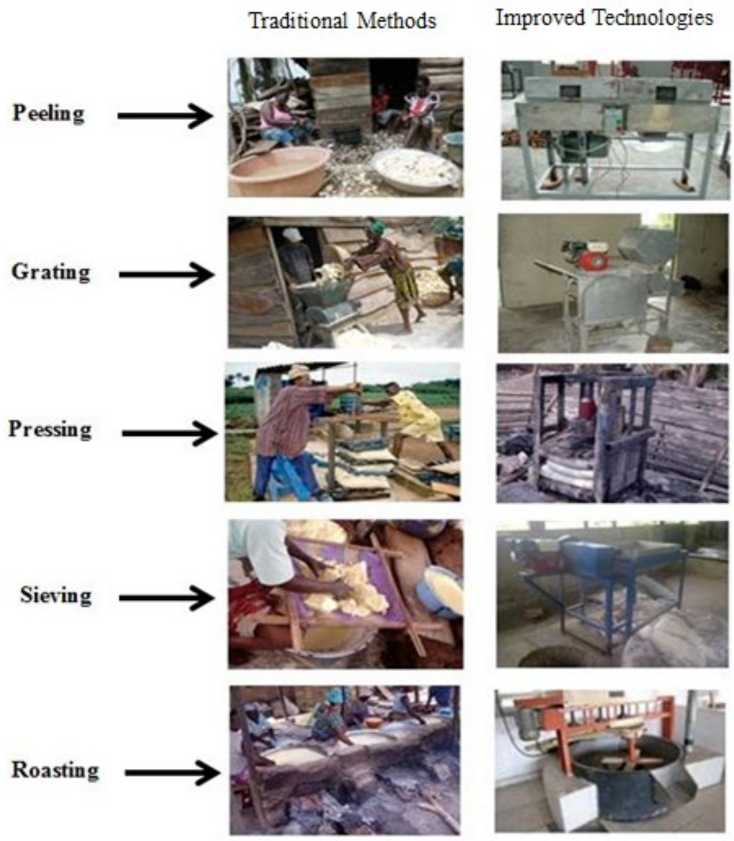

Figure 1: Existing methods and technologies for cassava processing

The grated cassava mash was packed in perforated polyethylene bags and left on the ground for 2 – 3 days for anaerobic fermentation. This was responsible for the characteristic sour taste of the roasted gari. Four to six bags of grated cassava mash was pressed for over 2 hours and the moisture content reduced from 65 - 75 % to 45 - 50 %. Pressing of grated mash could last for over 24 hours depending on the type of press used. The TMS 30572 cultivar of cassava was generally cultivated and average of 200 kg of pressed cassava cake was derived from 200 stands of the crop. After pulverizing and sifting of pressed cassava cake, the average moisture content of cassava meal varied between 47 % and 51 % wet basis. This range compared well with the 40 – 50 % range reported in literature (CIGR, 1999).

Figure 2 shows the innovative technologies that were developed to industrialize cassava processing. The performance evaluation of the machines (Sanni et al., 2015) showed that they were better than the existing traditional and improved processing techniques. They produced higher quantity and better quality of gari.

Table 1: Shortcomings of existing methods of cassava processing

Cassava Processing Steps	Traditional methods in common practice	Existing Technologies	Remarks
Peeling	Use of knife	Manually assisted rotary brush	Not adequate for industrial production
Washing	Use of stream water in small basins	None	Inefficient and not adequate for industrial production
Grating	Mechanical grater made of mild steel	Mechanical grater made of stainless steel	Efficient but not adequate for industrial production
Fermenting	Use of plastic bags placed on the ground	None	Inefficient and not adequate for industrial production
Pressing	Use of screw press	Hydraulic jack assisted press	Not adequate for industrial production
Sieving	Use of hand-woven sieve	Mechanical vibrating screen	Not adequate for industrial production
Roasting	Use of open tray placed on wood fire	Brazilian model fryer	The Brazilian model fryer can be improved upon
Cooling	Use of mats to spread out gari in open air	None	Inefficient and not adequate for industrial production
Packaging	Use of old plastic bags	None	Packaging of gari in various sizes is not common

Most of the human drudgery encountered in the use of traditional techniques were eliminated. Environmental polution was totally prevented, and loss of cassava at various processing stages was minimized (Owolarafe et al., 2000; Sanni et al., 2016a, 2016b).

Figure 2: Innovative technologies for industrial processing of cassava

Conclusion and Recommendations

The main aim of this paper is to disseminate the newly developed and highly innovative cassava processing technologies to potential investors among the small and medium enterprises in Nigeria and other parts of Africa. The cassava processing machines are products of years of collaborative and intensive research and development (R&D) work, between the Research Team based in the Department of Agricultural and Environmental Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria and MAKSTECH Industries and Engineering Services Ltd., Ilesa, Osun State, Nigeria. All the cassava processing operations that were hitherto done manually have been mechanized. The machines are being further developed upon. Two medium scale investors in South-west Nigeria have procured and installed the machines for gari production at commercial scale. Feedback from the investors will continue to be used to optimize the performances of the machines. The new technologies depend on electricity and therefore may not be applicable in rural communities where there is no power supply. Also the complete set of machines is capital intensive because most of their components are made of stainless steel material. However the output of gari from the machines is high and labour cost is drastically reduced. Therefore investment in the machines is viable, and can contribute to the growth of the small and medium enterprise.

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10015 The Coolbot™: a Low-cost Cold storage Alternative for Smallholders in Developing Countries

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Abstract
Poor temperature management is one of the environmental factors that contribute to high postharvest losses in perishable commodities. The high cost of conventional cold rooms required for cold storage makes them inaccessible for majority of smallholder farmers in developing countries hence the need for cheaper alternatives. One such alternative is the Coolbot™ technology which has been tested and adopted in several countries. In this paper, local adaptation of the Coolbot technology and testing of its application in mango fruits is demonstrated. The study was conducted in a participatory approach with smallholder mango farmers in Makueni County of Kenya between 2014 and 2015. An insulated room (3.7 X 3.7 X 4.0 M) was built from 200 mm thick structural insulated panels made from polystyrene. The room was then fitted with an air conditioner (LG brand of 24,000 BTU) and the Coolbot which was sourced from Store It Cold LLC (USA). The system was then optimized according to the manufacturer's instructions. Mango fruits sourced from smallholder commercial farmers were separated into two batches for storage in the Coolbot™ cold room and ambient room conditions. The temperature on the Coolbot gadget was set at 100C and monitored real-time using Xsense® data loggers. A random sample of 5 fruits was taken from each storage condition regularly to evaluate ripening-related changes. The results showed that the Coolbot was effective to attain and maintain the set storage temperature 10±20C over a 40-day storage period. At this temperature the shelf life of mango fruits was extended by up to 23 days more compared to those stored at ambient room conditions. The slow progression of ripening in the mango fruits stored in the Coolbot cold room was evidenced by low respiration and ethylene evolution rate, slower softening and retention of higher hue angles throughout the storage period. These findings confirm the efficacy of the Coolbot technology as an alternative cold storage option to extend the shelf life of perishable commodities such as mango fruit.

Key words:
Cold chain, cold storage Coolbot, post-harvest, quality

Introduction
It is estimated that 40 to 50% of fruits and vegetables produced for human consumption are lost or wasted along the supply chains before they reach the end user (FAO, 2014). Lack of cold storage facilities and consequently poor cold chain management is one of the key contributors to high postharvest losses in fruit and vegetables. Fruits and vegetables are still living at the time of harvest and continue metabolic processes such as transpiration and respiration. Previous studies have shown that the rate of deterioration from factors such as water loss and postharvest diseases is greatly reduced with reduction in temperature (Reid et al., 2010). It is estimated that deteriorative processes in perishable commodities increase 2-3 fold for every 10 °C increase in temperature (KMUTT, 2007). Therefore maintenance of low (safe) temperatures during postharvest handling of is critical for quality preservation. Majority of the smallholder farmers in developing countries lack access to cold storage infrastructure. Without proper storage facilities the farmers are forced to dispose off their perishable commodities soon after harvest and often at a very low price (Ambuko, 2016). Conventional cold rooms are expensive and therefore out of reach for majority of the smallholder farmers engaged in horticultural production. Therefore, affordable or low-cost cold storage options are required to save these farmers from exploitation by traders and middlemen. One such option is the Coolbot™ which was introduced in Kenya recently through a pilot study. The Coolbot™ is an electronic gadget which upon connection to a standard air conditioner (AC) overrides the AC's thermostat thereby 'tricking' it into working harder. This makes it possible to achieve temperatures as low as 0 ºC without ice building up on the evaporator coils of the AC. Without the Coolbot™ the AC can only lower the room temperature to a minimum of 180C, below which ice builds up on the coils. To scale up and commercialize the Coolbot technology for wider adoption by smallholder farmers and traders, there is need to test its efficacy under different conditions and in various commodities. The objective of this study was to evaluate the efficacy of the Coolbot™ to lower and maintain storage temperatures in an insulated room fitted with a commercial air conditioner.

Materials and methods
The participatory study was conducted in Makueni County which is one of the major mango producing counties of Kenya. An insulated room (3.7 X 3.7 X 4.0 M) was built from 200 mm thick structural insulated panels made from polystyrene. The room was fitted with an air conditioner (LG brand of 24,000 BTU) and Coolbot™ which was sourced from the technology developer, Store It Cold LLC (USA). The system was then optimized according to the manufacturer's instructions. Mango fruits were sourced from smallholder commercial farmers in Makueni County and sorted for uniformity. The fruits were separated into two batches for storage in the Coolbot™ cold room and ambient room conditions. The temperature on the Coolbot™ was set at 10±20C. Storage temperature was monitored real time using Xsense® data loggers. Progression of ripening and general deterioration was determined by sampling five fruits from each treatment regularly for measurement of ripening-related changes. The parameters measured included respiration rate using a gas

chromatograph (Models GC-8A, Shimadzu Corp., Kyoto, Japan), peel/flesh firmness using a penetrometer (Model CR-100D, Sun Scientific Co. Ltd, Japan) and peel/flesh color using a Minolta color meter (Model CR-200, Osaka, Japan). The data collected was analyzed by Analysis of Variance (ANOVA) using Genstat 15th edition and the means separated by Least Significant Difference (LSD) at P=0.05.

Results

Real time changes in temperature during the first 48 hours of storage is shown in Fig. 1 while Fig. 2. shows the changes in temperature over a 40-day storage period. Fig. 3 shows the effect of storage temperature on respiration rate of mango fruits stored under cold storage and ambient room conditions.

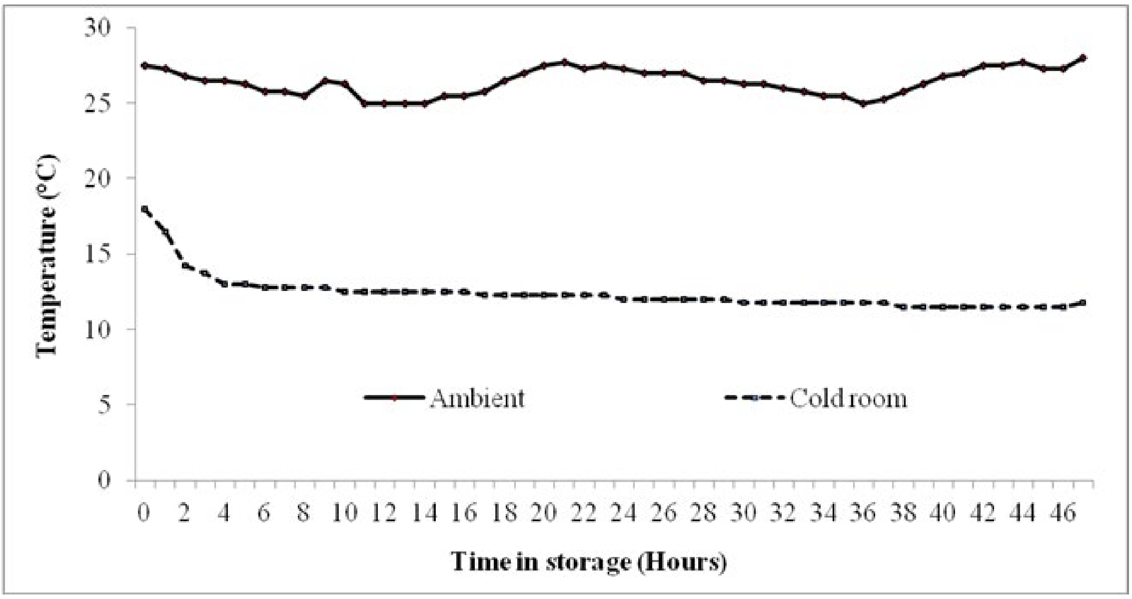

Figure 1. Real-time changes in temperature in the Coolbot™ cold room and ambient room during the first 48 hours of storage

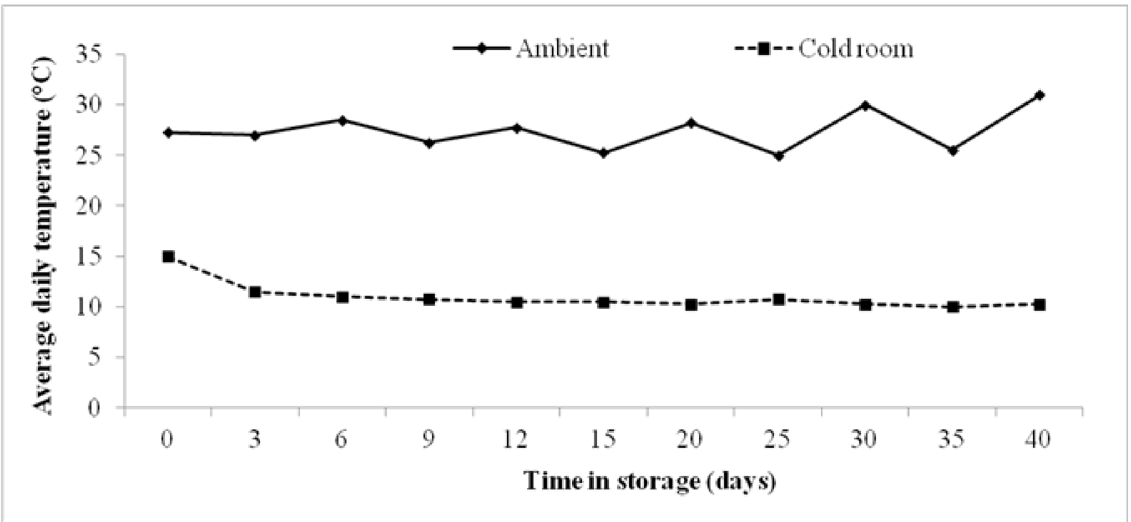

Figure 2. Changes in average daily temperature in the Coolbot™ cold room and ambient room during the 40-day storage period.

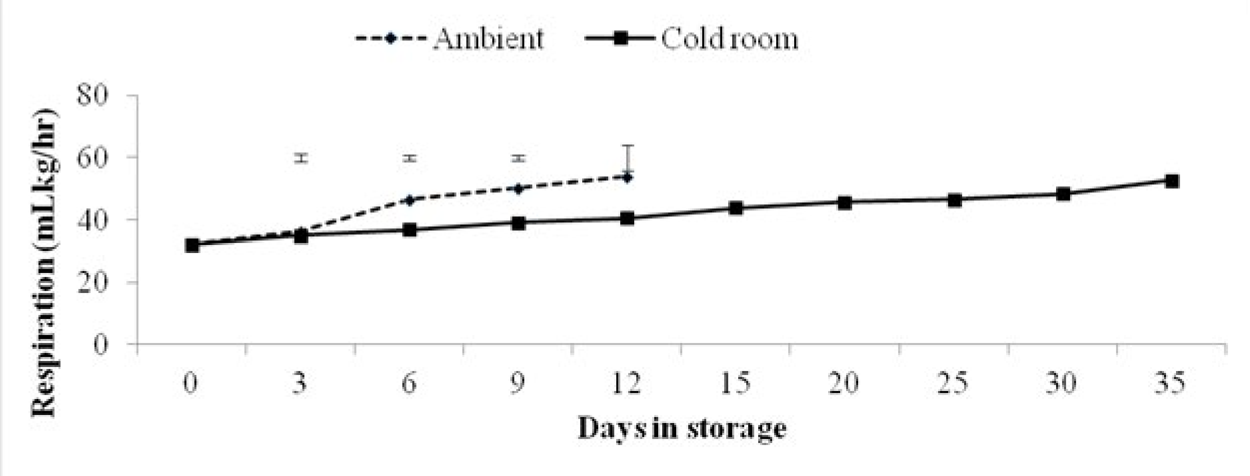

Figure 3. Changes in respiration rate of 'Apple' mango fruits stored in the cold room and at ambient room conditions. Top bars represent LSD of means (p<0.05).

Discussion

Alternative technologies such as Coolbot™ avail low-cost cold storage options for small holder farmers who cannot afford the expensive conventional cold rooms. In the present study, the Coolbot™ was used to effectively reduce the storage temperature to 10+20C which is safe for mango, a tropical fruit which is prone to chilling injury under lower temperatures. The air and internal temperature of the fruits dropped gradually to a low of 130C in the first 6 hours of storage. This temperature was maintained throughout the 40-day storage period. At this temperature, the rate of all the other ripening related changes including respiration, softening and yellowing (reduction in hue angle) were significantly slowed down/reduced. This in turn resulted in a longer shelf life since the cold-stored fruits remained saleable for up to 35 days which was 23 days more than those stored at ambient room conditions.

Conclusion and recomendations

These results demonstrate the efficacy of the Coolbot™ to lower and maintain storage temperatures and consequently reduce the rate of metabolic/deteriorative activities in the stored mango fruits. The Coolbot™ technology can therefore be promoted for adoption as a low-cost cold storage alternative to conventional cold rooms which are out of reach for majority of smallholder farmers.

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10016 Evaporative Cooling Technologies: Simple and Effective Cooling Alternatives for Smallholder Horticultural Farmers

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Abstract
Poor cold chain management is one of the factors that contribute to high postharvest losses (≥50%) in fruits and vegetable value chains. Adoption of conventional mechanical refrigeration among smallholder farmers is limited due to the high cost and lack of/unreliable connection to the national grid in most rural areas. There is therefore need to explore alternatives to the conventional cooling options. This paper presents the findings of on-station studies on two evaporative cooling technologies namely evaporative charcoal cooler (ECC) and a modified zero energy brick cooler (ZEBC). The efficacy of the two technologies (ECC and ZEBC) to attain lower than ambient room temperature and higher relative humidity was evaluated at the University of Nairobi's Upper Kabete Campus Field station. The room/chambers were fitted with data loggers to monitor temperature and relative humidity (RH) in real time. The results revealed that temperature differences ranging between 20C and 100C in comparison to ambient room conditions could be attained with the ECC and ZEBC depending on the time of day and season. In addition, significantly higher RH (80-99%) was achieved with evaporative cooling. The results confirmed the efficacy of evaporative cooling technologies to attain lower than ambient temperatures and higher relative humidity. The evaporative cooling technologies can be promoted for adoption by smallholder farmers in rural areas where connection to the national grid is still limited.

Key words:
Cold Chain,cold storage, evaporative cooling, postharvest losses

Introduction
Maintenance of a cold chain between harvest and utilization is critical to the preservation of fresh quality of perishable horticultural commodities. This is however hindered by the high cost of conventional cold rooms which is compounded by lack of connectivity to electrical power in the rural areas. This emphasizes the need for cheaper alternatives for the resource-poor smallholder farmers. Evaporative cooling presents such a cheaper alternative for farmers in rural areas without electricity. Evaporative cooling is premised on the notion that water is in constant state of transition from solid to liquid to vapor. To move from one state to the other, water takes or losses heat. For example change of water from liquid to vapor requires 2260 kJ/Kg of energy = latent heat of vaporization (Roy, 2011). This heat transfer through the evaporation of water is the basis of evaporative cooling technologies. Evaporative cooling technologies can take many forms but basically comprises of a porous wall made of a medium that can hold water and through which air can easily flow. The medium could be charcoal, sand, clay or any other material that is porous enough to hold water. This medium is kept wet and as dry/hot air flows over it, the water therein evaporates resulting in a cooling and humidifying effect at the same time. The cooling effect is higher when the surrounding temperature is high and relative humidity low (Amrat et al, 2013). Evaporative cooling systems are therefore best suited for hot and dry climates, typical of the tropics.

Previous studies have shown that evaporative cooling technologies can significantly increase the shelf life of fruits and vegetables in comparison to ambient room conditions. The shelf life of tomatoes, guava, rocket, okra and carrots was increased 5 to 10 fold using zeer pots (a type of evaporative cooler), compared to ambient room conditions (Longmone, 2003). In other studies a zero energy cool chambers (ZECC) was found to have maintained considerably and relatively low temperature compared to field, shed and room temperature. In the same chambers, a high relative humidity (85 – 96%) was reported compared to 21 – 94% in the case of the shed and field. Under this conditions, the shelf life of the stored fruits and vegetables (aonla, banana, grape fruit, guava, kinnow, lime, mango and sapota) increased 2 to 3 fold compared to those stored at ambient room temperature (Roy, 2011). Similar positive results have been reported in mango (Roy and Pal, 1991); gooseberry (Singh et al. 2010); tomato (Islam and Morimoto, 2012) among other horticultural commodities. The objective of this study was to establish the capacity of a modified zero energy cool chamber (ZECC) renamed zero energy brick cooler (ZEBC) to attain comparatively lower temperatures and higher relative humidity compared to the ambient storage room.

Materials and Methods
The study was carried out at the field station of the University of Nairobi, College of Agriculture and Veterinary Sciences, Nairobi, Kenya. A zero energy brick cooler (ZEBC) was constructed from locally available materials including earthen bricks, river bed sand, sisal sacks, sisal waste, fibre board, water tank and water drip lines. The ZEBC is an adaptation of the ZECC to local conditions. Another version of evaporative cooling, evaporative charcoal cooler (ECC) which is already in use by some horticultural farmers was used to compare the efficacy with the ZEBC, which is new in Kenya. The ZEBC and ECC were compared to ambient room conditions and tested using leafy vegetables. In each of the three storage environments, data loggers (Xsense®) were fitted to measure real time changes in temperature and relative humidity during the evaluation period. The experiment was conducted during the dry season (between December 2014 and February 2015) and wet season (April to June, 2017) to compare the seasonal differences in the performance of the evaporative cooling technologies.

Results

Fig. 1 shows real-time changes in temperature in three storage environments (the zero energy brick cooler, ZEBC; the evaporative Charcoal cooler, ECC and ambient room) during a nine-day storage period in the dry season. Fig. 2 shows real time changes in relative humidity for the same storage environments and season as Fig 1. During the dry season, relatively lower temperatures (14.5 – 180C) were realized through evaporative cooling in comparison to the prevalent room temperatures which fluctuated between 24 – 300C (Fig.1). The temperature difference between ambient room and the evaporative coolers ranged between 1–9.50C depending on the time of day and season. The temperature difference in the evaporative cooling chambers and ambient did not differ much during the wet season. In both seasons, the greatest difference in temperatures was observed during the hottest time of the day (12.00 to 15.00 hours). At this time of day the air temperature outside the chamber was at the highest point while the relative humidity was at lowest point hence a higher cooling effect.

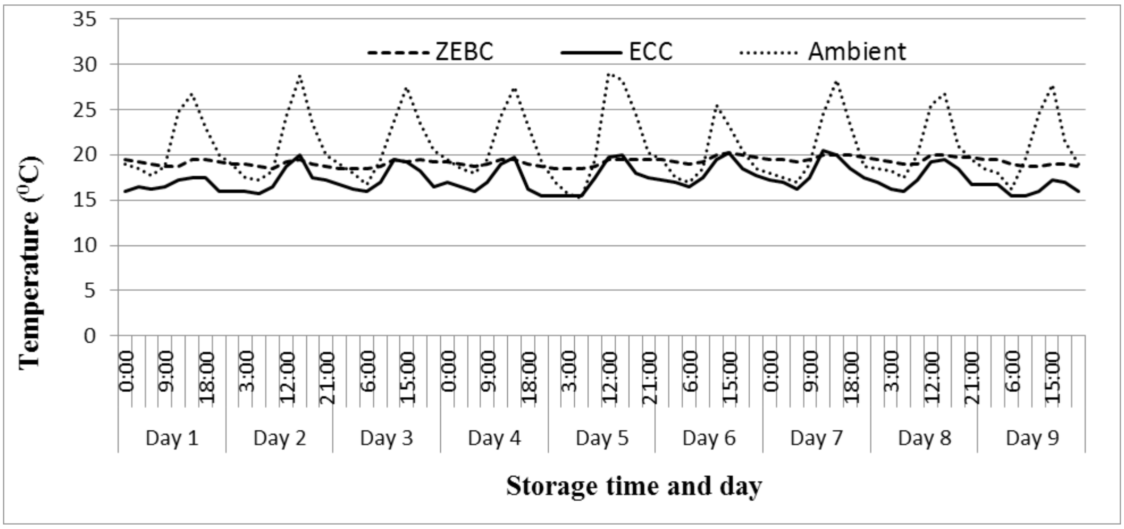

Fig.1. Real time change in temperature in the zero energy brick cooler (ZEBC), evaporative charcoal cooler (ECC) and ambient room conditions during the dry season.

Discussion

Maintaining a cold chain from harvest to the retail stage is critical in preserving quality of perishable commodities such as fruits and vegetables. While mechanical refrigeration using conventional cold rooms is a standard practice in technologically advanced countries, poor cold chain infrastructure remains a major challenge in developing countries. Therefore alternative low-cost technologies such as those based on evaporative cooling should be explored. In the present study, under ZEBC and ECC, relatively low temperature and high RH were attained compared to ambient room conditions. The findings of this study concur with previous studies in evaporative cooling technologies. Roy and Pal (1991) reported a 10-150C temperature difference and ≥90% RH in a ZECC with a similar design as the ZEBC. In their chamber, the relatively high RH and lower temperature resulted in a longer shelf life of mango fruits. Murugan et al. (2011) reported a 5-60C temperature difference between the room conditions and earthen pot cool chamber with the RH ranging between 87-92% in the chamber. Similarly, studies in another version of evaporative cooler designed from clay, reported a 100C temperature reduction and increase in RH from 40.3 to 92% compared to ambient room conditions (Ndukwu, 2011). This study confirms that ZEBC and ECC could attain considerably lower than ambient room temperatures and higher relative humidity. Although the temperature attained in the ZEBC and ECC are not cold enough for long term storage, these technologies are nonetheless useful in regions without electricity. They could be used for temporary holding of produce such as leafy vegetables which deteriorate fast after harvest losing their salability within hours after harvest. The ZEBC and ECC could also be recommended for precooling of produce to remove the field heat prior to refrigerated transport or conventional cold storage.

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10017 Application of Off-Season Flower Induction Chemicals to Address Seasonality in Mango Fruiting and the Associated Postharvest Losses

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Abstract
Seasonality in Mango (Mangifera indica) fruiting resulting in peak and off seasons is one of the factors that contribute to the high postharvest losses (40 – 50%) reported in the mango value chain. Off-season flower induction is a strategy that can be used to address mango seasonality. This paper will highlight the application of two flower induction chemicals, potassium nitrate (KNO3) and ethephon to induce off-season flowering in two mango varieties: 'Apple' and 'Ngowe'. The study was conducted in two contrasting agro-ecological zones in Kenya. Potassium nitrate was applied at two concentrations (2% and 4%), while ethephon was applied at three concentrations (300, 600 and 1000ppm) and compared to a control (water). The experiment was laid out in a randomized complete block design with three replicates and three trees per treatment. Effect of the treatments was established from reproductive growth parameters including days to flowering and fruit set, number of panicles per tree and average fruit set per 20 panicles. Potassium nitrate (4%) increased percentage flowering (% of tagged shoots) in both 'Ngowe' and 'Apple' but the effect was dependent on the AEZ and variety. In Embu, 4% KNO3 resulted in 46% flowering in 'Ngowe' compared to 4% in 'Apple'. On the contrary, in Makueni, the response was greater in 'Apple' (60%) compared to 'Ngowe' (27%). Response to ethephon increased with concentration with the 1000 ppm giving the best response; 22 and 28% flowering (% of tagged shoots) for Embu and Makueni, respectively, in 'Ngowe'. In both AEZs and varieties, flowering was $\leq$ 3% in untreated controls. Time to flowering was significantly shortened by both KNO3 and ethephon treatments with 'Ngowe' being more responsive than 'Apple'. The findings reveal the potential of KNO3 and ethephon to induce off-season flowering in 'Apple' and 'Ngowe' mango fruits. Application of the chemicals can be explored as one strategy to address seasonality in mango and the associated postharvest losses.

Key words:
Flowering, flower induction, mango, seasonality

Introduction
Mango is a tropical perennial fruit crop that can flower and fruit all year round. Mango fruiting is seasonal and in most mango producing regions of Kenya, the trees fruit only once between November and February. As a result of seasonality, during the high season, there is often an oversupply which leads to low prices and high postharvest losses. During the peak season, the on-farm prices range from 2 – 5 US cents per piece. A few farmers may be lucky to sell their fruits to exporters at a price of 7 – 10 US cents per piece (Ambuko, 2016). In Kenya the postharvest losses in the mango value chain are estimated to range between 40-50% but higher figures have been cited in some unpublished studies. Most of the smallholder farmers lack appropriate post-harvest handling techniques, leading to significant losses, which affects their profits. Furthermore, these farmers do not have good storage facilities available at the farm level, and this forces them to sell their mango fruits immediately after harvest. Some fruits are left to rot on trees as farmers lack adequate market for them translating to huge losses to the farmers. Furthermore seasonality has serious implications for mango processing. Seasonal production of the mangoes is only enough to supply processors for seven months of the year. Some processors are forced to close or operate below capacities during the low mango season.

Seasonality calls for interventions to regulate fruiting and achieve year-round supply of mango fruits to address the associated problems. Success has been achieved in stimulating off-season mango flowering using chemical/ hormone treatments such as ethephon, paclobutrazol, calcium nitrate, potassium nitrate and cultural practices such as pruning (Davenport, 2009). The phytohormone ethylene is well known to influence a number of physiological and developmental processes in plants including, but not limited to seed germination, seedling growth, and formation of the apical hook, senescence, fruit ripening, abscission and gravitropism (Abeles et al. 1992). It has been speculated that the ethylene generated when ethephon is sprayed plays a critical role in flower induction. The ethylene-generating agent, ethephon, has been used to successfully induce and increase flowering in various mango varieties in the Philippines and India. Flower induction also occurred at concentrations between 500 and 1,000 ppm. In 10-year-old 'Haden', 500-1,000 ppm applied one month before the normal flowering date increased flowering by 40- 55 percent (Nunez et al., 1980). Potassium nitrate (KNO3) has been shown to stimulate early flowering and to increase numbers of panicles in trees growing in tropical and subtropical regions, thus ensuring increased and regular production. The effective spray concentration ranges from 1 to 10% KNO3 with the optimum concentration varying with the age of the trees and climatic conditions (Davenport, 2009). Previous studies show variability in response to flower induction chemicals such as KNO3 and ethephon as affected by various factors such as cultivars, production conditions, stage of development, dosing range, among others. The objective of this study was to determine the effect of off-season flower inducing technologies (ethephon and potassium nitrate) on reproductive growth parameters and yield components of 'Apple' and 'Ngowe' mango trees grown under two different agro-ecological zones in Kenya.

Materials and Methods

The study was conducted in two agro-ecological zones (AEZs) of Kenya namely Embu County (a high potential mango production AEZ) and Makueni County (a low potential mango production AEZ). Two flower induction chemicals, potassium nitrate (KNO3) and Ethephon were evaluated in commercial farms. Test trees comprised of randomly selected 'Apple' and 'Ngowe' mango trees of similar size and vigor, 6 to 8 years. Potassium nitrate was applied at two concentrations (2 and 4%), while ethephon was applied at three concentrations (300, 600 and 1000ppm) and compared to a control (water). Prior to spraying, 100 terminal shoots were marked randomly on each tree for percentage flowering determination. After inflorescence development, 20 panicles per tree were marked randomly on each tree to monitor fruit set. The experiment was laid out in a randomized complete block design with three replicates and three trees per treatment. The effect of the treatments was established from reproductive growth parameters including days to flowering and fruit set; number of panicles per tree and average fruit set per 20 panicles.

Results

Table 1: Differences in the days to 50% flowering of 'Apple' and 'Ngowe' mango trees in Embu and Makueni Counties as affected by Potassium nitrate and Ethephon treatments.

	Production Location				
	Embu		Makueni		
Treatment/Variety	'Apple'	'Ngowe'	'Apple'	'Ngowe'	Means
2% KNO3	101.0(±4.6)h	97.3(±3.1)gh	77.0(±3.6)d	74.0(±1.7)d	87.3
4% KNO3	90.0(±3.0)f	83.0(±1.7)e	50.0(±6.0)a	45.0(±5.0)a	67.0
Ethephon 600ppm	103.0(±2.6)h	100.0(±5.6)h	59.0(±2.6)c	57.0(±3.0)c	79.8
Ethephon 1000ppm	93.0(±3.0)fg	88.0(±2.0)ef	55.0(±3.0)bc	51.0(±5.3)b	71.8
Control	129.0(±4.6)j	125.0(±3.6)j	113.0(±3.0)i	99.3(±2.1)h	116.6
LSD 0.05 (Treat)	7.5	3.8	6.5	3.9	
LSD0.05	5.2				
(Loc. x Var. x Treat)					
CV (%)	3.7				

Values followed by the same letter(s) in a column or a row do not differ significantly at 5% level of significance. Loc= location, Var= variety and Treat= treatment

Table 2: Differences in fruit set of 'Apple' and 'Ngowe' mango trees in Embu and Makueni Counties as affected by Potassium nitrate and Ethephon treatments

	Production Location				
	Embu		Makueni		
Treatment/Variety	'Apple'	'Ngowe'	'Apple'	'Ngowe'	Means
2% KNO3	56.7(±5.8)c	110.3(±6.2)e	139.5(±3.9)g	169.0(±4.0)i	118.9
4% KNO3	216.0(±2.6)k	280.8(±3.7)m	237.0(±2.6)l	288.0(±4.4)n	255.5
Ethephon 600ppm	83.3(±3.2)d	130.0(±7.1)f	113.0(±2.0)e	134.6(±0.8)fg	115.2
Ethephon 1000ppm	152.6(±5.0)h	250.0(±4.3)m	141.6(±6.1)g	181.0(±3.6)j	181.3
Control	31.0(±2.0)a	53.0(±8.5)c	39.0(±3.0)b	55.0(±2.0)g	44.5
LSD 0.05 (Treat)	7.1	4.1	7.6	4.0	
LSD 0.05					
(Loc. x Var. x Treat)	7.2				
CV (%)	3.1				

Values followed by the same letter(s) in a column or a row do not differ significantly at 5% level of significance. Loc= location, Var= variety and Treat= treatment

Discussion

Manipulation of mango trees to attain an off-season crop is a promising intervention to address seasonality in mango. The present study shows significant effect of the flower induction chemicals (potassium nitrate and ethephon) on mango tree flowering and fruit set. There was significant interaction amongst the treatments, mango production location and the varieties. The differences in responses observed could be attributed to many factors. One of the major differences in response was observed between the two AEZs – Makueni and Embu. The two AEZ differ significantly in temperature and rainfall. Embu is relatively cooler (mean temperature 19 oC) while Makueni is hotter (mean annual temperature ranging between 26oC to 35oC). The significant differences in temperature, coupled with differences in rainfall and soils could have significant effect on tree growth and physiology, subsequently affecting the trees' responses to treatments (Ouma, 2014). Significant KNO3 treatment effect on time to flowering, percentage flowering, number of panicles and fruit set was observed in both mango varieties regardless of the production location. KNO3 at 4% induced early flowering in treated trees compared to control trees. This effect could be in part attributed to additional N from KNO3. Increased nitrogen fertilization through the soil has been found to increase fruit retention and yield in mango (Yeshitela et al. 2006). Ethephon has been used to successfully induce and increase flowering in various mango varieties in the Philippines and India. In the present study, higher concentration of Ethephon (600 ppm and 1000 ppm) induced higher percentage flowering and fruit set. The role of ethephon in flower induction is not well understood. However ethylene is known to influence a number of physiological and developmental processes in plants.

Conclusion and Recommendation

These findings show that ethephon and KNO3 application can be explored as a strategy to induce an off-season crop. The chemicals can be used to substitute this natural phenomenon and realize a reasonable crop outside the peak season.

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10018 Effect of Edible Coatings on Shelf Life and Quality of Cassava Roots

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Abstract
Postharvest physiological deterioration (PPD) limits the shelf-life and utilization of cassava as it affects the physical, physiological and nutritional properties of the harvested roots. The response of cassava to PPD renders it unpalatable and unmarketable thereby contributing to postharvest losses. Edible coatings have been found to be effective in preserving the quality of various perishable products. There are variations in the activity of the different coating solutions hence need for optimization. The objective of this study was to determine the optimum concentration of both guar gum and xanthan gum capable of extending shelf life of the cassava for the longest time. The cassava (KME 1) was harvested at physiological maturity and cleaned. Whole cassava was dipped in 1%, 1.5% and 2% of guar gum, 1.5%, 2%, 2.5% of xanthan gum, and 1%, 1.5%, and 2.5% xanthan guar gum combination in the ratio of 1:1 with some roots left as control. Sampling was done every two days from each treatment for assessment. The coated cassava showed lower respiration and ethylene rates than the control samples. In addition, the change in quality parameters of the cassava; phenols, flesh firmness and cyanide content was significantly ($P \leq 0.05$) delayed in the coated samples. The results suggest that using the 1.5% xanthan gum, 1% xanthan guar gum combination and 2% xanthan/guar gum as edible coatings, extended the shelf-life of the cassava roots by up to 20 days at 25 °C. The coating technique proved to be an effective strategy of delaying the onset of PPD.

Keywords:
Cassava, guar gum, edible coatings, postharvest losses, xanthan gum

Introduction
Cassava provides dietary carbohydrate to approximately 800 million people in the tropics (Clement et al., 2010). It's a major staple food in West African countries and second most important food crop after maize in western and coastal provinces of Kenya with an annual production of 841,196 tons (Mulu-Mutuku et al., 2013). The root suffers PPD two days after harvest which renders it unpalatable and unmarketable. PPD has become a major constraint to the development of the cassava value chain due to the high losses incurred. There's an approximate 29% loss of all cassava produced in Africa (Harris et al. 2015). Furthermore, production and marketing of cassava has remained low as the crop is considered of marginal importance due to its high perishability (Bull 2011).

Edible surface coatings can protect perishables from moisture migration, microbial growth, light-induced chemical changes and oxidation of nutrients by acting as barriers against oils, gases, or vapors (Janjarasskul & Krochta, 2010). These functions enhance the quality of food products, resulting in shelf-life extension. They have been found to be an effective technology in shelf-life elongation of various perishable products. They are locally available and cost effective. Xanthan gum and guar gum have successfully elongated the shelf life of pawpaws and guava respectfully (Baraiya et al., 2016; Wijewardane, 2013). Xanthan/guar gum coatings at low concentrations form a viscous solution with improved pseudoplastic properties.

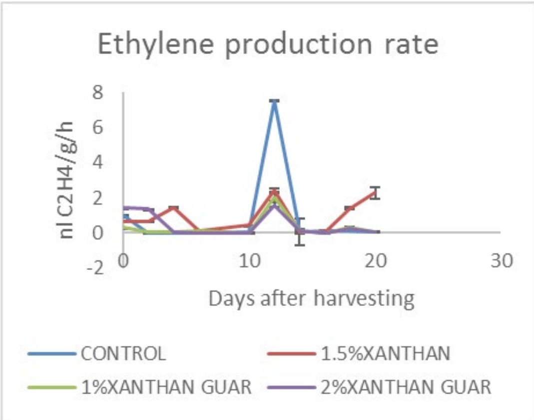
To enhance the commercialization of cassava in Kenya, there is need to develop methods of extending its shelf life and ensuring that it reaches the target market at peak quality. This study sought to determine the best combinations and concentrations of both xanthan gum and guar gum capable of extending the shelf life of harvested cassava roots to the maximum.

Materials and Methods
Acquisition of cassava roots and coating powders was from JKUAT farm and a food ingredient shop respectively. Formulation of coating solutions whose concentrations are based on preliminary studies i.e. 1.5%, 2%, 2.5% w/v xanthan gum, 1.5%, 2% w/v guar gum and 1%, 1.5%, 2% w/v xanthan guar gum combination. Application of coating solution by dipping method, air-drying and storage for 20 days. Coating was done on the same day that roots were harvested. Physical (flesh firmness according to Famiani et al. (2012) using a hand-held penetrometer), physiological (respiration rate and ethylene production rate according to Fugate et al., (2010) by acquisition of the head space gas) and chemical analysis (total phenolic content according to Ainsworth & Gillespie, (2007) by the Folin-Ciocalteu method and cyanide content using the alkaline titration method according to Length, (2014) of coated and control samples. Analysis was done at 2 day intervals for the storage duration. Comparisons among the various treatments and storage duration effects was determined by ANOVA using Genstat, while the mean variations were performed using Tukey test at 0.05 significance level.

Results and Discussion

The initial increase in the firmness of the cassava samples was due to water loss which was as a result of various processes. Starch hydrolysis which permeabilizes the cellular membrane enables water to exit from the cell wall hence hardening the flesh of the cassava (Martial et al. 2016). With increased storage duration, there's an increase in polysaccharide production which lignifies cell wall hence increasing the flesh firmness (Martial et al. 2016). The later decline in the firmness was due to the action of pectin enzymes which cause a dramatic loss of firmness. The cell wall pectins are degraded by the action of pectin methyl estearase and pectin lyase which originate from either microbial source from the cassava root itself or as a consequence of PPD.

The total cyanide content recorded declined with the storage duration time. However, the total cyanide content in the treated samples was below the acceptable limit given by WHO which is 10 mg/kg (Burns et al., 2012). The burst in production of the cyanide during the early days after harvest leads to inhibition of normal biological reactions that occur in the mitochondrion electron transfer chain of the cassava root leading to production of reactive oxygen species (ROS) which induce the onset of PPD (Zidenga, 2012). The general decline in the cyanide content is due to the hydrolysis of the cyanide which leads to its loss. Linamarase enzyme activity decreased with PPD as reported by Gavicho et al., (2014) and this may have brought about the general decrease in cyanide content with storage duration in both the coated and control samples



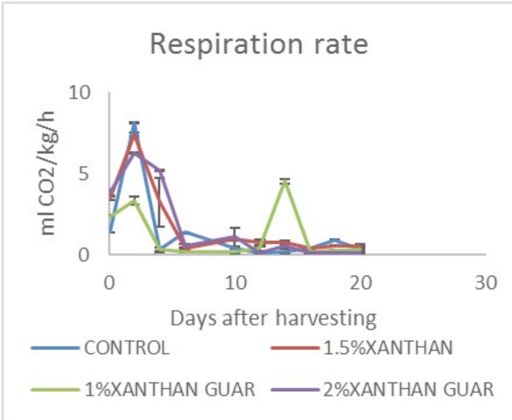


Figure 1: Effect of coating on the ethylene production rate and respiration rate of cassava roots during storage. Presented as mean ±SE for 3 replicates.

There was a slow progressive increase in ethylene production to 12 DAH (days after harvest) forming a peak followed by a decrease as it approached 20 DAH. The initial high concentration of the ethylene produced was due to the production of wound ethylene which is produced in response to injury that was caused during harvesting of the cassava root samples (Bull 2011). Two peaks were observed during cassava respiration as recorded by Salcedo & Siritunga (2011) generally at the second day after coating while the second peak depended on the efficiency of the coating solution. The first peak was due to the wounding and it occurs within the first 24 to 48 hours after harvest to suggest the onset of PPD. The second peak is due to biochemical changes induced by the development of the PPD. The second peak formation varied between the different treatments based on their functionality. The different concentrations of the coating solutions led to the significant ($P \leq 0.05$) differences in their effect on respiration rate. This process is delayed by the use of coating solutions. The treated root samples showed a delay in phenol reduction due to the efficiency of the coating solutions to delay PPD and enzyme inactivation due to oxygen depletion (Salcedo & Siritunga, 2011). There was also notable delay in the browning of the coated roots due to the inhibition of oxygen penetration by the coating solution as was reported by Baraiya et al. (2015).

Conclusion and Recommendations

The coated samples exhibited better postharvest quality as compared to the control samples during the 20 days of storage. The 1.5% and 2% xanthan/guar gum coating and 1.5% xanthan gum coating were able to extend the shelf life of the cassava upto 20 days at room temperature. The change in firmness was significantly delayed by the application of the coating solutions. CO2 and ethylene production were suppressed in the coated samples hence a delay in the PPD onset. The inhibition of polyphenol oxidase and ROS production led to minimal production of phenols and cyanide in the coated samples. This study recommends the use of 1.5% and 2% xanthan/guar gum coating and 1.5% xanthan gum as an effective strategy in delaying the PPD onset with minimal alterations to the quality of the cassava.

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10019 Combinatorial Effects of Hydrocooling, Sanitizer Application and Cold Storage in Maintaining Quality of Selected Vegetables

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Abstract
This study was undertaken to determine the effects of hydrocooling, low temperature storage and sanitizer application on postharvest shelf life of carrots, courgettes, African eggplants and tomatoes. Mature good quality produce was harvested and hydrocooled with water (2±1 0C) containing calcium chloride (CaCl2) at four concentrations, 0%, 0.5%, 1.0% and 1.5%, followed by low temperature storage at 100C. Controls setups with hydrocooled and non-hydrocooled produce were kept at ambient temperature (25±5 0C). Vitamin C, decay incidence or chilling injury, microbial load, colour and specific sugars assessment was done at 2 days interval. The highest vitamin C loss occurred in the produce stored at room temperature without hydrocooling for tomatoes, carrots and courgettes, from 21.6 mg/100g to 12.7mg/100m, 5.6 mg/100g to 3.0 mg/100g, 17.8mg/100g to 10.6 mg/100g respectively, while African eggplants had the highest vitamin C retention under same conditions, with similar trends being observed for colour and specific sugars. Optimal CaCl2 concentrations for extended shelf life and nutrient retention varied according to produce, with 0%, 1% and 1.5% for carrots, tomatoes and courgettes, resulting in lower decay incidences and microbial loads. In African eggplants CaCl2 delayed the onset of chilling injury at 1.5% by two days, once chilling injury set in, CaCl2 had no significant effect on the progression of chilling injury of the fruit. In conclusion, precooling tomatoes, courgettes and carrots with sanitizer extended shelf life by between 2 and 5 days.

Key words:
Hydrocooling, low temperature storage, postharvest quality.

Introduction
Fresh produce quality is influenced by postharvest handling techniques and conditions. In developing countries maintaining low temperatures of produce after harvest throughout the supply chain is a challenge due to the high capital costs. This results in quality and quantity losses in fruits and vegetables; an issue of great concern to postharvest technologist in the world (Kitinoja et al., 2011). Deterioration begins soon after harvest, and is accelerated by poor packaging, ventilation, physical stress presence of pest and diseases, as well as poor timing of harvesting (Kitinoja et al., 2011). The lead contributing factor to postharvest food losses of perishable produce in developing world has been identified as absence or poor cold chain due to lack of investment in storage and cooling facilities. Reduction of postharvest loses in fruits and vegetables remain to be a worldwide goal (Vigneault et al., 2009).To attain longer postharvest quality and produce marketability, temperature control for produce is quite important. The desire to prolong product storage life and reach distant markets with quality that satisfies consumer calls for uniform and fast cooling of perishables (Manganaris et al., 2007). Hydro-cooling uses clean, sanitized water as the cooling medium (Kitinoja and Thompson 2010). The process is efficient in removing field heat and also serves to clean the produce. A disinfectant added to water aids in reducing the spread of diseases, thus better quality which is perceived by the consumer from the appearance of uniform colour, absence of decay, injuries or shriveling (Vigneault et al., 2009).This research aimed at establishing the optimal calcium chloride concentration in the different produce as resulting in postharvest life extension.

Materials and Methods
Good quality fresh produce was hydrocooled using the system designed and tested by (Chepngeno et al., 2015). Calcium chloride 0% 0.5%, 1.0% and 1.5% used in the hydrocooling water at 2±10C, and compared with hydrocooled and non-hydrocooled produce were kept at ambient temperature (25±5 0C). The storage rot or chilling injury incidence from produce subjected to the treatments was determined as the percentage (count) of the sample with decay from total proportion and colour assessment done using Chroma colour meter (CR-300, Minolita Japan).

Nutritional Assessment
Vitamin C and specific sugars (glucose, fructose and sucrose) was determined using the HPLC method with C18-4D column and Shimadzu UV-VIS detector with 0.8 % metaphosphoric acid mobile phase, at 1.2 mL/min flow rate and wavelength of 266.0 nm against ascorbic acid standard and NH2P-50E column at 10 Pkm pressure and 1 ml/min flow rate and refractive index detector with the specific sugar standards respectively.

Microbial Assessment
Produce of known weight from treatments above were washed in sterile distilled water using a shaker, with fruit to distilled water ratio as 1:9, and wash water diluted using peptone water, up to 105. This was plated in triplicate on total plate count agar and potato dextrose agar prepared as per manufacturer's instructions and incubated at 250C for 24 hours.

Data analysis

Results are described as Mean ± Standard error of three replicates. Analysis of variance (ANOVA) and Mean comparison was done using Duncan Muncan Multiple Range Test P≤ 0.05 using Genstat statistical package 16th edition.

Results and Discussion

The produce studied exhibited chemical, physical and microbial load change throughout the storage period; with significant variations in response to the treatments applied. Vitamin C a key nutrient in fruits and vegetable that is often used in quality assessment declined as shown in figure 1 below.

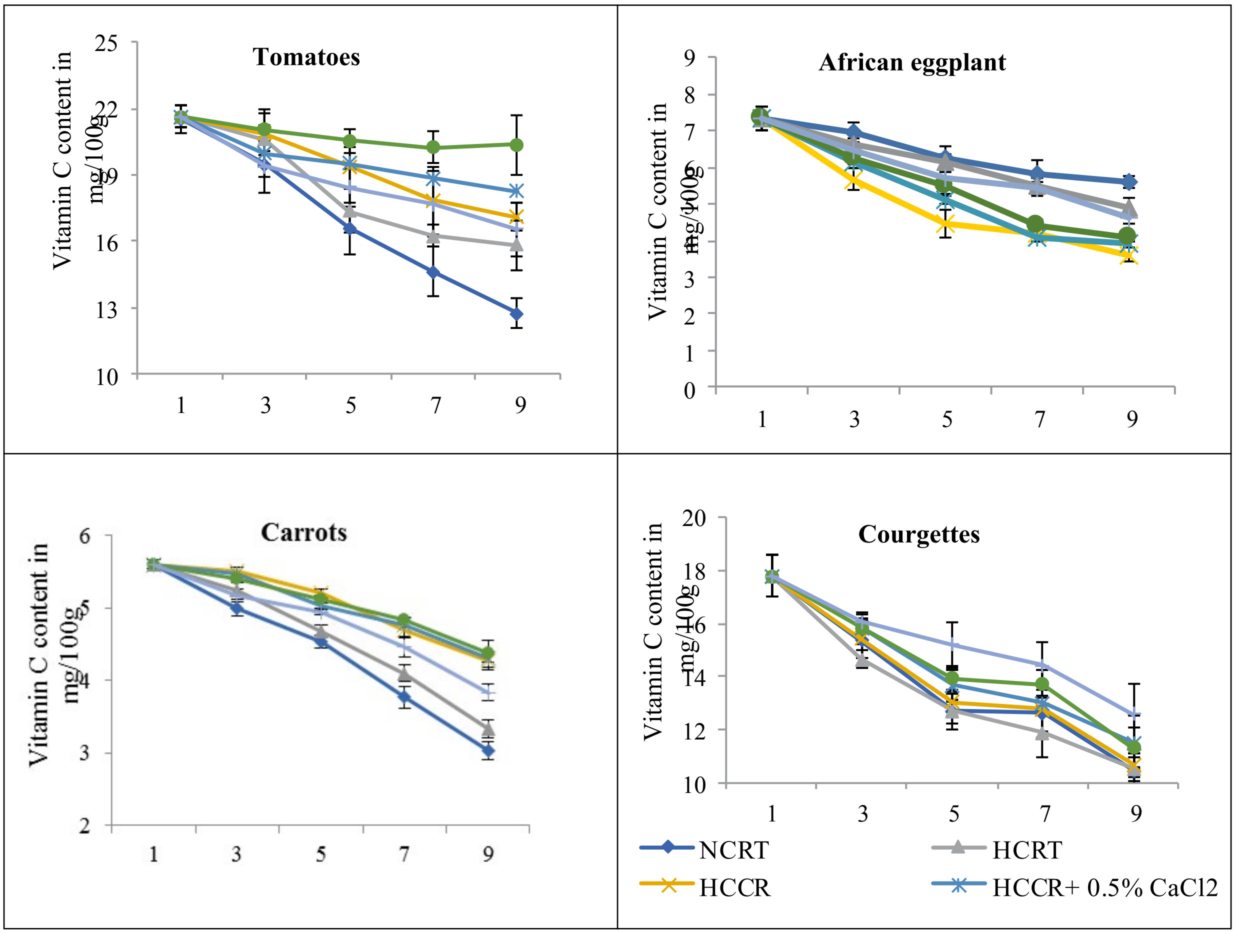

Fig 1. Graphs of tomatoes, African eggplant, carrots and courgettes respectively, where NCRT= not cooled and stored at ambient temperature, HCRT= Hydrocooled and stored at ambient temperature and HCCR = Hydrocooled and stored at low temperature (0% Calcium Chloride). HCCR + 0.5%, 1.0% and 1.5% is concentration of calcium chloride added to the cooling water. * Vertical bars represent standard errors and n=3

The marketable portion of all produce declined with storage time in all treatments, following a simmlar pattern as observed in Vitamin C. Tomatoes became flaccid and some decayed and shriveled. Eggplants became scalded and skin shrivelled, with brown lesions developing near the seeds. Carrots wilted and re-sprouted at the base where leaves had been chopped off, with a few root hairs also developing. Courgettes developed pinched ends in some treatments, with clear discolouration and softening of the product. Produce attained 30% unacceptable proportion under control both hydrocooled and non-hydrocooled in 3, 8 and 9, 12 days for courgettes, tomatoes, carrots and eggplant. In cold storage the same was attained on 9, 13, 15 and 4 days at 1% courgettes, 0% in carrots, 1.5%, tomatoes and 0% in eggplants. Fructose and glucose accumulated during storage for all produce, while sucrose declined. Tomatoes had initial sugar content of 0.55 mg/100g, 0.38 mg/100g and 0.80 mg/100g for glucose, fructose and sucrose respectively. At the end of the study period, glucose and fructose had increased under the control treatment to 1.49 mg/100g and 1.58 mg/100g, while sucrose declined to 0.40 mg/100g. African eggplants, courgettes and carrots followed similar trends of increase in glucose and fructose, while sucrose decreased during storage time. Produce colour change was significantly (P≤ 0.005) fast in fruits kept at ambient temperature. Within 7 days tomatoes attained a deep red colour (hue angle ≈400), carrots and courgettes showed lower L* values of 52.7 and 28.6 respectively with no significant change in hue. Treatments with CaCl2 0%, 1% and 1.5% for carrots, tomatoes and courgettes, took another 3, 5 and 7 days respectively to attain the comparable colour score. Eggplants in the control and 0% CaCl2 had Hue of 101.20 and 92.70 on day 9. According to Muir et al., (2009) duration and temperature of storage are two important factors responsible for the loss of pigments and colour, and special care must be taken to produce food that retains its bright attractive colour during subsequent marketing and consumption. Microbial loads both in bacterial and in yeast and mold was highly reduced by the highest CaCl2 concentration, and their regeneration slowed by low storage temperature. Effect of storage temperature, time and precooling with water, or water with calcium chloride at various concentrations had a significant effect (P≤0.05) on total plate count and in yeasts and moulds. Produce stored at lower temperatures showed lower microbial loads throughout storage time.

Higher calcium chloride concentrations resulted in lower count in total plate count and yeast and moulds for all the produce studied.
Hydrocooling the produce with portable tap water (free of microbial contamination) significantly reduced the initial microbial load in all the produces tested. This was similar to those of Workneh et al., (2003) in carrots when he compared the effects of tap water, anolyte water and chlorinated water on microbial load

Conclusion and Recommendations

Combining low storage temperature and hydrocooling has a significant effect on the postharvest quality of carrots, courgettes and tomatoes. Precooling of these vegetables to their target temperatures without further low temperature storage was only effective for 3 days. Although the produce subjected to hydrocooling and low temperature storage were superior in quality, there was no significant statistical difference in their quality with those subjected to low temperature storage without prior precooling. This shows that hydrocooling alone is not sufficient to maintain the postharvest quality of perishables. Further to this, there is need to establish the optimal calcium chloride concentration in the different produce since each produce responded differently.

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10020 Effects of Pre-treatment During Drying on The Antioxidant Properties of Tomato

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Abstract
Drying technology has been practiced in an attempt to lower the water activity and increase the shelf stability of the dried product. However, drying leads to reduced product quality due to heat induced chemical reactions that are irreversible. These reactions can be slowed or inhibited through chemical pretreatment during drying. Therefore, the objective of this study was to determine the effect of pretreatment on the retention of the antioxidant properties of a dried tomato product. A selected tomato variety (Kilele) was obtained from a greenhouse in Jomo Kenyatta University of Agriculture and Technology. Tomato quarters of this variety were prepared and treated by spraying with (a) 0.5% sodium metabisulphate, (b) 0.5% Calcium chloride and (c) distilled water (control) and oven dried at 50 °C, 60 °C and 70 °C to 13% moisture content. Lycopene, ß carotene and total phenolics content was determined in both the fresh and dried tomato samples. Results showed a significant difference in retention of lycopene ($p<0.05$), ß carotene ($p<0.05$) and total phenolic compounds ($p<0.05$) on all pretreated samples compared to the control. Findings demonstrated that pretreatment of tomatoes during drying may enhance high overall quality in tomato drying.

Key words:
Lycopene, ß carotene, pretreatment.

Introduction
Tomato (Lycopersicon esculentum Mill) is one of the most popular vegetable that is consumed in the world (Brooks et al.,2008). Its wide popularity is mainly associated with its diverse health attributes and culinary properties (Brooks et al., 2008). Tomatoes are good sources of antioxidants such as lycopene, polyphenolic compounds, vitamin A, Vitamin E, ascorbic acid and ß carotene (Santos-Sánchez et al., 2012). Scientific evidence suggests that regular consumption of tomatoes in the diet confers significant health benefits such as cancer prevention as well as offer protection from age degenerative diseases that are mainly associated with free radical reactions (Nisha et al., 2011).

In Kenya, tomato production ranks third after kales and cabbages in the horticultural industry and is a major contributor to the Gross Domestic Product (Geoffrey et al., 2014). However, being climacteric fruits, tomatoes are inherently perishable (Ahmed et al., 2016). Therefore, extensive postharvest losses in tomatoes are experienced especially during the harvest season which results to considerable loss of income to both small and large scale farmers (Ayandiji et al., 2011). As a result there is need to develop postharvest loss prevention technologies that ensure prevention of these losses One such technology is drying which significantly reduces the water content therefore making microbial activity slow or virtually absent thus extending the shelf life of the dried product (Joshi et al., 2009). However during drying, oxidation and isomerization leads to quality loss and reduced acceptance of the dried product (Taylor et al.,2010). As a result, control of these reactions is key in ensuring that quality is maintained in the final product. In this regard, osmotic assisted dehydration has been proven effective in maintaining product quality during drying (Azoubel & Oliveira, 2008) . Therefore, this study aimed at investigating the effect of pretreatment during drying on the antioxidant properties of a selected tomato variety.

Materials and Methods
Sample preparation and oven drying
Kilele tomato variety of uniform ripeness (red ripe) was selected for the study. Tomato quarters were prepared and divided into three equal batches. The first batch was treated by spraying with 0.5% w/v calcium chloride (0.5% C.C), the second with 0.5%w/v sodium metabisulphate (0.5% N.M) while the third was sprayed with distilled water (control) and allowed to stand for 20 minutes to drain away excess spray. Drying was carried out in an oven drier at 50 °C, 60 °C and 70 °C to final moisture content of ~13%. At the end of each drying procedure, moisture content of the samples was determined and the dried samples were put into zip lock bags and stored at -20 °C away from light until further analysis. All the experiments were carried out in triplicates and the results expressed on dry weight basis (DW).

Determination of total phenolic compounds
Folin ciocalteu method was used to determine the amount of total phenolic compounds as described by Ainsworth & Gillespie, (2007) with slight modifications. The absorbance was measured at 765 nm using UV-vis spectrometer (Shimadzu UV Vis 1800, Tokyo, Japan model. The amount of total phenolic content was expressed as gallic acid equivalents (GAE) per 100 g of the sample.

ß Carotene and lycopene content determination
The method suggested by Chen, (2005) was employed with some modification for the determination of lycopene and ß carotene. The ß carotene and lycopene were analyzed using a Shimadzu brand HPLC (10A model ,Tokyo, Japan) at a wavelength of 445 and 470 nm respectively. Pure ß carotene and lycopene standards were used for identification and quantification.

Results and Discussion

Effect of pretreatment on the total phenolic content in dried tomatoes.

This study showed that Kilele variety contained total phenolic content (TPC) of 754±9.76mg/100g DW. This was in agreement with Kerkhofs et al. (2005) who reported TPC content of 682.1mg GAE /100g DW in Aranka tomato cultivar. A separate study reported lower TPC values in the range of 248.4-335.9 mg GAE/100g DW in the tomato varieties studied (Boonkasem et al., 2015). This differences in TPC may be linked to genotypic variations that have been proven to influence the levels of total phenolics in tomato fruits (Hanson et al., 2004).

It was generally observed that after drying there was a significant reduction in TPC content in the dried samples compared to the fresh. This may be associated with degradation that occurs in phenolic compounds after exposure to heat and oxygen. Statistical analysis showed that pretreatment had a significant effect ($p<0.05$) on the degree of TPC retention in the dried samples. Degree of retention followed the order 0.5%N.M>0.5%C.C>control. This may be associated with the ability of osmotic solvents to shorten drying time (data not shown) hence reduced exposure time to reach stable moisture content (13%) It was also noted that samples dried at a higher temperature (70 °C) contained higher TPC content as compared to those dried at a lower temperature (50 °C).This may be attributed to possible higher concentration effect after drying at 70 °C as compared to drying at 50 °C

Effect of pretreatment on β carotene content and lycopene

The ß-carotene and lycopene content in the fresh sample was 26.0 and 108.46 mg/100g DW respectively. This corresponds to about 1.35 and 6.17 mg/100g FW. Similar values were reported by Georgé et al. (2011) who found ß-carotene to occur in the rage of 0.6± 0.1 – 1.0±0.1 mg/100g F.W. In a separate study, Olufemi. (2009) determined lycopene content in eight tomato varieties to occur in the range of 70.25-147.29 ug/g f. w which corresponds to about 117-245.33 mg/100g DW. Statistical analysis showed a significant ($p<0.05$) decrease in both ß-carotene and lycopene content after oven drying relative to the fresh as shown in Figure 1 and 2 respectively. It was generally observed that 0.5%N.M and 0.5%C.C pretreatments better preserved these compounds as compared to the control. The final lycopene content in the pretreated samples occurred in the range of 60.58-93.25 while that of the control occurred in the range of 43.92-56.69 mg/100g DW. ß carotene content in the control samples occurred in the range of 2.33-5.88 while that in the pretreated samples occurred in the range of 7.29- 14.13mg/100g DW. The higher retention of both lycopene and ßcarotene in the dried samples may be attributed to the ability of 0.5%C.C and 0.5%N.M to act as reducing agents in oxidative reactions hence preserving the carotenoid quality of the dried product (Sahin et al., 2011; Sra & Sandhu, 2011).

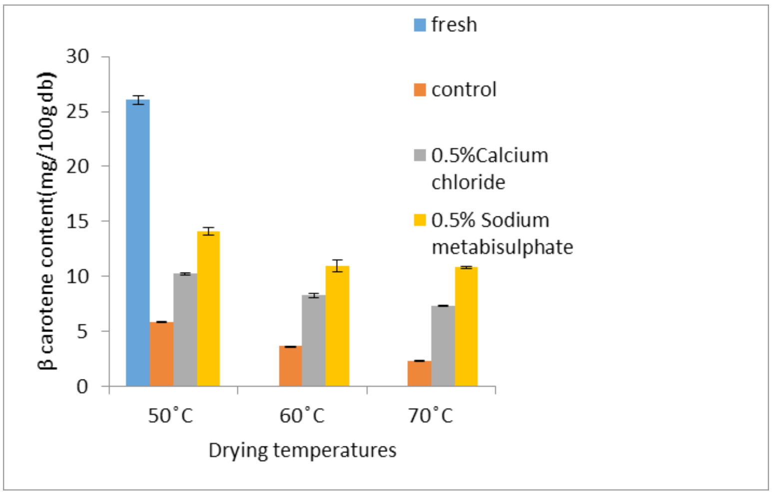

Fig1.ß carotene content of fresh and dried samples oven dried at 50 °C, 60 °C and 70 °C

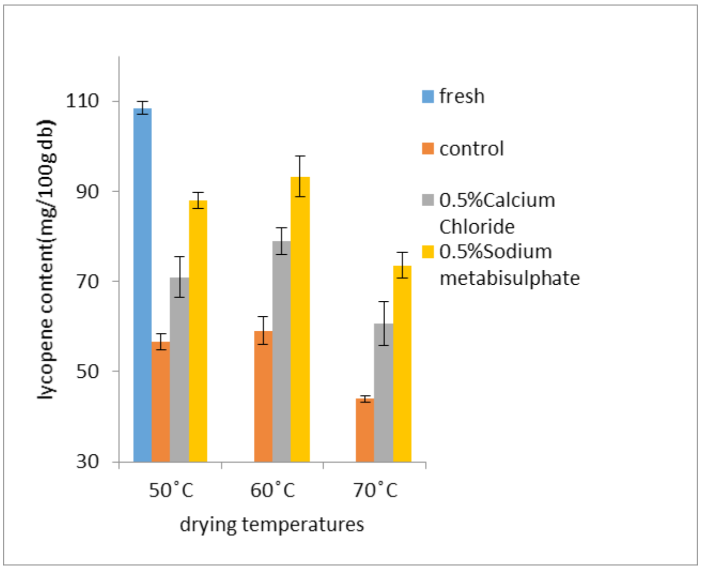

Fig. 2.Lycopene content of fresh and dried samples oven dried at 50 °C, 60 °C and 70 °C.

Conclusion

Attempt to lower moisture content in Kilele tomato variety to ensure shelf stability resulted in overall reduction in lycopene, ß-carotene and total phenolic compounds compared to the fresh samples. However, pretreatment with 0.5%N.M and 0.5% C.C significantly preserved the overall quality of dried tomato samples during oven drying as compared to the control. It was observed that lycopene, total phenolic compounds and b-carotene were better preserved by drying at 60 °C (0.5%N.M), 70 °C (0.5%N.M) and 50 °C (0.5%N.M) respectively. The study therefore showed that pretreatment is one of the techniques that can be used in controlling undesirable quality changes that occur during tomato drying.

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10021 Effect of Drying Methods and Temperature on the Bioactive Compounds in African Eggplant

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Abstract

The short shelf life of African eggplants is a major cause of postharvest losses during the peak season. One of the commonly used food preservation methods for producing shelf stable products is drying. However, drying can lead to degradation of the nutrients and phytochemicals depending on drying method and temperature conditions. This study evaluated the effect of four drying methods (solar, oven, vacuum and freeze) on the degradation of total phenolics, beta carotene, antioxidant capacity and lycopene in five African eggplant accessions at two maturity stages. Fruits were dried up to ~10% moisture content. Oven and vacuum drying was done at 50, 60 and 70oC. The results showed that response variables were significantly ($p < 0.05$) affected by drying method and drying temperature with freeze drying, vacuum drying, solar drying and oven drying presenting increasing degradation order respectively. Among the fresh samples, beta carotene, total phenolic content and free radical scavenging activity presented ranges of (11.67-29.50mg/100g db), (609.64-1691.70mg/100g GAE db) and (79.55-502.23mg/ml db IC50 value) respectively. Lycopene was detected in dried manyire green (0.16mg/100g db) only. These results demonstrate that generally, freeze drying leads to least degradation of bioactive compounds.

Keywords:

Antioxidant capacity Beta carotene, lycopene total phenolics.

Introduction

African eggplants belong to the Solanum genus, and includes three cultivated species namely Solanum macrocarpon L., Solanum aethiopicum L. and Solanum anguivi. They are native to Africa (Daunay et al., 2001) and are a wild relative of the common eggplant (Solanum melongena) (Schippers, 2000). S. aethiopicum L. is in the top five list of important vegetables of tropical Africa, together with tomato, onion, pepper and okra (Schippers, 2000; Maundu et al., 2009, Lim, 2015). The fruits and leaves are consumed in soups and stews. African eggplants are a rich source of bioactive compounds which have high health benefits to the human body. They include the anthocyanins of the fruit epidermis and the phenolic acids which are found in the flesh. These phytochemicals are also responsible for the fruit organoleptic properties by imparting a bitter taste and interfering with other molecules during the cooking process (Daunay et al., 2001). Bioactive components are high in antioxidant and antiradical activities that are responsible for reducing the risk of radicals-mediated pathogenesis such as carcinogenesis, atherosclerosis, diabetes, Alzheimer, cataracts and age-related functional decline (Lim, 2015). In the recent past consumer awareness on bioactive components and their potential health benefits has brought about increased search for foods that are high in functional bioactive compounds). Kenyans are progressively and increasingly demanding and producing high bioactive foods which include African eggplant. However, this is accompanied by increase in postharvest losses due to the high perishability nature of this commodity. Perishable commodities require low temperatures during handling, transport and distribution facilities which are inadequate or poorly established in developing countries such as Kenya. In addition, African eggplant is sensitive to chilling injury below 10oC. Fruits and vegetables can be processed to extend their postharvest life (Vicente et al 2014). Drying of agricultural products has always occupied an important role in food preservation for human consumption (Sobukola and Dairo 2007). Drying brings about substantial reduction in weight and volume, thus minimizing packaging, storage and transportation costs. On the other hand, processing can induce changes in the physical and chemical properties of commodities (Muthukumarappan & Tiwari, 2010). Consequently, food processors are emphasizing on simultaneous production and minimal loss of available antioxidants during processing to meet the current market trend. Changes in phytochemical compounds are becoming important for optimizing and choosing drying methods and conditions (Akdaş & Başlar, 2015). To our knowledge, there is no comprehensive study that has been reported on the drying of African eggplant. This study evaluated the retention of health beneficial bioactive compounds (namely total phenolic content, antioxidant capacity and beta-carotene) under four drying methods namely; solar drying, oven drying, vacuum drying and freeze drying in five African eggplant accessions.

Materials and Methods

Five selected African eggplant accessions namely; AB2, Manyire green, Sangawili, Aubergine blanche and S00047A with different characteristics were used in this present study. These varieties were obtained from the African Vegetable Research and Development Center (AVRDC), Arusha. Sixteen plants of each accession were grown in three replicates in a completely randomized block design in an open-air field plot at the facilities of the Jomo Kenyatta University of Agriculture and Technology experimental farm. African Eggplant fruits were harvested at mature red stages. They were stored overnight at room and dried using four different methods namely oven, vacuum, freeze and solar drying. The drying of eggplants was finalized when the moisture content decreased to ~10% from the initial moisture contents. Moisture content was determined using method 984.25 AOAC, (2005). Beta Carotene content was determined following the method by Delia, (2004). Total phenolic content (TPC) was measured using the Folin–Ciocalteu colorimetric method (Wojdylo et al., 2007). The antioxidant activity of the extracts and the standard were assessed on the basis of the radical scavenging effect of the stable 1, 1-diphenyl-2-picrylhydrazyl (DPPH) - free radical activity (Sreenivasan et al., 2007) with some modifications.

For the extraction of lycopene, the method suggested by Lin and Chen (2005) was used with some modifications. All data analyses were carried out using Stata version 12 software (Stata Corp., College Station, Texas 77845 USA).

Results and Discussion

Overall, the results show that freeze drying led to least degradation of beta carotene and total phenolics content (Figure 1 and 2). This confirms the fact the general assumption that freeze drying leads to high quality products (Ratti, 2001). In addition accession played a role in the effect of degradation of the bioactive compounds measured. This could be associated with the different phytochemical profiles in each accession. Oven drying at 70oC led to the highest degradation of beta carotene (Figure 1). This indicates that high temperatures play part in degradation of beta carotene. Similar results have been reported in the drying of tomatoes (Demiray, Tulek, & Yilmaz, 2013). Carotenoid retention in foods have been reported to decrease with processing time, higher processing temperature, and cutting of the food (Delia, 2004). Vacuum drying at 70oC retained more beta carotene compared to oven drying at 70oC (Figure 1). In the case of total phenolic contents for all accessions for higher for oven dried sample than vacuum dried samples (Figure 2). Similar results have been reported in other species (Akdaş & Başlar, 2015)and this has been associated the escape of volatile and semi-volatile phenolic compounds through the evaporated water in the samples during vacuum drying. This combined with thermal degradation leads to more degradation leads to loss of phenolic compounds. The lowest retention of phenolics after solar drying (Figure 2) could be associated with the extended period of drying during which the polyphenol oxidase enzymes are active. It has been reported that high temperatures inactivate the polyphenol enzymes thus reducing the enzyme mediated oxidation of phenolics (Zaro et al., 2015). The reduction of the IC50 values was observed for all accessions (Table 1). These values represent the concentration of a sample that induces 50% inhibition of DPPH free radicals. Its degradation is as a result of the behavior of all bioactive compounds in a product that possess antioxidant capacity (Karaman et al. 2014). There was no lycopene detected in the fresh fruits. However one out of five dried accessions (manyire green) showed some little amount of lycopene (0.16mg/100g db). This could be of interest when it comes to breeding programs.

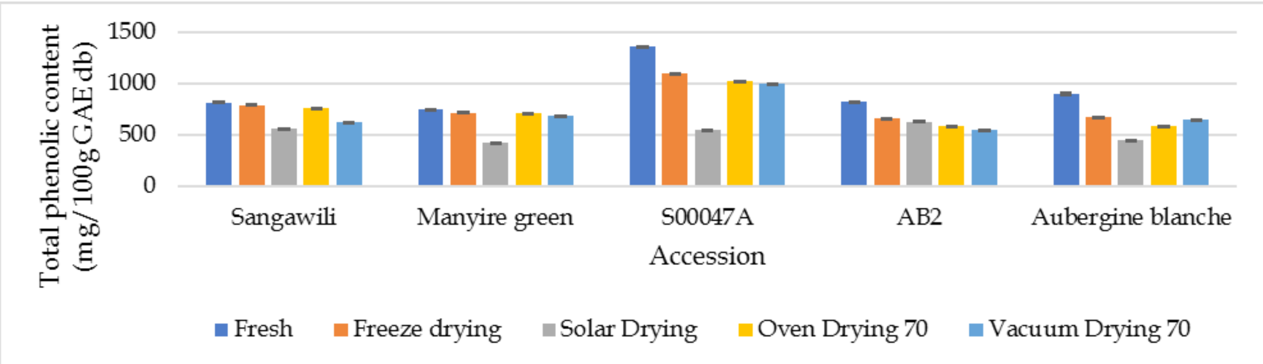

Figure 2: Total phenolic content degradation chart

Table 1: IC50 values (mg/ml db) as affected by different drying methods

Accession	Fresh	Freeze Drying	Solar Drying	Oven Drying 70	Vacuum Drying 70
Sangawili	325.61	5.70	5.47	16.52	4.85
Manyire green	163.28	4.98	5.78	6.76	5.38
S00047A	99.58	4.25	4.80	4.73	4.79
AB2	283.32	6.58	5.49	15.19	9.35
Aubergine blanche	298.01	6.37	5.16	5.57	5.99

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10022 Yield and Quality Characteristics of Waste Potato Peel Starch as Influenced by Extraction Method

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Abstract
Potato peels represent a severe disposal problem to the potato industry. Utilization of peels into useful products such as starch may turn the peels into a competitive raw material for starch extraction since it contains considerable amount of starch. Starch was extracted from potato peels using water, pectinase and sodium hydroxide. The Yield, functional and pasting properties of extracted starch were measured. The starch content of the peels was found to be 50% on dry weight basis. The yield (44.6%) was significantly ($p<0.05$) enhanced by extraction using pectinase enzyme more than water (17.2%) and sodium hydroxide (17.6%). The effectiveness of pectinase to increase yield was attributed to disintegration of pectin network resulting in release of starch granules. Peak viscosity and gelatinization temperature significantly differed ($p<0.05$) with extraction method while peak temperature did not differ significantly ($p>0.05$). The swelling properties of starch differed significantly ($p<0.05$) with the extraction methods. The highest swelling power was in pectinase extracted starch (16.85%) and lowest in water (13.6%). However, solubility of starch extracted with pectinase was significantly ($p<0.05$) lower (10%) compared to water (13.08%) and sodium hydroxide (13.87%). Water binding index was significantly improved with pectinase (121.11%) and lower (113.25%) in sodium hydroxide. The clarity of paste was found to be significantly ($p<0.05$) more in pectinase extracted starch compared with water and sodium hydroxide. The current study shows potential for utilization of potato peel waste for production of starch for industrial application.

Key words:
Functional properties, pasting properties,, potato waste, solubility

Introduction
The economy of developing countries Kenya included is still based on agriculture. Potato is one of the crops contributing immensely to Kenya's agricultural sub-sector (FAO, 2008). Potatoes are processed into variety of products such as chips, fries (Abong' et al, 2010), mashed potatoes and flakes (Abong and Kabira, 2012) which results into great amount of peels some of which go to waste. Industrial processing generates between 70 and 140 thousand tons of peels worldwide annually (Wu, 2016). The wastes from potato processing are mainly potato skins, starch and inert material (Vlyssides et al., 2007). Peeling is a major unit operation in processing of potato. Common peeling methods are abrasive, steam or lye peeling. The peeling procedure affects the amount of waste generated (Arapoglou et al., 2010). Besides the amount of waste peeling method also affects the composition of extracted starch content of potato peel waste (Camire et al, 1997). Potato peel waste represents a severe disposal problem for the potato industry since wet peels will quickly spoil due to microbial activities. The failure or inability to salvage and re-use such materials economically results in un-necessary waste and depletion of natural resources. Hence there is a need to encourage the bioconversion of this waste peels into useful products such as starch since they contain considerable amount of starch. The problem in the extraction of starch from peel waste is that very low yield depending on methods of extraction. The objective of the current study was to determine the yield and quality characteristics of waste potato peel starch as influenced by extraction method.

Materials and Methods
Preparation of peels for starch extraction
Potato peels were collected from College of Agriculture and Veterinary Sciences cafeteria located in Nairobi, Kenya. The peels were collected fresh and transferred to the Department of Food Science, Nutrition and Technology Chemistry Laboratory for extraction and evaluation. The peels were each sorted washed under running tap water. The peels were then cut into 2-3 cm3 chunks and washed in distilled water before extraction was accomplished using three methods: water, sodium hydroxide and pectinase.

Extraction with water
Potato peel waste was washed thoroughly to remove extraneous matter. Peels were weighed and equal amount of water was added in a blender before blending. Then slurry was then filtered in a double muslin cloth and the filtrate centrifuged at 3500 rpm for 10 minutes. The supernatant layer was discarded and precipitated starch washed with water and 95% ethanol and centrifuged again. Washing was repeated several times to remove impurities from the starch before drying.

Extraction with pectinase
The peels were washed under running water to remove the adhering dirt. About 100 g of peels was weighed to the nearest 0.01g and blended in a commercial blender and the slurry was transferred to a flask and a 100 ml of water added followed by pectinase at concentration of 0.1mg/ 100 g. The flask was then covered using aluminum foil and kept at incubation temperature of 40°C while agitating. The slurry after 45 minutes of incubation was suspended in 200 ml of water then passed through a double muslin cloth. The filtrate was collected and centrifuged at 3500 rpm for 10 minutes. The sediment was washed thrice while supernatant was discarded to retain starch that was then dried.

Extraction with sodium hydroxide
Peels were washed in running tap water to remove any adhering dirt before soaking in a solution of 0.03 N sodium hydroxide for 45 minutes. The solution was discarded and the peels were blended in a high speed commercial blender with an aqueous 0.03N NaOH (1:2). The pH was adjusted to 6.0 to avoid altering the starch fractions. The slurry was then passed through a double muslin cloth. The filtrate was collected and centrifuged at 3500rpm for 10 minutes. Sediment was washed thrice and the liquid supernatant discarded and the starch dried.

Analytical methods
The swelling power, solubility index, water binding index and pasting properties of respective starch were determined as per standard methods. All the experiments were conducted in triplicates. Analysis of variance was done to determine significant differences on the starch yields and functional properties using GENSTAT 15th Edition. Significance difference between treatment means was $p<0.05$.

Results and Discussion

Starch content and yield
Starch yield for different extraction methods differed significantly ($p<0.05$) being highest (44.6%) in pectinase extraction and lowest (17.2%) in water (Figure 1). Pectinase enzyme disintegrated the pectate network of the cell wall leading to release of starch granules (Dzogbefia et al., 2008).

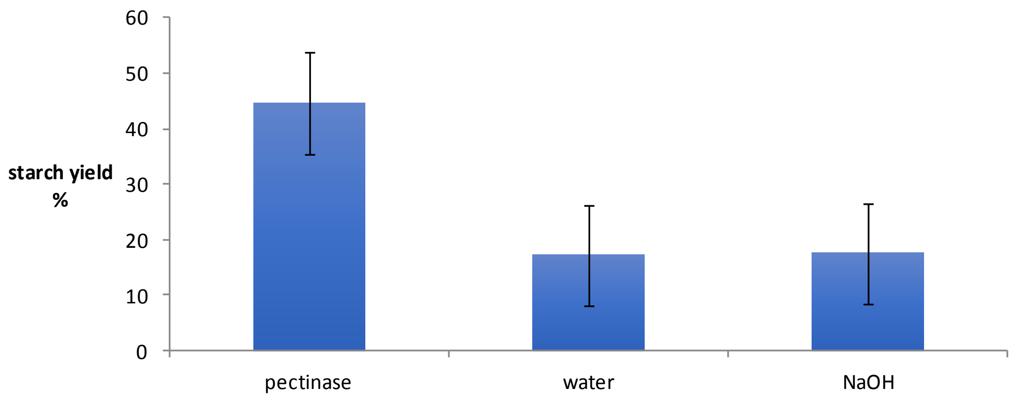

Figure 1: Starch yield from potato peels under different extraction methods

Pasting properties
The pasting property of starch extracted by different methods is as shown in Table 1. Peak viscosity did not differ significantly ($p>0.05$) with extraction method. It ranged from 600BU in water and Sodium hydroxide to 598 BU in pectinase. The gelatinization time and peak viscosity were not affected significantly ($P>0.05$) by the extraction methods.

Table 1: Pasting properties of starch extracted with sodium hydroxide, pectinase and water

Extraction[a,b]	Peak viscosity (BU)	Peak temp	Gelatinization Temp (°C)	Gelatinization time (min)
NaOH	600 ± 0.05a	73± 0.12a	67.5± o.15a	9
Water	600 ±0.02a	73± 0.09a	68± 0.17b	9
Pectinase	598 ± 0.15b	73.2± 0.05a	68± 0b	9
F value	> 0.081	>0.05	<0.465	
Lsd	1.84	0.13	0.65	

[a]Values reported as mean ± S.D of three replications; [b]Means followed by same small letters within a column are not significantly different(P>0.05)
temp - temperature

Swelling, solubility and water binding index
The swelling properties of starch differed significantly ($P<0.05$) with extraction (Table 2). The highest swelling power was in pectinase (16.85) and lowest in water (13.6). However, solubility of extracted starch with pectinase was significantly ($P<0.05$) lower compared to that of water (13.08%) and sodium hydroxide (13.87%). This might be due to loss of amylose during incubation as a result of amylosis (Kwame, 2015). On the contrary, treatment with NaOH and water significantly enhanced solubility.

Table 2: Swelling, solubility and water binding index of starch extracted by water, sodium hydroxide and pectinase

Extraction[a,b]	Swelling (g/g)	Solubility (%)	Water binding %
Pectinase	16.685 ± 0.25a	10.030 ± 0.13a	121.105 ± 0.4a
NaOH	15.505 ± 0.22b	13.865 ±0.06b	113.245 ± 0.43b
Water	13.634 ± 0.11c	13.075 ± 0.13c	115.950 ± 0.34c
F value	< 0.001	< 0.001	< 0.001
Lsd	0.1411	0.197	0.167

[a]Values reported as mean ± S.D of three replications
[b]Means followed by same small letters within a column are not significantly different (P>0.05)

Starch clarity

The clarity of starch extracted with pectinase was significantly (P<0.05) more (23.76%) compared to water (15.3%) and Sodium hydroxide (15.65%) as shown in Figure 2.

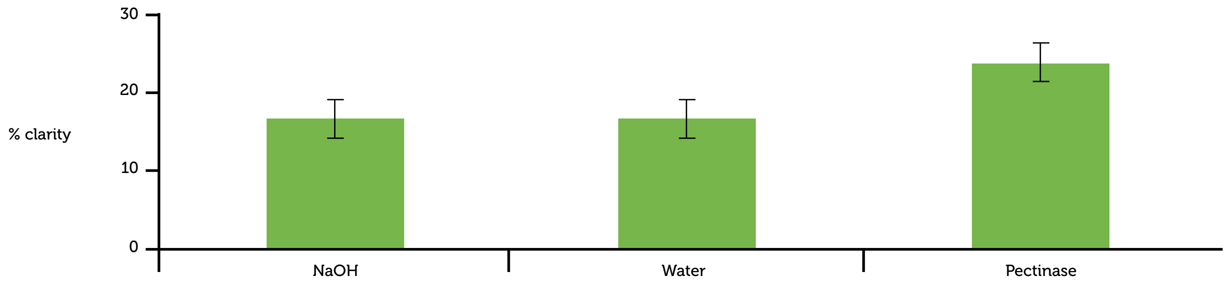

Figure 4: Clarity of starch extracted with water, pectinase and sodium hydroxide

Conclusions and Recommendation

Extraction of potato peel waste starch with pectinase resulted into the highest yield. The pasting properties of starch were not significantly affected by the extraction methods. Hence pectinase can be used for higher recovery of starch without adversely affecting its pasting properties.

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Sub Theme 2

Perishable Livestock and Fish Food Products (Including Milk, Meat, Eggs, Fish)

2001 Experiences and Challenges in Transfer of Milk Postharvest Technologies in Pastoral Communities of Kenya

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Abstract
Postharvest technologies enhance food security. This paper describes experiences and challenges in the transfer of milk postharvest technologies in pastoralist communities of Kenya. The paper is based on field experience and synthesis of literature on milk processing in pastoralist areas. Cultured fermented milk, ghee, cheese and milk sweets were developed using appropriate technology. Cream separator enabled ghee making from camel milk which was impossible using traditional methods. Other technologies included hygienic milk handling, evaporative cooling and solar milk pasteurisation. Technology transfer was through participatory demonstrations, study tours, exchange visits and product exhibitions in field days, shows and trade fairs, reaching over 10,000 clients in Marsabit, Garissa and Turkana counties. Direct beneficiaries transferred the technologies to the wider community by explaining the various technologies. Technology transfer was catalysed through adult literacy classes and competitive farmer grants. Up-scaling was done using stakeholders, extension pamphlets and videos. Adoption of hygienic milk handling and cultured fermented milk was over 50%. This pioneering work on milk processing in pastoral areas significantly contributed to food security and influenced policy, leading to development of Kenya standards for camel milk. Challenges in technology transfer included high illiteracy and poverty, seasonality in milk supply, unavailability of milk processing equipment and ingredients locally, and lack of electricity. For these marginalised groups, application of appropriate milk postharvest technologies will lead to higher degree of food self-sufficiency and less dependency on food aid. The challenges to technology transfer should be addressed for maximum contribution of the technologies to food security.

Key words:
Food security, milk, pastoralist

Introduction
Milk is one of the key foods available to pastoralists in the arid and semi-arid lands (ASALs) of Kenya. It contributes to food security and income through sales. However, milk is perishable and needs to be handled well to minimise spoilage and postharvest losses. Postharvest milk losses in pastoral areas of nortern Kenya are estimated at 30% (Kuria et al., 2009). It is also important to diversify the various products that can be made from milk. In pastoral areas, a milk surplus is usually experienced during the last months of the rainy season and directly after the rains. Most of the milk is consumed fresh or fermented. Pastoralists mainly preserve raw milk by smoking milk containers with smoke from specific trees and shrubs. This practice, however, extends shelf life for only a short period. The Kenya Agricultural Livestock, Research Organisation (KALRO), together with stakeholders and communities pioneered research on milk processing in pastoral communities in Kenya. Value addition research and development was implemented between 2000 and 2016. Several research and outreach approaches were initiated and tested. This pioneering work on milk processing in pastoral areas significantly contributed to food security and influenced policy, leading to development of Kenya standards for camel milk. This paper reviews the experiences and challenges in the technology transfer process. The paper is based on field experience and synthesis of literature on milk processing in pastoralist areas of Kenya, including journal articles, case studies and project reports. The review aims at highlighting the plight faced by pastoralists in terms of processing and preserving milk, with a view of stimulating an integrated approach by all stakeholders to address factors hindering milk preservation in the ASALs. The findings have important implications for designing appropriate milk processing technologies and transfer technologies for pastoralists in Kenya and other parts of Africa.

Materials and Methods
Research approaches used were those that would enhance technology adoption and uptake at community level. The diagnostic and constraint identification phase included participatory methods, rapid rural appraisals, and detailed exploratory and diagnostic surveys. Identification, development, testing, and dissemination of technologies aimed at solving identified production constraints were carried out on site using Farming Systems Research and Participatory Learning and Action Research approaches. Some of the tools used included community-based planning workshops, feedback workshops, and participatory monitoring. Producers were included in the research planning process and invited to participate in institutional workshops and research advisory committee meetings, both at the local (Marsabit) and national (Nairobi) levels. Capacity building involved providing adult literacy classes for participating groups, technical training and demonstrations, and exposure of producers to novel concepts and practices through study tours and exchange visits. Partnerships were formed and sustained during the milk technology development. The partnership was between KARI (now Kenya Agricultural and Livestock Research Organisation, KALRO), other researchers, community based organisations, non-governmental organisations, service providers, among others.

Results and Discussion

Milk Postharvest Technologies in Pastoralist Areas and Technology Transfer Process: The primary aims of processing milk are the production of quality and safe food for consumption, and the creation of additional income for livestock owners and milk traders (Tamimie, 2009). Value addition research and development was mainly implemented between 2000 and 2016. The technologies, innovations and information packages developed are summarised in this paper. Whereas the technologies were tested at group level, they have been adapted at household level in various ways. Several milk shops have been established in towns and settlements in the ASALs selling dairy products.
Cultured fermented milk: Cultured fermented (mala and yoghurt) milk were made using starter cultures, and these resulted into products with uniform taste and consistency; unlike the traditionally spontaneously fermented product.
Ghee preparation using cream separator technology: The traditional method of extracting milk fat from cow milk does not work on camels because of the structure of camel milk. With the cream separator technology introduced, the production of ghee (clarified butter), which by the local methods for cattle milk is very labour intensive, has been made much easier and can be made without destroying the skim milk component. Ghee is considered a delicacy by the pastoralists and constitutes a significant part of the diet where it is consumed with all types of foods thin and thick porridge prepared from maize four (uji and ugali, respectively), maize, rice, etc. (KALRO/World Vision, 2015). The ghee is first heated before consumption.
Cheese production: Cheese is an ideal dairy product for conserving milk nutrients especially during seasonal surplus in the ASALs. However, the product was not popular among pastoralists (as is common with the rest of the Kenyan population). Hence its promotion was limited. Its promotion could be accompanied by intensive nutrition education and behaviour change communication to enhance its adoption.
Strategies for hygienic milk handling: These included washing of hands before milking, washing of animal teat before milking and milking in clean containers. Adoption of hygienic milk handling and cultured fermented milk was estimated at over 50% (Nyamori et al., 2005). Other innovations for promoting marketing of hygienic milk involved promoting the use of metal cans wrapped with wet hemp to aid in cooling the milk, and in designing suitable donkey careers to facilitate milk marketing. This became popularly known as the "Milk Can Revolution" (Adongo, 2011). This was necessitated by the poor hygiene along the milk chain, and the consumer willingness to pay for good quality milk (Wayua et al., 2009), which is an advantage to value addition initiatives targeting milk hygiene in pastoral areas.
Evaporative charcoal cooler: This was necessitated by the postharvest losses occasioned by the high ambient temperatures and lack of cooling facilities in the ASALs. The technology is a small cabinet, 0.75 m3 in capacity made of galvanised angle iron frame reinforced with wire mesh inside and out, leaving a 10 cm-wide cavity filled with charcoal. A water reservoir at the top keeps the charcoal wet through drip system. A wind driven fan on the roof enhances air movement through the wet charcoal walls by sucking out the air in the cooler, keeping the storage space temperature below ambient temperature.

Use of solar energy in processing of milk: Solar energy can be used to provide process heat for pasteurising milk. This was targeted to address the scarcity of energy sources for processing milk in the ASALs. The pasteuriser consists of a flat-plate water heating solar collector and a 1.5 mm stainless steel cylindrical milk vat. The milk vat has a capacity of 80 L and a 50 mm wide hot water jacket insulated with 38 mm thick fibreglass. Water in the solar collector is directly heated by the sun; the hot water produced is used for pasteurising milk. Introduction of solar energy for milk processing is supported from the position of both resource availability and demand for energy, and the need to protect the fragile environment in the ASALs.
Technology transfer process: Technology transfer was through participatory demonstrations with groups, study tours, exchange visits, and product exhibitions in field days, shows and trade fairs. During exhibitions, farmers participating in research activities demonstrated various technologies reaching, for example, over 10,000 clients in Marsabit, Garissa and Turkana counties (Wayua et al., 2014). Direct beneficiaries transferred the technologies to the wider community by explaining the various technologies.
Technology transfer and adoption process was catalysed through adult literacy classes and competitive farmer grants through the Agricultural Technology and Information Response Initiative (ATIRI). The initiative gave farmers a chance to identify their own problems and, based on this, demand specific technologies that were developed and promoted to address their constraints. This enhanced the technology adoption process. Experiences from ATIRI, however, showed that pastoralists were less likely to adopt labour intensive technologies; which had to be considered in the development of milk value addition technologies.
Up-scaling was done using stakeholders, extension pamphlets and video documentaries. This pioneering work on milk processing in pastoral areas significantly contributed to food security and influenced policy, leading to development of Kenya Standards for camel milk

Challenges in Transfer of Milk Postharvest Technologies in Pastoral Communities of Kenya

- Despite the positive achievements from the developed technologies and information packages, sustaining some of the gains made has been a major challenge. Some of the introduced technologies have collapsed, due to varied reasons including seasonality in milk supply in the ASALs. It was also generally observed that pastoralists were slow in adopting technologies, and this hampered milk technology development efforts. The pastoralists were less likely to adopt labour intensive technologies.
- Effective heating and cooling are essential to food processing and preservation processes and the related marketing of the products. The milk value chain in the ASALs offers challenges to the food technologist who desires to market high quality, safe products processed in remote ASAL areas with high temperatures and without the infrastructure for roads or electricity. Products spoil fast at high temperatures and where the level of contamination is also high. Any cooking process meant for preservation is currently done by use of scanty wood fuel which has negative consequences on the environment, and consequently leads to increased climate change as a result of reduction of carbon sink. Considering the low socio-economic status of the population in the ASALs and the poor infrastructure in these areas, appropriate postharvest technologies are needed to minimise milk losses along the value chain. Besides solar energy reported in this paper, there is need for assessment of the use of other renewable energy technologies (such as wind, which is abundant in the ASALs) in milk processing.
- The ultimate aim of value addition is to develop milk products with longer shelf life such as Ultra-Heat treated (UHT) and powdered milk which can be stored for long. Attempts so far have not been successful; UHT processing of camel milk is presently not possible as the caseins in the UHT milk decomposes after 3 weeks upon storage at room temperature (Konuspayeva and Bernard, 2016). On the other hand, processing of milk powder requires sophisticated infrastructure such as reliable electricity and modern dairy equipment which at the moment is out of reach for pastoralists in the ASALs.
- Development of milk technology should not be done in isolation but as an integral part of a whole system. The technology itself is like a 'hardware' which needs a 'software' for the system to work efficiently. The software here includes stable and functioning groups with efficient group dynamics, literacy levels to be considered

and necessary infrastructure (e.g. energy, transport, water and communication) to be available. This has been the shortcomings of many projects implemented by development agents in the region, which have ended up failing.

- Financing the high up-front costs of milk technology development is an impediment to a more widespread use of the developed technologies. The Government needs to promote policies aimed at making financial services and credit facilities more accessible to pastoralist communities, in order to provide the much-needed capital for investing in enterprises such as small-scale milk collection and processing. Financial institutions such as K-Rep and Equity Bank have already ventured into pastoralist areas to provide the much needed capital.
- Other challenges in technology transfer included high illiteracy and poverty, unavailability of milk processing equipment and ingredients locally and lack of electricity.

Conclusion and Recommendations

The review shows that considerable progress has been made in the development and transfer of milk postharvest technologies in pastoral communities in Kenya. Value added dairy products including cultured fermented milk, ghee, cheese and milk sweets were developed using appropriate technology. Cream separator enabled ghee making from camel milk which was impossible using traditional methods. Other technologies included hygienic milk handling, evaporative cooling and solar milk pasteurisation. Challenges in technology transfer included high illiteracy and poverty, unavailability of milk processing equipment and ingredients locally, lack of electricity and marketing. For these marginalised groups, application of these technologies will lead to higher degree of food self-sufficiency and less dependency on food aid. The challenges to technology transfer should be addressed for maximum contribution of the technologies to food security and income generation.

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2002 Reducing Fish Postharvest Losses by Use of Solar Tent Dryers

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Abstract
Open-sun drying for processing small fish species doesn't offer immediate solutions to fish losses which accounts for over 30% in Malawi especially during peak catch periods. High losses of small fish species in Malawi occur between January and April season which is associated with rains and high humidity. A solar tent dryer was therefore designed and tested for drying small fish species namely: Usipa (Engraulicypris sardella), Utaka (Copadichromis spp.) and Ndunduma (Diplotaxodon limnothrissa) in Lake Malawi for drying efficiency, profitability, and fish quality and develop the value chain for the small fish products. The dryer can achieve up to 10% moisture content which increases shelf-life of fish products to seven weeks compared to three weeks for open sun-dried products. Spoilage indicators, Total Volatile Basic Nitrogen (TVB-N g/100mg) and pH (-log [H+]) for fish dried in solar dryers were found to be lower than in open sun drying. The dryer is used all year round and improves on access to quality fish products. The novelty is on the development of a business model that includes the human-environment relationship where the youth (boys and girls) are actively engaged. Solar tent drying was economically and socially sound as it reduced labour demand from women who are the main processors for small fish species. The solar dryer can therefore reduce postharvest losses without increasing fishing effort and result in increased fish consumption and utilization through improved organoleptic preference.

Key words:
Fish, losses, postharvest, processing, solar tent-dryer

Introduction
High post-harvest losses reaching as high as 40% are threatening the contribution of fish to food and income security in sub-Saharan Africa (FAO 2012). These losses are high due to poor handling as a result of poor infrastructure such as roads and lack of ice plants which together result in an annual economic loss of $2-5 billion (Béné 2011). In Malawi 30% of fisheries production from Lake Chilwa valued at $16 million annually, is estimated to be lost through poor post-harvest handling (Chiwaula et al. 2011). These losses are manifested in physical damage, quality deterioration and finally market value. Loss in small-scale fisheries accounts for more than half of total fish production in the world and translates in even big losses in food and nutrition security to millions of people, especially in developing countries. Current open-sun drying processing methods do not offer immediate solutions especially during peak catch periods for small fish species. In Malawi, the peak fish production is between January and April which is also associated with rains and high humidity. When comparison is made between sun-drying and solar tent drying, solar drying provides high air temperatures and consequential lower relative humidity which is conducive to improved drying rates and lower final moisture content of the dried fish. As a result, the risk of spoilage during actual drying process and in subsequent storage is reduced. The higher temperatures attained inhibit insect and microbial growth. Drying in an enclosed structure has the additional benefit of providing protection against rain, dust, insects, animals and birds (FAO, 1985).

A solar tent dryer was therefore designed and tested for drying small fish species namely: Usipa (Engraulicypris sardella), Utaka (Copadichromis spp.) and Ndunduma (Diplotaxodon limnothrissa) in Lake Malawi for drying efficiency, profitability, and fish quality and develop the value chain for the small fish products. This study was conducted with the aim of developing environmentally friendly fish processing method that will reduce fish post-harvest losses by increasing shelf life and safeguarding markets for value added fish products.

Materials and Methods
The Solar tent dryer was made up of a UV treated polythene 200 µm sheet worn over a wooden frame. Three sizes of solar tent dryers were tested for drying effectiveness where an optimal size was determined to be of 12m x 5m x 5.5m (length x width x height at the centre). The height at the side was 2.5m. The solar tent dryer consisted of inlet air vent on the bottom with a dimension of 30 cm x 30cm and outlet vents up on both sides of the vertex with a dimension of 40cm x 40cm. This provided for natural circulation of air to speed up the convection current process. Both vents were sealed with galvanized fine meshed gauze wire to prevent entry of flies. The dimensions of the drying racks were 11m x 1 m (length x width). In order to provide air circulation, the gap between drying racks was 90cm.

Reductions in post-harvest losses were assessed by levels of a) contamination in terms of flies, dust, and microbiological organisms (Total Volatile Base Nitrogen levels).Total volatile base nitrogen (TVB-N) is an important compound providing a measure of the progress of spoilage that is dependent of sensory assessment; b) sensory and organoleptic quality; c) nutrient content; and d) shelf life of the solar dried fish. A procedure earlier used by Okoro et al (2010) was followed for microbiological analysis of the fish samples. Additionally, qualitative, quantitative, and economic costs and benefits of solar drying tents were assessed.

Results and Discussion

Results of spoilage indicators, TVB-Ng/100mg and pH (-log[H+]) for solar tent dried and open sun dried fish range were 15.45-17.31, 6.26-6.62 and 15.70-20.56, 6.32-6.31 respectively. The Total bacteria viable counts, TVB-N (g/100mg) and pH (-log[H+]) at the period of sensory rejection were 5.5x106cfu/g/cm2, 17.20 and 6.36 for open sun drying and 3.1x103cfu/g/cm2, 17.14 and 6.30 for solar tent dried, respectively (Table 1).

Table 1: Total Viable Counts of stored Diplotaxodon limnothrissa

Storage period (weeks)	Solar tent Fish		Open Sun Dried Fish	
	TVC	Fungi Colonies (CFU/g)	TVC	Fungi Colonies (CFU/g)
1	3.9×10^{2}	0	5.2×10^{6}	0
2	4.1×10^{2}	0	5.5×10^{6}	2.0×10^{1}
3	4.3×10^{2}	0	5.7×10^{6}	3.1×10^{1}
4	4.3×10^{2}	0	5.9×10^{6}	3.3×10^{1}
5	4.5×10^{2}	0	6.1×10^{6}	3.5×10^{1}
6	4.5×10^{2}	0	6.3×10^{6}	3.7×10^{1}
7	4.5×10^{2}	0	6.5×10^{6}	4.0×10^{1}
8	4.7×10^{2}	0	7.1×10^{6}	4.1×10^{1}

It was also found that drying fish in solar tent dryers does not compromise fish fat and protein content while moisture content is reduced to about 10% regardless of changes in weather conditions thereby increasing the shelf-life of the fish product.

The shelf life of solar dried fish has been found to be seven weeks compared to three weeks for open sun-dried fish, which means that solar dried fish can be stored for longer without compromising quality. This indicates that the solar dryer has the advantage of increasing fish supply by reducing postharvest losses without increasing fishing effort and results in increased fish consumption and utilization. Results on the loss assessment after using solar dryers also indicated that out-scaling the solar drying technology can reduce post-harvest losses up to 25% occurring at the beach and processing value chain nodes. By improving overall shelf life of the fish product, the solar tent also improve access to quality fish products and ensure uniform pricing across seasons.

Solar tent drying was also socially sound as it is reduced labour demand from women who are the main processors for small fish species. The dryer was found to be most effective in drying time and reduction in labour demands, especially for women who dominate small fish processing, for turning and guarding fish against flies, dust and theft by birds and other vermin. From focus group discussions conducted in five project sites comprising 54 men and 55 women, participants in general agreed that using solar tent dryers reduced labour demand by five hours per day.

Assessments on willingness to pay (WTP) studies showed that it is highly likely that fish processors will pay to own and use solar dryers (Table 2). The average amount male fish processors are willing to pay was estimated at MK17, 732 (~US$25) and female fish processors - MK13, 765 (~US$19). Investment analysis had shown that the probability of making a loss from investing in solar dryers was only 18%.

Table 2: Estimated probability and level of WTP

Variable	Mean			t-statistic
	Female	Male	All	
Probability of WTP	0.76	0.72	0.74	2.42**
Level of WTP (MK)	13, 765.25	17,731.86	15,447.42	4.72***

Note: ***denotes statistically significant at 1%; **denotes statistically significant at 5%; * denotes statistically significant at 10%. Source: Chiwaula et al 2017 (in press)

Conclusion and Recommendations

The solar tent dryer is an effective technology for reducing fish postharvest losses and adding value especially for small pelagics perceived to be of low value. The novelty of the current design of the solar tent dryer relates to its size which is even suitable for commercial purposes. The solar tent dryer is proving to be effective in both economic and social aspects thereby generating interest to many entrepreneurs including women and the youth. Women who for a long time, have been sidelined in accessing new technologies that free their labour demand and participation in lucrative markets need to be incorporated in value chain development in fisheries and national economy.

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2003 Evaluation of Commercial Feasibility of the Deep-Frying Processing Technology in the Reduction of Post-Slaughter Losses in Kenya

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Abstract
Post-slaughter losses in the meat value chain have been estimated to be 50% and are caused by poor livestock production systems, poor pre-slaughter handling, poor slaughter techniques/operations, and inadequate processing technologies among other challenges. The aim of the study was to assess the market competitiveness of traditional products that were upgraded to commercial products using innovative and simple meat processing technologies. Data was collected by a multi-method research approach using structured questionnaires in exploratory surveys, interviews, Focus Group Discussions among selected pastoralist communities in Turkana, Garissa, Kajiado and Isiolo Counties. The study identified four major pastoral meat products including Nyirinyiri which is prepared and consumed in North-Eastern Kenya mostly by the Somali and Borana communities in Garissa County, Enyas and Ng'amorumoru commonly produced in Turkana County in Northern Kenya by the Turkana community and Olpurda prepared in Kajiado County by the Maasai community. The potential for commercial improvement was showed to range from 60% - 72%. The findings also reveal that Nyirinyiri had the greatest potential for improvement with a score of 72%. Ng'amorumoru scored 66%, Olpurda scored 63% while Enyas scored 61% indicating commercial potential. All the products were acceptable in attributes such as availability and cost of raw materials and expected shelf-life (score of 3.4 - 4.0). It was concluded that the 4 products have high commercial potential and the low-cost associated with deep-fried products and the vast appeal based on shelf life, appearance, texture, and flavor were key for competitiveness of pastoral products.

Key words:
Commercial feasibility, market access, pastoral meat products, post-slaughter losses

Introduction
The livestock sector in Kenya contributes over 12% to Kenyan gross domestic product (GDP) although the sector is dominated by small-scale producers in the pastoral regions (MOLD, 2010a). In addition, the livestock sector is the fastest growing sector at 48% due increased meat consumption among Kenyan consumers. In the Arid and Semi-Arid regions (ASALs), the livestock sector accounts for 90% of employment and 95% of family incomes for pastoral communities (MOLD, 2010b). Post-slaughter losses (50%) in the pastoral regions are caused by poor livestock production systems, poor pre-slaughter handling, poor slaughter techniques/operations, and inadequate processing technologies among other challenges (Zhou et al., 2010). The competitiveness of pastoral meat products is attributed to lack of active engagement in the formal meat markets and the fast changing dynamics in processing and preservation of value added commercial meat products (Bredahl, 2004).

Reports indicate that among the commercially viable process technologies that can be up-scaled in the pastoral regions include the deep-frying technology, drip-drying process, cooling products over deep-frying oil and addition of spices and smoking (Gichure et al., 2014). There is need to increase the shelf life of meat by maintaining desired consumer qualities. This can only be achieved by having clean, efficient and well organized transport, storage display and handling systems. These systems provide an immediate environment which if handled very nicely and with a lot of care can prevent microbial growth as well as prevent meat deterioration due to other factors. This will not only increase the shelf life of meat but also the value leading to increased revenue from the meat business. Increasing shelf life will also have an impact on food security as a lot of meat is lost due to microbial spoilage.

Therefore, this project was designed with the objective of reducing post-slaughter losses through development of commercially feasible meat products using innovative processing technologies. This study also assessed the market competitiveness of traditional products made using these processes as identified in the study regions using quality cues and comparative advantage to evaluate the competitiveness.

Materials and Methods
Data was collected by a multi-method research approach using structured questionnaires in exploratory surveys, interviews, Focus Group Discussions among selected pastoralist communities in Turkana, Garissa, Kajiado and Isiolo Counties. Process analysis was done to document the procedure and process for the preparation of the 4 pastoral products using 5 kilograms fresh steak of high microbiological quality for sample. A 5-point Likert scale was used to rank competitiveness where 5 was good, 4 was slightly good, 3 was neither good nor bad, 2 was slightly bad while 1 was bad was used while Analysis of Variance (ANOVA) values generated using Genstat version 12 for windows. Nine (9) measures of competitiveness were assessed including appearance; flavor (aroma and taste); texture (mouth feel); convenience; availability of raw materials; cost of raw materials, expected market performance of the products; expected market price of the meat product; and expected shelf-life and storage.

Results and Discussion

The findings of the study showed that among the current pastoral indigenous products and processing techniques (including deep-frying; drip drying; the use of oils and cooling; sun-drying; solar drying; smoking; use of herbs and spices; and salting), the deep frying technology of beef produced a high quality, shelf stable and culturally acceptable commercial beef products (Table 1). Deep frying is a form of hurdle technology that comprises several other preservation techniques with processing step that included addition of sodium chloride (NaCl); drip-drying; shallow-frying; use of herbs and spices; and cooling in deep-frying media to create anaerobic condition.

Table 1: Pastoral meat products based on methods used to preserve them

Technology used	Somali, Boran	Turkana		Maasai
Deep-fried products	Nyirinyiri	Ng'amorumoru	Enyas	Olpurda
1 Use of common salt	-/+	+	+	-/+
2 Drip-drying in the sun	+	-/+	-/+	-/+
3 Drip-drying under shade	-/+	+	+	-/+
4 Removal of excess moisture by shallow-frying	+	+	+	+
5 Deep-frying in either vegetable oil, ghee or rendered tallow	+	+	+	+
6 Addition of spices and herbs	+	-	-	-/+
7 Smoking of the container before filling in the meat products	-	-	+	-
8 Cooling to solidify the oil over the meat	-/+	+	+	+
9 Store in local container	-/+	-/+	-/+	-/+

Key: - represents Never, -/+ represents At times or rarely, + represents Always

The study identified four major pastoral meat products including Nyirinyiri which is prepared and consumed in North-Eastern Kenya mostly by the Somali and Borana communities in Garissa County, Enyas and Ng'amorumoru commonly produced in Turkana County in Northern Kenya by the Turkana community and Olpurda prepared in Kajiado County by the Maasai community. The potential for commercial improvement was shown to range from 60% - 72%. Products samples were assessed using trained panelists who ranked the products based on expected quality and comparative advantage using a 5-point Likert scale. The findings reveal that Nyirinyiri had the greatest potential for improvement with a score of 72%. Ng'amorumoru scored 66%; Olpurda scored 63% while Enyas scored 61% indicating commercial potential. The only attributes which were unacceptable by the panelist include appearance for Enyas (2.8) and Olpurda (2.7); flavor for Ng'amorumoru (2.9); texture for Olpurda (2.9); convenience for Ng'amorumoru (2.7) and Olpurda (2.4); expected market performance of the products for Ng'amorumoru (2.7), Enyas (2.7) and Olpurda (2.7); and the expected market price of the meat products (2.6). All the products were acceptable in attributes such as availability and cost of raw materials and expected shelf-life with mean score of 3.4 to 4.0 (Table 2).

The low-cost associated with deep-fried products, and the vast appeal based on shelf life, appearance, texture, and flavor were key for competitiveness of pastoral products. Our research confirms findings that the low-cost associated with deep-fat frying process, and the vast appeal based on shelf life, color, texture, and flavor of deep-fried products was essential for competitiveness of pastoral products. Nyirinyiri and Ng'amorumoru were found to be the most competitive products based on both quality cues and measures of competitiveness (Figure 1).

Figure 1: Final finished deep fried product - beef

In addition to the volatiles, the relatively high score for flavor was attributed to use of cardamom spices in Nyirinyiri, deep-frying in rendered animal fat for Olpurda and use of smoke for Enyas and Ng'amorumoru. Use of spices and smoke has inhibitory effect to microbial spoilage and chemical oxidation of products. Processing and preservation of meat by pastoralists is indicative of their rich culture and it is essential to protect and preserve their ethnic identity. With rapid urbanization, people from the pastoral communities have migrated to towns, thereby creating demand of the indigenous products. Since the products are yet to be mainstreamed into the formal meat value chains, it creates an opportunity for standardizing and upgrading the most competitive products and processes. From the study, Nyirinyiri and Ng'amorumoru were found to be most competitive products while drip-drying, deep-frying, smoking and use of spices were the most competitive processes

The study recommends further studies to standardize the pastoral products with the aim of improving competitiveness (Figure 2). The cost analysis and commercial feasibility studies showed that a KES 150/100g deep-fried packaged beef product can easily sell in the formal markets in Nairobi and even at lower prices in the pastoral regions. On basis of technology used, deep-frying, drip-drying and cooling products over deep frying oil had the greatest potential. Further studies should be focused on upgrading these processes for incorporation into the formal meat value chan. Additional enhancement of pastoral product quality was done through addition spices and smoke.

Figure 2: Final finished deep fried product- chevon

Table 2: Score to establish competitiveness of Kenyan Pastoral Products

Quality cues		Somali, Boran	Turkana	Maasai	
		Nyirinyiri	Ng'amorumoru	Enyas	Olpurda
1	Appearance	5	4	3	4
2	Flavor (aroma and taste)	4	4	3	4
3	Texture (mouthfeel)	4	3	3	2
4	Convenience	4	3	3	3
5	Availability of raw materials	4	4	4	4
6	Cost of raw materials	4	4	4	4
7	Market performance of the products	4	3	3	3
8	Market price of the meat product	3	3	3	3
9	Shelf-life and storage	3	5	5	4
	Potential for improvement (Score out of 45)	35	33	31	31
	Potential for improvement (Percentage)	(77.8%)	(73.3%)	(68.9%)	(68.9%)

Conclusion and Recommendations

It was concluded that the deep-frying technology is commercially viable in the formal meat value chain and can be used to reduce post-slaughter losses as well as generate income for the pastoral communities in Kenya. It is also an indication of the rich culture and ethnic identity of meat preservation technologies among the pastoral communities in Kenya. The commercial feasibility of mainstreaming these processing technologies into the formal meat value chains can be leveraged to create employment opportunities in these marginalized communities by upgrading the most competitive products and processing technologies. In addition, it is evident that processing and value addition of meat is one of the best strategies to address post-slaughter losses along the meat value chains. Further, more research is needed on product development and processing technologies need to focus on upgrading these processes for up-scaling and incorporation into the formal meat value chain.

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2004 Reduction of Post-Slaughter Losses in the Meat Value Chain through Value Addition and Innovative Processing Technologies

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Abstract

Growing populations, urbanization and economic growth in developing countries are contributing to growing demand for livestock and livestock products. However, post-slaughter losses (50%) in the meat value chain remain a challenge for pastoral communities in Kenya. The study aimed to use simple low-cost and innovative meat processing technologies to produce meat products based on indigenous knowledge of the pastoral communities. A multi-method research approach was used to collect data using structured questionnaires in exploratory surveys, and Focus Group Discussions among pastoralist. Laboratory simulations for the new products and process development were done in the University of Nairobi laboratories. The effect of size of meat chunks, oil types, oven-drying time and deep-frying time on the physical, chemical and sensory attributes of deep-fried products was determined. The products were processed using a previously documented process flow analysis for Nyirinyiri, Enyas, Ng'amorumoru and Olpurda. The developed meat products had high proteins (52.10% to 66.48%), energy (329.69 Kcal/100g to 404.20 Kcal/100g); fats (10.78% to 15.40%) and moisture (14.05% to 19.35%) content were considerably low. No pathogenic microorganisms were present. Deep-frying and cooling products in the frying media were seen to increase the fat content (40-48%), carbohydrates (80-91%) and caloric value (54-61%) of the products. The sensory evaluation showed that Nyirinyiri was most preferred (5.34 ± 0.337) followed by Ng'amorumoru (5.23 ± 0.00) ($p<0.05$). The products had high shelf stability (6 months) and were low-cost (KES 200-250/kg). This showed that simple meat processing technologies like deep frying can be used in preservation of meat products hence loss reduction.

Keywords:

Meat value chain, post-slaughter losses, processing technology, value addition

Introduction

Post-slaughter losses in the meat value chain in most developing countries have been attributed to inappropriate post-slaughter handling, under-utilization of edible by-products and lack of appropriate processing technologies (Cederberg et al., 2011). Post-slaughter losses contribute up-to a third of total losses along meat value chains. Pre-slaughter losses include weight loss or even death during loading, transportation and marketing or quality deterioration during handling, slaughter and storage (Cassens, 2008; Parfitt et al., 2010; Cederberg et al., 2011). This is despite the fact that Kenya has an estimated livestock resource of 14.1 million indigenous cattle and 3.4 million exotic cattle. Red meat from food animals has been reported to be a major source of proteins, carbohydrates and bioactive compounds such as zinc, iron, conjugated linoleic acid and B vitamins. Despite its great nutritional benefits, about 20 per cent of meat is lost post-slaughter in the Sub-Saharan region (Parfitt et al., 2010). This has necessitated the pastoral communities to use a number of techniques and technologies for post-slaughter handling, processing and preservation to prolong its shelf-life to minimize losses (Cassens, 2008; Parfitt et al., 2010; Cederberg et al., 2011). This study presents scientific evidence on how value addition and innovative processing technology can be leveraged to address these challenges and opportunities for commercial exploitation to reduce post-slaughter losses along the meat value chain. The study also assessed the physico-chemical and sensory attributes of selected indigenous pastoral meat products with potential for commercial up-scaling in Kenya. The developed deep fried products included Nyirinyiri which is prepared and consumed in North-Eastern Kenya mostly by the Somali and Borana communities in Garissa County, Enyas and Ng'amorumoru commonly produced in Turkana County in Northern Kenya by the Turkana community and Olpurda prepared in Kajiado County by the Maasai community were based on four indigenous products which were found to be the most competitive products based on both quality cues and measures of competitiveness. The process technology was based on indigenous knowledge and techniques used by pastoral communities in Kenya.

Materials and Methods

A multi-method research approach was used to collect data using structured questionnaires in exploratory surveys, and Focus Group Discussions among pastoralist communities in Turkana, Garissa, Kajiado and Isiolo Counties. Laboratory simulations for the new products and process development were done in the pilot plant, Department of Food Science, Nutrition and Technology using 60 kg lean steak from hind leg of mature goat obtained from Dagoretti slaughterhouse. Central composite design was used to bring out different potential factors which contribute to quality of the deep-fried products. The effect of size of meat chunks, oven-drying time and deep-frying time on the physical, chemical and sensory attributes of deep-fried products was also determined. Standard analytical methods were used to assess the microbial profile (Listeria spps evaluated using ISO 11290-1:2004; E. coli evaluated using ISO 16649-3:2001; Staphylococcus evaluated using ISO 6888-1:1999; Salmonella evaluated using ISO 6579 and Total Plate Count evaluated using ISO 4833-2:2013. Sensory analysis methods were based on ISO 8587:2006 while chemical analysis (moisture content, carbohydrates, protein, fat, fiber and peroxide values) were analyzed according to the standard methods of AOAC standard methods (AOAC, 2008) and stability tests using accelerated shelf life analysis at 54 0C for 6 days. Physical properties like color were assessed using a colorimeter, texture profile analysis using a texture analyzer machine and fatty acids profile was done using gas chromatography. Sensory evaluation was used to analyze color, appearance, ease of scooping, preference based on size of meat chunks, preference based on oiliness, odor, taste and chewiness using 11 trained panelists. Statistical package data SPSS 18.0 (SPSS Inc., Chicago, IL) was used for statistical analysis and to bring out comparisons among means.

Table 1: Chemical composition and peroxide values of pre-dried and deep-fried beef chunks

Size of chunks (mm)	Drying time (minutes)	Moisture (%)	Lipids (%)	Proteins (%)	Fiber (%)	Total ash (%)	Soluble carbohydrates (%)	Energy (Kcal/100g)	Peroxide value (mEq/kg)
10	0	15.7±1.7	15.4±1.9	65.4±5.2	0.1±0.1	3.9±0.1	1.0±0.4	404.2±20.4	2.5±0.1
10	60	14.9±3.6	14.0±2.1	65.1±6.4	0.1±0.1	3.8±0.6	1.0±0.2	394.9±36.2	1.3±0.7
10	120	14.2±2.3	11.8±1.2	63.7±5.7	0.2±0.1	3.8±1.2	4.9±1.5	380.8±18.5	1.2±0.2
15	0	17.1±3.0	15.0±2.1	64.0±6.7	0.1±0.1	3.9±0.9	2.9±1.1	375.7±40.3	1.3±0.7
15	60	16.0±2.4	10.8±1.7	65.3±6.0	0.1±0.1	3.9±1.0	2.2±0.3	396.1±15.1	0.8±0.7
15	120	14.1±3.6	12.0±1.5	66.5±9.3	0.2±0.1	3.9±1.4	0.4±0.1	402.1±29.6	0.5±0.1
20	0	19.4±5.5	12.6±3.9	52.1±6.5	0.1±0.1	3.8±2.0	2.0±0.6	329.7±22.9	3.7±1.8
20	60	18.8±3.7	13.1±2.0	60.2±4.2	0.1±0.1	3.8±1.0	2.0±0.8	367.9±15.2	2.6±0.5
20	120	14.6±3.1	14.1±2.0	62.7±7.7	0.1±0.1	3.7±0.4	0.5±0.6	379.9±43.8	3.4±2.8

Results and Discussion

Results showed that there is a technological base for production of high quality, shelf stable and low-cost commercial meat products. Raw meat had approximately 78% moisture, 18% proteins, 2 % lipids, 2% carbohydrates and 2% ash content (Table 1). Nyirinyiri was pre-dried by sun-drying in the sun for about two hours while Enyas, Ng'amorumoru and Olpurda were pre-dried under shade for about two hours, followed by boiling and evaporating excess water. Boiling and evaporating excess were more effective in moisture reduction than sun-drying. The developed meat products have high proteins (52.10% to 66.48%), energy (329.69 Kcal/100g to 404.20 Kcal/100g); fats (10.78% to 15.40%) and moisture (14.05% to 19.35%) content were considerably low (Table 1). No pathogenic microorganisms were present. Deep-frying and cooling products in the frying media were seen to increase the fat content (40-48%), carbohydrates (80-91%) and caloric value (54-61%) of the products. The smaller the meat chunks, the higher the fat content mainly because of increased surface area to volume ratio of the meat chunks. The products were cooled in the deep-frying media to create anaerobic environment for storage (Figure 1).

Figure 1: Deep frying technology for beef processing

The sensory evaluation showed that Nyirinyiri was most preferred (5.34±0.337) followed by Ng'amorumoru (5.23±0.00) ($p<0.05$). It was reported that smoking, addition of spices and herbs, and incorporation of ghee and rendered fat in the formulations improved sensory attributes tested particularly appearance and color (Figure 2). Taste, overall acceptability, convenience and color were the most preferred attributes while texture, size, odor and oiliness were scored least mean values ($p<0.05$) (Table 2). The products had high shelf stability (6 months) and were low-cost (KES 200-250/kg). Pastoral products were cooled in the deep-frying oil so as to create anaerobic condition as the chunks are encapsulated in the solidified fat. Studies have found out that products tend to take up oil during post-frying cooling; this explains the high lipids content of deep-fried products cooled with deep-frying media.

In case animal fat was the deep-frying media, the solidified fat will form a network that is tough and products have to be reheated before consumption. It has also been reported that the oil used for deep-frying was found to influence the nutritional qualities of meat chunks; deep-frying in animal fat results in lower moisture contents and higher proteins, fats and carbohydrates contents. This translated into lower score on convenience as observed for Olpurda. Ghee and vegetable oils were semi-liquid during storage; hence the chunks could be easily scooped. Palm oil was used since it was cheaper than sunflower or corn oil (Scollan et al., 2006; Mohamed et al., 2008). All the products were within acceptable ranges with regards to chemical quality. However with storage, only the cured and smoked batches maintained their stability within the acceptable limits. With regards to microbial quality, the beef chunks were in line with the Kenya bureau of standards requirement (KEBS) legal limits (KS 2455:2013, KS59-2:2013) with regards to total variable counts, catalase positive Staphylococcus, Salmonella, E. coli and Listeria.

Figure 2: Final finished deep fried product

However, the products became unacceptable during storage at accelerated temperature with the smoked samples being most stable against microbial deterioration. Packaging in airtight plastic and glass jars was seen to increase stability of the products with regards to chemical and microbial spoilage. Vacuum packaging in polythene sheet was not effective in improving stability as it failed to maintain its integrity during storage. In case animal fat was the deep-frying media, the solidified fat will form a network that is tough and products have to be reheated before consumption. It has also been reported that the oil used for deep-frying was found to influence the nutritional qualities of meat chunks; deep-frying in animal fat results in lower moisture contents and higher proteins, fats and carbohydrates contents. This translated into lower score on convenience as observed for Olpurda. Ghee and vegetable oils were semi-liquid during storage; hence the chunks could be easily scooped. Palm oil was used since it was cheaper than sunflower or corn oil (Scollan et al., 2006; Mohamed et al., 2008). All the products were within acceptable ranges with regards to chemical quality. However with storage, only the cured and smoked batches maintained their stability within the acceptable limits. With regards to microbial quality, the beef chunks were in line with the Kenya bureau of standards requirement (KEBS) legal limits (KS 2455:2013, KS59-2:2013) with regards to total variable counts, catalase positive Staphylococcus, Salmonella, E. coli and Listeria. However, the products became unacceptable during storage at accelerated temperature with the smoked samples being most

stable against microbial deterioration. Packaging in airtight plastic and glass jars was seen to increase stability of the products with regards to chemical and microbial spoilage. Vacuum packaging in polythene sheet was not effective in improving stability as it failed to maintain its integrity during storage.

Table 2: Mean score of the sensory attributes of the products

Size of cut (mm)	Drying period (mins)	Color	Appearance	Ease of scooping	Oiliness	Size of cut	Odor	Taste	Chewiness	Overall acceptability	Mean score
10	0	4.5 a	4.5 a	5.9 a	5.8 a	5.3 ab	4.9 a	4.9 a	3.3 a	4.6 a	4.9
10	60	4.3 a	4.3 a	5.9 a	5.7 a	5.1 ab	4.8 a	4.9 a	3.8 ab	4.6 a	4.8
10	120	4.3 a	3.9 a	5.5 a	5.5 a	4.7 a	4.7 a	4.9 a	3.9 ab	4.7 a	4.7
15	0	4.9 a	4.7 ab	5.3 a	5.2 a	5.0 ab	5.0 a	5.2 a	4.4 b	4.9 a	5.0
15	60	4.9 a	4.5 a	5.4 a	5.3 a	5.6 ab	5.1 a	5.2 a	4.2 ab	4.9 a	5.0
15	120	4.8 a	4.5 a	5.7 a	5.3 a	5.8 ab	5.1 a	5.0 a	3.7 ab	4.8 a	5.0
20	0	6.1 b	5.8 b	5.5 a	5.7 a	6.3 b	5.0 a	4.9 a	3.5 a	4.6 a	5.3
20	60	5.1 ab	5.7 b	5.3 a	5.4 a	5.6 ab	5.4 a	4.7 a	4.3 b	4.7 a	5.1
20	120	5.1 ab	5.1 ab	5.3 a	5.1 a	5.4 ab	5.6 a	4.6 a	4.6 b	4.8 a	5.1
Mean		4.9	4.8	5.5	5.4	5.4	5.1	4.9	4.0	4.7	

Mean ± standard deviation (N= at least three determinations); Means followed by the same letter are not significantly different from each other ($p < 0.05$)

Conclusions and Recommendations

The study concluded that post-slaughter losses can be reduced by value addition and upgrading of indigenous process techniques with great potential for commercialization in Kenya. Further research is needed to up-scale this technologies for integration into the formal meat sector for income generation and creation of employment for the pastoral communities. Post-harvest losses can be reduced by increasing efficiency along the chains, value addition and by- products utilization. In addition, the research recommends use of locally available meat processing and packaging technology and use of non- meat functional ingredients utilization to minimize losses, increase shelf-life and improve utilization of slaughter by-products. In addition, there is need to increase extension services for improving hygiene and safety especially at the low market ends.

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Sub Theme 3

Non-Perishable Food Commodities (Grains, Including Cereals and Pulses, Processed Foods)

3001 Isolation and Identification of Compounds from Piper Guineense Seed Extract for the Management of Sitophilus zeamais on Stored Maize

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Abstract
The maize weevil, Sitophilus zeamais Motschulsky causes severe postharvest losses on maize grain thereby threatening food security throughout the developing world. Synthetic insecticides have effectively controlled insect pest but they have undesirable effects on the environment. This study proposes an alternative method for the control of the maize weevils. Isolation and identification of compounds from the seed extract of the African Black Pepper, Piper guineense Schum and Thonn were carried out at ICIPE, Nairobi. The study also evaluated the biological activities of the compounds obtained on the adult maize weevil in the Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria, under laboratory conditions of 27 ± 2°C at ambient temperature and 65 ± 5% relative humidity. Experiments were arranged in a Completely Randomised Design with four replications. Identified compounds were tested singly and in blend and parameters assessed including mortality, oviposition and repellent effects. Chromatographic separations yielded five pure compounds namely; dihydrowisanine, guineensine, piperine, piperlonguminine and trichostachine. Piperine and guineensine performed better ($P < 0.05$) than other compounds causing high mortality, ovicidal and repellent effect on S. zeamias. Germination of maize seeds treated with the compounds was not affected. The results of the study also showed that piperine and guineensine may have a synergistic effect when combined as an insecticide. In conclusion, Piper guineense offers a unique and useful source of biopesticide material for controlling Sitophilus zeamais.

Keywords:
Biological activities, isolation, Piper guineense , piperine, guineensine

Introduction
Maize is an important source of dietary carbohydrate for humans and livestock in Africa. The maize weevil, Sitophilus zeamais Motschulsky causes up to 30% yield loss to stored maize thereby threatening food security. Synthetic insecticides have effectively controlled insect pest but they have undesirable effects on the environment thus necessitating the search for eco-friendly and cheaper insect pest control alternatives which include the use of powdered plant parts and their extracts (Adedire, 2003; Akinkurolere, Adedire & Odeyemi 2006). The African black pepper, Piper guineense Schum and Thonn is among the plants investigated and it has shown enormous potential in the control of insect pest (Akinbuluma & Ewete, 2014).

The use of its seed oil and powder for the control of insects pests in stored food commodities did not result in health hazards in consumers because P. guineense is an edible spice and constitutes an integral part of the diets of many Africans (Lale & Yusuf, 2000). However, information on the use of bioactive compounds from Piper guineense is scanty and has not been well documented. This study was carried out with the objective of isolating and evaluating the bioactive compounds from Piper guineense seeds for the management of S. zeamais on stored maize.

Materials and Methods
Seed samples of Piper guineense were extracted in 95% ethanol and concentrated in vacuo. Efficacy of crude fruit extract of P. guineense at concentrations 10, 20, 30, and 40% (v/v) was evaluated on Sitophilus zeamais with respect to mortality, number of eggs laid and number of F1 progeny emergence and the determination of median lethal concentration (LC50) of the extract. Isolation and identification of compounds from the seed extract were carried out at icipe, Nairobi. Dried sample was loaded and isolated with Column chromatography using solvents of increasing polarity namely hexane, dichloromethane (DCM), ethyl acetate and methanol. Further chromatographic methods on the sample using the Reverse Phase - High Performance Liquid Chromatography (RP-HPLC) and Liquid Chromatography – Quadrupole - Time of Flight (LC-Q-TOF) coupled with mass spectrometry (MS) afforded separations based on the mass fragmentation of individual compounds.

The study also evaluated the biological activities of the five compounds, and their blends with piperine (in separate experiments), on the adult maize weevil in the Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria, under laboratory conditions of 27 ± 2° C ambient temperature and 65 ± 5% relative humidity. Each compound at 5.0% (w/v) was evaluated on 30 g TZPB SR– W maize variety in Kilner jars containing ten (1male: 1female) adult S. zeamais. Each experiment was arranged in a Completely Randomised Design with four replications. Parameters assessed were mortality, number of eggs laid and repellent effects of the compounds on S. zeamais as well as the effects of the compounds and blends on the germination of maize seeds. Data was analysed with analysis of variance (ANOVA) and t-test at 0.05.

Results and Discussion
Toxicity of crude extract of Piper guineense seeds was concentration dependent. Forty percent concentration (% v/v) caused the highest percentage mortality (100.00±0.00%), least number of eggs laid (1.10±0.10) and F1 progeny emergence (1.29±0.18). The extract had a low median lethal concentration (LC50) (28.84 %v/v) and was highly repellent to S. zeamais at all the concentrations tested. Column chromatography of P. guineense seed extract yielded 13 compounds when aggregated using a thin

layer chromatography. Chromatographic analysis using RP-HPLC revealed some differences in the elution profiles of the compounds. Further analysis using the LC-QToF-MS yielded five pure major compounds namely; dihydrowisanine, guineensine, piperine, piperlonguminine and trichostachine with different mass fragments and MS ions at 318, 384, 286, 274 and 272, respectively.

A representative compound, trichostachine gave [M + H] + at m/z 272, [M + Na] + at m/z 294 and [Dimer + Na] + at m/z 565, indicating a molecular mass of 271 (Figures 1). Each compound showed a characteristic single peak between 1 – 7 minutes. Biological assays revealed that piperine and guineensine had the highest percent mortalities (82.5±6.29, 97.5±2.50) (Table 1a) and the least number of eggs laid (0.75±0.50, 1.25±0.96), respectively (Table 1b) when compared to other compounds. All the compounds were repellent to S. zeamais. There was no significant difference in the germination of maize seeds treated with the compounds and the control. Piperine and guineensine blend also elicited the highest mortality (92.5±7.50%) at 96 hours after infestation and the least number of egg laid (0.00±0.00) by adult female Sitophilus zeamais.

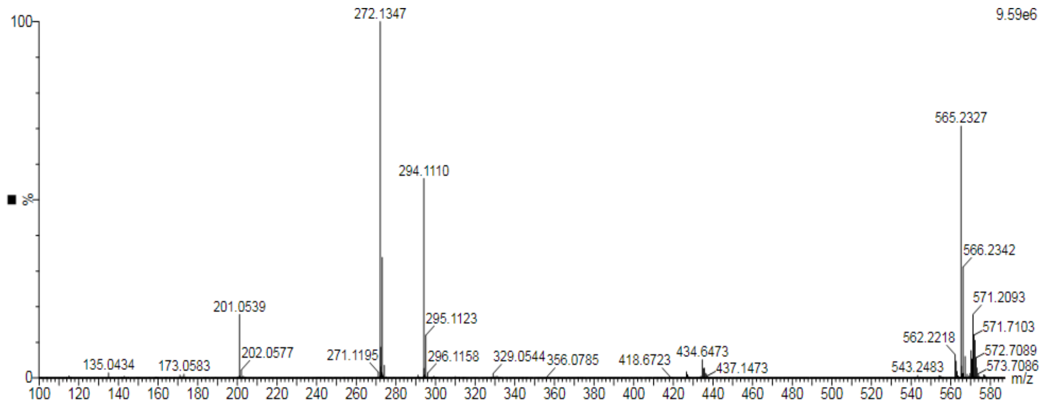

Figure 1: Representative mass fragment ion chromatogram showing trichostachine detected in P. guineense seed extract

Table 1a: Effects of compounds from Piper guineense seed extract on mortality of Sitophilus zeamais

Compounds 5.0 (% w/v)	Percentage mean mortality (±) S.D over 4 days post treatment			
	24 h	48 h	72 h	96 h
Dihydrowisanine	15.0ab ± 5.00	17.5ab ± 4.08	27.5b ± 4.79	40.0b ± 7.07
Guineensine	60.0de ± 14.72	80.0e ± 7.07	92.5d ± 4.79	97.5e ± 2.50
Piperine	42.5cd ± 11.09	60.0d ± 7.07	72.5c ± 2.50	82.5de ± 6.29
Piperlonguminine	32.5bc ± 4.79	35.0bc ± 2.89	40.0b ± 4.09	55.0bc ± 6.46
Trichostachine	17.5abc ± 4.79	20.0b ± 4.08	27.5b ± 6.29	67.5cd ± 4.79
Control (solvent)	0.0a ± 0.00	0.0a ± 0.00	0.0a ± 0.00	0.0a ± 0.00

Means followed by the same letters in the column are not significantly different at 5% level

Table 1b: Effects of compounds from Piper guineense fruit extract on oviposition and repellency to adult Sitophilus zeamais and germination of maize seeds

Piper guineense compounds (5.0% w/v)	No. of eggs laid (± SD)	% seed germination (± SD)
Dihydrowisanine	1.25ab ± 1.26	77.5 ± 4.79
Guineensine	1.25ab ± 0.96	82.5 ± 2.50
Piperine	0.75ab ±0.50	77.5 ± 7.50
Piperlonguminine	1.50ab ± 1.29	70.0 ± 4.08
Trichostachine	1.75ab ± 1.26	77.5 ± 2.50
Control (ethanol)	5.00c ± 0.82	Ns

Means followed by the same letters in the column are not significantly different at 5% level
ns – means not significantly different

Conclusion and Recommendations

Bioactive compounds from Piper guineense seeds at 5.0% (v/v) caused high mortality, reduced the number of egg laid and F1 progeny of Sitophilus zeamais on stored maize. Guineensine and piperine had the highest insecticidal activities than those of other compounds. Earlier reports by Batista-Pereira et al. (2006) established the insecticidal potency of piperine as comparable to that of some synthetic cinnamoyl amides. The results obtained also showed that piperine and guineensine blend may have a synergistic effect on S. zeamais when combined as an insecticide. Piper guineense thus offers a unique and useful source of biopesticide material for controlling Sitophilus zeamais in stored maize. Since the plant species is used as spices, medicinal and aromatic herbs, it can be cultivated for large-scale use to boost the economy of the developing countries as cheap biopesticides and phytomedicines. This calls for the development of suitable propagation and cultivation methods.

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3002 Effect of Sealing Methods on Metal Silos for Control of Prostephanus truncatus in Stored Maize Grain

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Abstract
Larger grain borer, Prostephanus truncatus (Horn) is the most destructive storage pest causing over 30% dry weight loss of stored maize grain. Although pesticides are available for its management, they have negative effects on human beings and environment. Metal silos are promoted globally as cheap, effective and environmental friendly for management of storage pests. An on-station experiment was conducted to determine the effect of sealing metal silos with different materials available locally for control of P. truncatus in stored maize. Metal silos with 100 kilogram holding capacity were loaded with 90 kilogram of grain, lighted candle placed on top of the grain and metal silo out-let and in-let lids sealed using rubber band, grease, rubber band combined with grease, and lid without sealing (control). Thirty five days after storage, metal silo sealed using rubber band combined with grease had significantly ($p<0.05$) least weight loss (0.6%) and grain damage (4.5%) compared to control with weight loss (1.9%) and grain damage (6.6%). Metal silo sealed using rubber band combined with grease had significantly ($p<0.05$) higher CO_2 (2.1% v/v) than control (0.5% v/v) which had the least. Insect mortality was significantly higher (100%) in metal silo sealed using rubber band, grease and rubber combined with grease compared to control (80%). Therefore, metal silos effectively controlled P. truncatus in stored maize grain for up to 35 days with 100% insect mortality when properly sealed using rubber band, grease and rubber band combined with grease.

Key words:
Carbon dioxide, maize, metal silo, oxygen, Prostephanus truncatus.

Introduction
Larger grain borer, Prostephanus truncatus (Horn) is the most destructive pest causing over 30% weight loss of farm-stored maize (Boxall, 2002). It was introduced in Kenya through Taveta border in 1983 and has since spread to Eastern, Coast, Nyanza and most recently Rift valley and Western regions, threatening food and income security of many small holder farmers in the country (Omondi et al., 2011). Several management options have been explored including chemical, biological and cultural methods but none is efficient and cost effective in managing P. truncatus (De Groote et al., 2013). Globally, metal silos have been promoted as alternatives for pesticide use in managing storage pests), as they are cheap, effective and environmental friendly with a shelf-life of over 10 years (CIMMYT, 2009). De Groote et al. (2013) reported that metal silos were effective in control of Sitophillus zeamais and P. truncatus in stored maize for up to six months without use of insecticides in Kenya. There is however, need to determine if sealing materials available locally to farmers when used can affect the effectiveness of the metal silos in controlling P. truncatus in stored maize. This paper, therefore reports on the evaluation of different methods of sealing metal silo lids for control of P. truncatus in stored maize grain.

Materials and Methods
Adult P. truncatus used in this study were obtained from KALRO/CIMMYT Kiboko postharvest insect pest laboratory where the experiment was conducted. They were reared on freshly harvested maize grain of susceptible hybrid H513 at 28 $\pm$2 oC and 65 $\pm$ 5% relative humidity. The grain was cleaned, dried and fumigated using Phostoxin tablet (55% Aluminium phosphide, 45.0% inert material) in sealed plastic drums for seven days. After fumigation, the grain was thoroughly mixed and aerated by sieving a day before use to avoid residual effect of phosphine gas in the grain. Four hundred grams of grain was put in 1.5 litre glass jars covered with perforated lids and two hundred unsexed P. truncatus adults introduced into each glass jar. After ovipositing for ten days, the glass jar contents were sieved using 4.7mm and 1.0 mm sieves to separate the dust, grain and the insects. The grain was kept in clean 1.5 litre glass jars and monitored daily for progeny emergence. Those that emerged on the same day were transferred to fresh grain in glass jars and kept in the incubation room at 28 $\pm$2 oC, 65 $\pm$ 5% relative humidity and in a 12:12, light: dark regime until sufficient number were obtained for the experiment (Tefera et al., 2011). Four treatments consisting of metal silos with 100 kilogram holding capacity, made of galvanized metal sheet of 24 inch gauge fabricated locally by trained tinsmith were used (CIMMYT, 2009). The metal silos were designed to have an elastic rubber cork (1cm in diameter) that was fitted five centimeters from the neck of the metal silo. Each metal silo was loaded with 90 kilogram of grain and one hundred ten day old adult P.truncatus artificially introduced into the grain. A lighted candle was placed on top of the grain to deplete oxygen as the metal silo in-let and out-let lids were covered and sealed using rubber band, grease, rubber band combined with grease and lid without sealing (control). All treatments were arranged in a completely randomized design with four metal silos per treatment and kept for 35 days in a room with corrugated iron sheets at 27$\pm$2oC and 58$\pm$5% relative humidity.

Oxygen and carbon dioxide levels were measured in the headspace of the metal silos every week using a portable Mocon PAC CHECK® Model 325 Headspace analyzer (Mocon, Minneapolis, MN, USA) fitted with a 1.15" 20 gauge needle for measuring through the elastic rubber cork fitted in the metal silo. After 35 days, grain samples were collected from each metal silo using a compartmentalized double tube sampling spear (Seedburo Equipment, Company Chicago, USA) as described by De Groote et al.(2013). The samples from each metal silo were thoroughly mixed, 1 kg of the sample was drawn randomly and used to assess grain damage and weight loss. The samples were sieved using 4.7 mm and 1.0 mm sieves to separate the grains, insects (live and dead) and dust. The total number of damaged (holed and windowed) and undamaged grains were counted and their weight recorded. Grain damage was expressed as a proportion of damaged grain over the total number of grains sampled whereas insect mortality was expressed as a proportion of dead insects over the total number of insects infested (Tefera et al., 2011). Weight loss was determined using the count and weighing method (Gwinner et al., 1996). Data was analyzed using GenStat and the means separated using Fisher's Protected LSD test at 5% probability level.

Results and Discussion

Thirty five days after storage, metal silo sealed using rubber band combined with grease had significantly ($p<0.05$) least weight loss (0.6%) and grain damage (4.5%) compared to the control with highest weight loss (1.9%) and grain damage (6.6%) (Figure 1 and 2). Metal silo sealed using rubber band combined with grease had significantly ($p<0.05$) higher carbon dioxide (2.1% v/v) compared to the control with least carbon dioxide (0.5% v/v). Insect mortality was significantly higher (100%) in metal silo sealed using rubber band, grease and rubber combined with grease compared to control which had the least (80%). Therefore, metal silos effectively controlled P. truncatus in stored maize grain for up to 35 days with 100% insect mortality when properly sealed using rubber band, grease and rubber band combined with grease. Use of lighted candle in metal silo, interfered with air composition, quickly killing P. truncatus, resulting in reduced grain damage and weight loss of the stored maize.

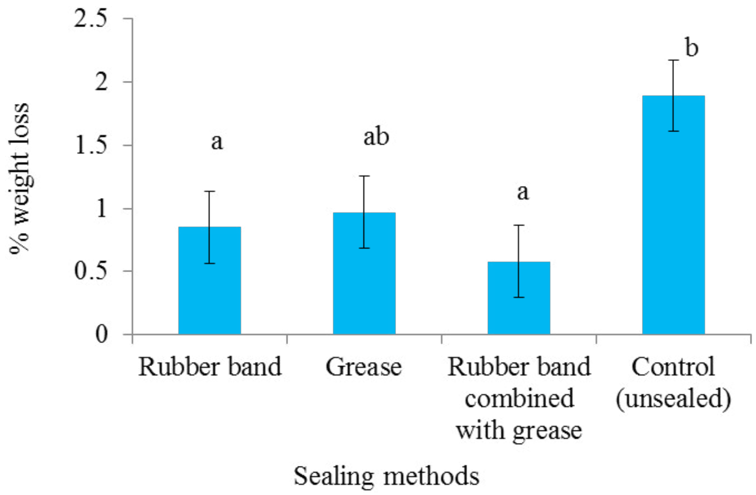

Figure 1. Weight loss (%) incurred in metal silos sealed with different sealing methods
*The bars with different letter (s) across the graph are significantly different at P<0.05

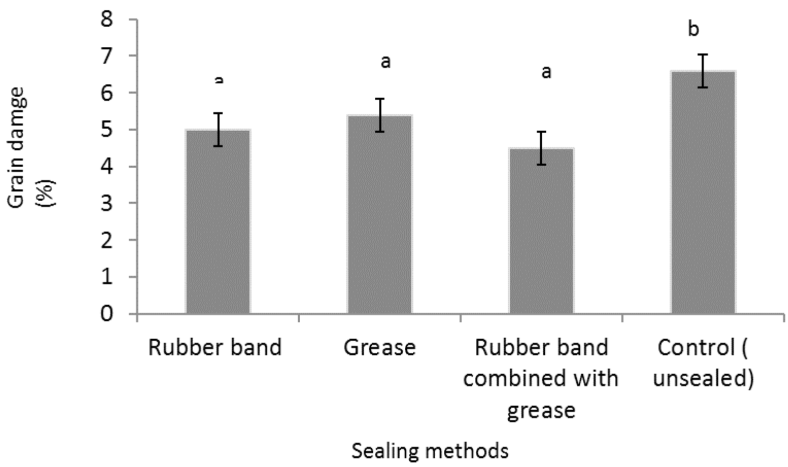

Figure 2. Grain damage (%) in metal silo sealed with different sealing methods.
*The bars with different letter (s) across the graph are significantly different at P<0.0

Conclusion and Recommendations

From this study, metal silos can preserve grain quality and effectively control P. truncatus without use of insecticides when the lids are properly sealed with rubber band or grease and the maize dried to moisture content below 13.5%. Use of lighted candle inside metal silos assists in raising carbon dioxide level while depleting oxygen right from the start of storage and eventually leads to increased insect mortality, reduced grain damage and weight loss. In addition, the metal silos without seals are able to store grain for at least 35 days without insecticides. We therefore recommend use of rubber band, grease or rubber band combined with grease for sealing the metal silos. These are available locally to seal the in-let and the out-let of the metal silos while storing grain. This should be accompanied by clean grain of 13.5% moisture content at the beginning of grain storage. The metal silos with the grain should not be opened for at least a month and a lighted candle must be used every time the silo is opened to help quickly elevate carbon dioxide and reduce oxygen levels.

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3003 Effectiveness of Integrated Pest Management for Preservation of Stored Maize in specific Nigerian grain Markets

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Abstract
In Nigeria, local farmers and grain merchants store harvested produce on-farm and in small storehouses (SHs) in markets where infestation by stored-product insects cause significant losses especially in quality and quantity thus resulting in lower economic returns. Infestation is usually controlled by the unilateral use of chemical insecticides, causing pesticide resistance in insects and harm to human health and environment. In this study, effectiveness of integrated pest management practice and D.I.C.E (IPMD) — which includes sanitation, drying, and regular inspection of grains for control of stored-product insect pests — was compared with traditional storage practice (TRN) where there was little sanitation and monitoring of insect pests. This study is on-going in three markets located in Ibadan, Oyo and Ilorin towns in Southwest Nigeria. There are two storehouses (SHs) in each market and TRN or IPMD was randomly assigned to each SH as a treatment. Percent insect damaged kernels, weight loss and aflatoxin accumulation levels were used as indicators for grain quality. Data presented are for 10-months period (February 2016 – November 2016). Mean numbers of Insect-damaged kernels in the TRN treatment increased progressively from 0.01 in February to 0.12 in November becoming significantly higher in October and November — 0.08 and 0.12 when compared to IPMD treatment — 0.06 and 0.07 respectively. Similarly, numbers of live insects from March to November in TRN significantly increased (0.52–4.45) with storage period than in IPMD (0.23–1.13). Aflatoxin levels were below 5ppb. Based on data from this study, IPMD was effective in preserving grain quality during storage.

Keywords:
Aflatoxin, insect damaged kernel, sanitation, traditional storage practice

Introduction
Maize (Zea mays L.) is a staple in Nigeria and is used as food, feed and industrial raw material. Maize production is seasonal and consequently needs to be stored in a manner that permits preservation for use as food and seed during the next planting season. In the past several decades, syn¬thetic pesticides have been the method of choice for the control of stored maize pests. However, this has led to pests developing resistance, negative effects on non-target organisms and environmental pollution (Rajendran and Sriranjini, 2008). Therefore, there is urgent need for reduced risk pest control measures that are practical — affordable, effective, easy to apply (user friendly), and legal.

Food security in sub-Saharan Africa is a major challenge and can be tackled by increasing food production, distribution and most importantly reducing postharvest losses because large quantities of food are lost due to spoilage and infestation along value chains, as food moves from points of production to consumers (FAO, 2011). Successful control of storage pests in commercial and domestic premises would immediately increase the amount of grain and food without any increase in field agricultural productivity (Burkholder, 1977). There is no single method for reducing food loss along the value chain, hence the need for combined strategies to facilitate increase in food availability. The use of a combination of tools for pest mitigation is referred to as integrated pest management (IPM) and can be an effective tool in minimizing postharvest losses. The objective of this study was to assess the effectiveness of IPM in protecting stored maize in specific grain markets in Nigeria.

Materials and methods

Disinfestation of maize
A yellow maize variety called "SWAN 2" was used for this experiment and was purchased from a single local farm at Ijaye Farm Settlement, Ibadan, Nigeria. aflasafe™ is produced by International Institute for Tropical Agriculture (IITA) in collaboration with other institutions. Aflasafe is a biocontrol method for the management of aflatoxin produced primarily by Aspergillus flavus (PACA, 2016). The product was tossed on field soil by hand 2–3 weeks prior to flowering of crop at 10–20 kg per hectare (IITA/CGIAR, 2015). Maize was fumigated using Phostoxin® tablets to ensure that it was pest free before the experiment was set up.

Study Sites
The experiment was conducted in six storehouses (SHs) located in three major grain markets in Southwest Nigeria. The markets

were, Arisekola market (AR) in Ibadan, Eleekara market (EL) in Oyo and Mandate market (MAN) in Ilorin. The experiment was conducted during the period February–November 2016.

Treatments

The experiment had two treatments. One treatment was management of a SH using IPM and D.I.C.E, hereafter referred to as IPMD. D.I.C.E. means post-harvest practices which include proper drying and inspection of grains before bagging, cleaning of storehouse/surroundings and examination of SH to ensure pest exclusion and moisture management. The second treatment was management using the typical traditional Nigerian practice (TRN) i.e. little sanitation and monitoring. Each market (location) had two SHs and a single treatment was randomly assigned to each. Maize stored in the SHs was clean, pest free, residual insecticide free and had a moisture content of 9.7%. Maize was in 100-kg capacity polypropylene (PP) bags. There were 25 bags (sub-replicates) on wooden pallets per SH, i.e. fifty bags of maize per location. Altogether, there were a total of 150 bags used for the study. The experimental design was randomized complete block design (RCBD).

Sampling and data collection

Bags in each stack of twenty-five were numbered 1–25 but only 15 bags were randomly selected for sampling using randomization software; these 15 bags were sampled during each sampling event. Sampling was monthly from February–November 2016.

Data collection

For each sample obtained, maize was sieved using a U.S. Standard #10 sieve (2.0-mm openings) (Seedburo Equipment Chicago, IL) to remove adult insects which were then identified and counted. A 250-g sample was then weighed out to obtain data on number of insect damaged kernels (IDK) and percent weight loss due to insect infestation. Percent IDK on numerical basis due to insect exit holes on grain kernels was determined using method of Quitco and Quindoza, 1986:

$$\%\, IDK\ (nb) = \frac{Nd}{250} * 100$$

Where, Nd = number of damaged grain

Percent weight loss due to insect damage calculated using count and weigh method (FAO, 1992) as:

$$\%\, Weight\ loss = \frac{(Wu * Nd) - (Wd * Nu)}{Wu(Nd + Nu)} * 100$$

Where, Wu = weight of undamaged grains,
Nu = number of undamaged grains,
Wd = weight of damaged grains,
Nd = number of damaged grains.

Determination of Aflatoxin levels

Initial and final aflatoxin levels were determined using the VICAM Afla Safe Quantitative Test kit following manufacturer's instructions (www.vicam.com). The VICAM Vertu reader was charged for 24 hours before being used. The test kit barcode was scanned for the type of sample and lot of strip. Each maize sample analyzed was ground into powder using a Daewoo blender provided with the Afla Safe test kit. Thereafter, 5 g of ground sample was weighed and placed in an extraction tube. Thirty (30 ml) of Aqua Premix was poured into the extraction tube and plugged with aluminium foil to prevent spillage during vortexing for 2 minutes at maximum speed. The extract was then filtered into a clean extraction tube. 100 µL of Afla-V Diluents was transferred to the test vial and mixed thoroughly with 100 µL of sample extract by vortexing. After vortexing, 100 µL of the mixture was transferred to the Afla-V test strip by dropping 1 drop/second vertically into the circular opening. Test strip was allowed to develop for 5 minutes on a flat surface before being inserted into the Vertu reader to read the result.

Statistical analyses

Treatment effects were analysed using analysis of variance (ANOVA) method (PROC MIXED) in SAS version 9.4 (SAS Institute, Cary, NC) and significance of means differences was determined by Tukey's HSD (honest significant difference) test at $P< 0.05$.

Results

IDK (in 250 g of maize)

IDK increased progressively from February–November; in TRN it increased from 0.01 to 0.12 and from 0.01 to 0.07 in IPMD. IDK numbers from TRN and IPMD were not significantly different from February to September but IDK was significantly higher in TRN between October and November compared to IPMD (Table 1).

Table 1. Effects of traditional Nigerian practice (TRN) and IPM and D.I.C.E. (IPMD) on mean number of insect damaged kernels.

Month	Treatments		P-value
	IPMD	TRN	
February	0.01 ± 0.00[a]	0.01 ± 0.00[a]	0.97
March	0.03 ± 0.00[a]	0.02 ± 0.00[a]	0.71
April	0.03 ± 0.00[a]	0.03 ± 0.00[a]	0.93
May	0.03 ± 0.00[a]	0.04 ± 0.00[a]	0.30
June	0.05± 0.01 [a]	0.05 ± 0.01[a]	0.63
July	0.04 ± 0.01[a]	0.05 ± 0.01[a]	0.53
August	0.05 ± 0.01[a]	0.05 ± 0.01[a]	0.90
September	0.09 ± 0.01[b]	0.07 ± 0.01[b]	0.08
October	0.06 ± 0.00[c]	0.08 ± 0.01[d]	0.02
November	0.07 ± 0.01[e]	0.12 ± 0.01[f]	<0.001

Means followed by the same letter along the column are not significantly different (P < 0.05).

Total number of live insects (per kg)

Mean number of live insects in TRN increased with increase in storage period from 0.05 in March to 4.45 in November. In IPMD the increase over the same period was 0.23 to 1.13 in November, respectively. The number of live insects in TRN in November was significantly higher than in IPMD. In TRN, number of live insects was found to be significantly higher in the months of June, July, September, October and November compared to earlier months of February–May; in IPMD, a sudden increase in numbers of live insects from 0.68 to 1.31 was observed in August (Table 2).

Table 2. Effects of traditional Nigerian practice (TRN) and IPM and D.I.C.E. (IPMD) on total numbers of live insects

Month	Treatments		P-value
	IPMD	TRN	
March	0.23 ± 0.08[a]	0.52 ± 0.04[a]	0.75
April	0.26 ± 0.08[a]	0.53 ± 0.11 [a]	0.78
May	0.89 ± 0.14 [a]	0.87 ± 0.14[a]	0.99
June	0.86 ± 0.13 [a]	0.91 ± 0.27[b]	0.007
July	0.68 ± 0.14 [c]	1.86 ± 0.28[d]	0.003
August	1.31 ± 0.17[e]	0.93 ± 0.14[e]	0.16
September	0.14 ± 0.06[f]	2.75 ± 0.26[g]	<0.001
October	0.21 ± 0.07[h]	3.63 ± 0.33 [i]	<0.001
November	1.13 ± 0.24 [j]	4.45 ± 0.39[k]	<0.001

Means followed by the same letter along the column are not significantly different (P < 0.05).

Grain weight loss (in 250 g)

There was a significant increase in percentage weight loss of grains in TRN from 0.23 to 0.50 during the October to November period; in IPMD, weight loss in the same period was from 0.09 to 0.17, respectively (Table 3).

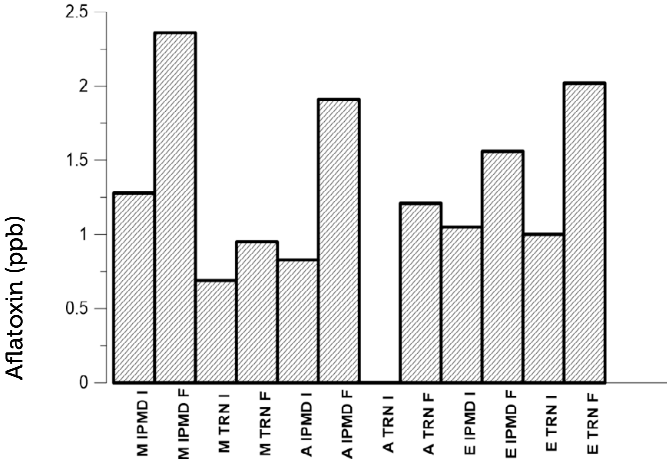
Table 3. Effects of traditional Nigerian practice (TRN) and IPM and D.I.C.E. (IPMD) on grain weight loss

Month	Treatments		P-value
	IPMD	TRN	
February	0.02 ± 0.01[a]	0.02 ± 0.01[a]	0.96
March	0.06 ± 0.01[a]	0.05 ± 0.02[a]	0.88
April	0.05 ± 0.01[a]	0.04 ± 0.01[a]	0.98
May	0.06 ± 0.01[a]	0.12 ± 0.03 [a]	0.24
June	0.09 ± 0.01[a]	0.10 ± 0.03 [a]	0.75
July	0.06 ± 0.01[a]	0.09 ± 0.03[a]	0.47
August	0.06 ± 0.01[a]	0.08 ± 0.02[a]	0.79
September	0.17 ± 0.03 [b]	0.18 ± 0.03[b]	0.86
October	0.09 ± 0.02[a]	0.23 ± 0.07[b]	0.01
November	0.17 ± 0.04 [b]	0.50 ± 0.10[c]	<0.001

Means followed by the same letter along the column are not significantly different (P < 0.05).

Aflatoxin levels

Initial and final levels of aflatoxin in sampled maize from TRN and IPMD treatments by February and November were between 0.00 and 2.27ppb respectively (Figure 1). These levels are lower than the regulatory limit of 20 ppb recommended by the United States food and drug administration for agricultural commodities.



IPMD I- Integrated Pest Management and Dice Storehouse, Initial aflatoxin level
IPMD F- Integrated Pest Management and Dice Storehouse, Final aflatoxin level
TRN I- Traditional management Storehouse, Initial aflatoxin level
TRN F- Traditional management Storehouse, Final aflatoxin level
M - Mandate market
A - Arisekola market
E - Eleekara market

Figure 1: Initial and final aflatoxin levels in maize stored using two storage techniques.

Discussion

The study demonstrated that IPMD storage practice is more effective in preserving grain quality than TRN practice; based on comparisons of insect damaged kernels, weight loss and number of live insects during storage. Our data on number of live insects in IPMD by November corroborate a report that stored grains with less than 2 live insects per kilogram is acceptable according to the Federal Grain Inspection Service Standards (Peairs, 2010) and consequently, there were fewer numbers of kernels with insect exit holes in IPMD. Aflatoxin levels in samples from either TRN or IPMD are within allowable limits of up to 20ppb for maize (FAO, 2003).

Conclusion and Recommendations

IPMD storage practice will help farmers reduce their dependence on synthetic pesticides, financial losses caused by insect pests and allow them have healthy and viable seeds for planting. Based on our data, if storage of 5 months or longer is planned, then regular sampling (monitoring/examination) of grain must be conducted to prevent significant losses due to insect pests. However, we recommend that sampling be conducted regularly regardless of how long storage is planned as insurance against sudden increases in insect pest populations. Additionally, we recommend application of aflasafe™ during crop production because it resulted in aflatoxin levels lower than the 15–20 ppb allowable threshold in stored maize for either food or feed; aflatoxin levels remained below this limit even during months (November) when insect populations were high in TRN.

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3004 Insect Population Dynamics in Maize Stored Using Four Storage Treatment Methods

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Abstract

Stored product insects cause significant losses in maize in sub-Saharan Africa (SSA). Several reduced-risk technologies are available for use as alternatives to conventional insecticides in SSA. In the present study, conducted February–December 2016, efficacy of Piper guineense, Bularafa diatomaceous earth (DE), PICS bags, ZeroFly bags and permethrin (Rambo™) to preserve maize quality in Nigerian markets was assessed. A sixth treatment was a negative control comprising maize in untreated polypropylene bags. Study locations were in four markets in Ibadan, Oyo and Ilorin towns. Each market had a storehouse (SH) which contained experimental 100-kg bags. In each SH, each treatment had six bags which were all sampled monthly to assess the efficacy of five technologies in preserving stored maize; in the PICS treatment, six bags were destructively sampled every four months. PICS bags were the most effective and had infestation levels of ≤ 0.54 live insects per kg of maize. Infestation levels in the control were ≤ 53.15. Psocids were prevalent during the rainy season with highest levels of 14.71 in the ZeroFly® treatment in October. The fact that the highest infestation levels (53.15) were found in the control indicates the importance of insect pest management in SHs. Based on data obtained, order of effectiveness of the treatments was PICS > Zerofly > Permethrin > DE > Botanical > Negative control. Clearly, PICS bags, ZeroFly bags, DE and P. guineense, which are reduced-risk measures for insect control can be incorporated in integrated management of stored product insect pests in SHs.

Keywords:

Bularafa diatomaceous earth, PICS bag, Piper guineense, reduced risk technology, Zerofly bag

Introduction

Maize (Zea mays L.), one of the most important cereal crops in Nigeria, is persistently damaged by several insect pests (Ranum et al., (2014)); this causes post-harvest losses which remain a major challenge to small-scale farmers. In many African countries, postharvest losses of cereal crops due to insect pest infestation are estimated at 25% of the total crop harvested. In some Nigerian communities, 20–30% of total grain production is lost. In extreme circumstances losses of up to 80% have been reported (Fox, 2013). To reduce insect pest-related losses, synthetic insecticides are commonly used by farmers and grain merchants but this has negative effects on human health and the environment. The unintended consequences of synthetic insecticide use have prompted our search for low-cost, reduced-risk and sustainable alternatives.

In this study, the efficacies of four storage treatments to deter insect population growth were evaluated. These technologies were: untreated maize in PICS bags; untreated maize in ZeroFly® bags; Bularafa-derived diatomaceous earth (DE)-treated maize in polypropylene (PP) bags; and Piper guineense-treated maize in PP bags. These treatments were compared with two others; maize treated with Rambo® (a common synthetic pyrethroid insecticide used in Nigerian grains markets with permethrin as the active ingredient) in PP bags and untreated maize in PP bags — these two treatments comprised the positive and negative controls, respectively.

Materials and Methods

A yellow maize variety known as "SWAN 2" was used for this experiment and was purchased from a single local farm at Ijaye Farm Settlement, Ibadan, Nigeria. Aflasafe was applied to fields during maize production (Alejandro Ortega-Beltran, 2017). Maize was fumigated using Phostoxin® tablets to ensure that it was pest free before the experiment was set up. The experiment was conducted during the period February–November, 2016 in four storehouses (SHs) located in three grain markets in Southwest Nigeria. The markets were, Arisekola market (AR) in Ibadan, Eleekara market (EL) in Oyo and Ago market (AGO) in Ilorin.

In the Bularafa-derived DE-treated maize, the DE was applied at a rate of 100 g per 100 kg of maize or 0.1% w/w or 1000 ppm (Nwaubani et al., 2014). In the P. guineense seed dust treatment, the application rate for the botanical was 1,500 g per 100 kg bag of maize or 1.5 % w/w or 15,000 ppm (Otitodun et al., 2015). Rambo was applied at a rate of 176 g per 100 kg of maize or 10 ppm (manufacturer's specification). Maize used for the experiment was clean, pest free, residual insecticide free and had a moisture content of approximately 9.7%. In each SH, six 100-kg bags were assigned to each treatment. In the case of the PICS treatment (hermetic storage), there were 18 bags in each SH to permit destructive sampling of 6 bags every 4 months. The experimental design was a randomized complete block design (RCBD) with a replication of four. Treatment effects were determined using analysis of variance (ANOVA) (PROC MIXED) performed with SAS version 9.4 (SAS Institute, Cary, NC) and differences in significance of means was determined by Tukey's HSD (honest significant difference) test at $P < 0.05$.

Results and Discussion

Two primary pests (Rhyzopertha dominica and Sitophilus zeamais) and three secondary pests (Oryzaephilus surinamensis, Liposcelis spp. (Psocids or booklice) and Cryptolestes ferrugineus) were found infesting maize during the study. Data for only insect species that had an abundance of >2 insects per kg are reported. Sitophilus zeamais population in the Control was significantly higher than in the other treatments in October and November when there were 6.96 and 11.29 weevils per kg, respectively. In the other five treatments, the number of S. zeamais was numerically highest in the Botanical (P. guineense) treatment where there were 1.50 insects/ kg in November but this density was not significantly different when compared with densities in other treatments (Table 1).

Table 1. Effects of four treatments on mean numbers of live Sitophilus zeamais per kg of maize

Months	Mean number of live Sitophilus zeamais$\pm$ SE				
	Botanical	Control	DE	Permethrin	ZeroFly
August	0.00 ± 0.00^{a}	0.04 ± 0.04^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
September	0.04 ± 0.04^{a}	0.96 ± 0.75^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
October	0.13 ± 0.13^{a}	6.96 ± 2.14^{b}	0.04 ± 0.04^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
November	1.50 ± 1.25^{a}	11.29 ± 3.20^{b}	0.08 ± 0.58^{a}	0.33 ± 0.29^{a}	0.08 ± 0.06^{a}

Psocid infestation was significantly high during the rainy months of July, September, October and November. In July, the numbers of live psocids per kg were significantly higher in the Control (10.33) and ZeroFly (14.71) treatments than in the other treatments. Psocid numbers were significantly higher in DE than in other treatments in September (10.79) October (13.71) and November (13.42).

Table 2. Effects of four treatments on mean numbers of live psocid per kg of maize.

Months	Mean number of live psocids $\pm$ SE				
	Botanical	Control	DE	Permethrin	ZeroFly
May	0.00 ± 0.00^{a}	1.38 ± 0.67^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
June	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 000^{a}	0.54 ± 0.31^{a}	0.00 ± 0.00^{a}
July	6.96 ± 2.98^{ab}	10.33 ± 2.62^{ab}	4.71 ± 1.74^{a}	1.88 ± 0.71^{a}	14.71 ± 12.43^{b}
August	3.13 ± 1.13^{a}	1.42 ± 0.67^{a}	6.04 ± 1.57^{a}	1.33 ± 0.51^{a}	5.08 ± 2.88^{a}
September	2.92 ± 1.05^{a}	1.50 ± 0.47^{a}	10.79 ± 2.43^{ab}	4.00 ± 0.45^{a}	3.58 ± 1.02^{a}
October	2.33 ± 0.87^{a}	3.42 ± 0.92^{a}	13.71 ± 2.27^{b}	6.25 ± 1.88^{a}	2.25 ± 0.71^{a}
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

All treatments had very low to moderately high numbers of live insects (0–1.71 per kg) until the onset of the rains in June when insect density in the Control increased to > 2.0. In July, significantly higher numbers were found in the Control (16.13) and ZeroFly (15.00) compared with other treatments. In September, there were significantly higher numbers in the Control (10.88) and DE (13.42) treatments compared to other treatments. In October, the Control (17.63), and DE (14.17) had significantly higher numbers than Botanical (10.75), Permethrin (6.50) and ZeroFly (2.63). Number of insects in the control (26.54) in November was significantly higher than in all the other treatments. There were significantly lower numbers of live insects in PICS (0.54) and ZeroFly (2.62) in October compared to other treatments. The highest number of insects was found in the Control (17.63) but this was not significantly higher than in DE (14.17) (Table 4).

Conclusion and Recommendations

The negative control had the highest insect infestation levels and this highlights the importance of using effective back up interventions to manage insect infestations in stored grain after fumigation. The botanical treatment (P. guineense) did not offer satisfactory control of stored-product insects; future research should investigate applying this botanical at a higher dosage. DE seemed to be effective only during the first 4 months of storage. Ways of formulating the crude DE used in such a way that it offers long term protection needs to be investigated. Permethrin and ZeroFly bags were quite effective against stored-product insect pests. However, because ZeroFly bags reduce infestation without direct application of insecticide to the maize, it is a much more preferred treatment. Use of grain protectant such as Rambo® can result in undesirable levels of insecticide residues in stored grain.

In most cases where moderate to high densities of live insects were found, psocids disproportionately contributed to numbers of insects involved, zerofly bags inclusive (Tables 2). Psocids (booklice) are however more troublesome due to their presence than actual damage they cause on grains. Maize infested by Psocids in this study remained aesthetically neat without damage. High number of Psocids in the Zerofly bags could be suggesting a growing tendency of resistance against the Deltamethrin in Zerofly bag. PICS bags were the most effective treatment against stored-product insect infestation. Our data show that ZeroFly and PICS bags can be used as effective tools in IPM system of stored-maize.

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3005 Effect of Temperature, Relative Humidity and Moisture on Aflatoxin Contamination of Stored Maize

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Abstract
Aspergillus flavus attacks maize kernels producing aflatoxin which is harmful to human and animal health. High temperature, relative humidity and grain moisture content promote A. flavus growth leading to aflatoxin contamination of maize during storage. In this study, aflatoxin contamination of maize kernels was investigated for selected temperature, relative humidity and moisture content levels. Maize kernels at moisture content levels of 14, 15, 16, 18, and 20% (wet basis) was inoculated with A. flavus spores and incubated in a climatic test chamber for ten days at 20°C and 30°C, and relative humidity of 60% and 90%. The results indicated that temperature and relative humidity significantly ($p \leq 0.05$) affected aflatoxin contamination whereas moisture content had no significant ($p > 0.05$) effect. Aflatoxin contamination was pronounced at 30°C, ranging between 0.3 µg.kg-1 – 11179.7 µg.kg-1, compared to 20°C that ranged between 0.8 µg.kg-1 – 733.7 µg.kg-1. Relative humidity of 90% had higher levels of aflatoxin contamination of between 3.9 µg.kg-1 – 11179.7 µg.kg-1, while 60% had levels of aflatoxin contamination of between 0.3 µg.kg-1 – 2.4 µg.kg-1. The results indicate that aflatoxin contamination at a relative humidity of 60% was lower than 5 µg.kg-1. Consequently, maintaining storage conditions at a relative humidity level of less than 60% results in minimal aflatoxin contamination of maize kernels, thus assuring its safety for human consumption.

Keywords:
A. flavus, aflatoxin, maize, storage.

Introduction
Maize is very susceptible to fungal degradation, particularly Aspergillus flavus (A. flavus) which produces aflatoxin. Aflatoxin contamination of maize results in significant grain losses in Sub-Saharan Africa (SSA) as well as negative impacts on human and animal health (Gnonlonfin et al., 2013, Wagacha et al., 2013). A. flavus, the primary cause of aflatoxin, attacks maize in the field and poor storage techniques compound its effects. Inadequate storage techniques and environmental conditions fuel fungal growth and aflatoxin contamination of maize. The primary factors that promote infection of stored maize by A. flavus are high temperature, grain moisture content and relative humidity of the surrounding air (Alborch et al., 2011). The traditional storage methods used by maize farmers in SSA do not offer environmental control of the storage environment. This lack of control exposes the stored maize to conditions that promote the growth of fungi and mycotoxin production (Giorni et al., 2012). Inadequate ventilation that characterises most of the storage structures used by the resource-poor small-scale farmers leads to moist hot spots that exacerbate A. flavus and aflatoxin contamination. A. flavus is a mesophilic fungus that thrives in a temperature range of 100C – 430C and relative humidity above 85% (Al-Shikli et al., 2010, Giorni et al., 2012, Pratiwi et al., 2015). Studies have established how moisture content and temperature (Giorni et al., 2012), as well as relative humidity and temperature (Al-Shikli et al., 2010, Pratiwi et al., 2015), affects A. flavus growth and aflatoxin production. The objective of this study was to investigate the combined effect of grain moisture content and the ambient storage conditions, viz., temperature and relative humidity, on the aflatoxin contamination of maize during storage.

Materials and Methods
White maize variety SC411 was obtained from the Seed Co Pty Ltd (South Africa) at a MC of 12.19% ± 0.10 (w.b). The maize kernels were surface sterilised by immersing in 5% (v/v) sodium hypochlorite and stirred for one minute then rinsed twice with distilled water. The maize was then soaked in distilled water to obtain five different MC, viz., 14, 15, 16, 18 and 20% (w.b) and stored in Ziploc bags at 4°C awaiting inoculation with A. flavus. The inoculum was made by plating A. flavus on potato dextrose agar (Merk, Darmstadt, Germany) at 25°C for five days after which the conidia was harvested and filtered through a cheese cloth to obtain pure spore suspension. Five hundred grams of the rehydrated maize grain at MC of 14, 15, 16, 18 and 20%, were weighed into autoclaved plastic containers. Two millilitres of the inoculum was sprinkled on each sample and mixed by hand. The samples were then randomly placed into the climatic test chamber (CTS GmbH, Hechingen, Germany) and incubated for ten days at set T and RH. Sampling was done immediately before incubation and at the end of incubation period. Analysis for the presence and level of aflatoxin B1 (AFB1), aflatoxin B2 (AFB2), aflatoxin G1 (AFG1), and aflatoxin G2 (AFG2) was done using a liquid chromatography-tandem mass spectroscopy (LC-MS/MS). The experiment was designed as a 2 × 2 × 5 factorial experiment. The three factors were T (200C and 300C); RH (60 % and 90 %) and MC (14%, 15%, 16%, 18%, and 20%). All the treatments were replicated thrice resulting in 60 runs for a given response variable. Statistical analysis was done based on AFB1 results. The Analysis of variance (ANOVA) was done at 5% level of significance.

Results and Discussion
AFB1 was detected in all treatments. AFG1 levels were the highest in all treatments except at MC levels of 15%, 16% and 18% at 300C and 60% RH where it was not detected. AFB2 levels were the lowest across all treatments. There was low/undetectable

(nd) levels of AFB1, AFB2 and AFG2 at 60% RH across all T and MC levels (nd – 2.81 µg.kg-1), compared to AFG1 that showed relatively higher levels of between 11.16 µg.kg-1 - 17.08 µg.kg-1 at 200C and 60% RH. Both AFB2 and AFG2 were not detected at 300C and 60% RH at all MC levels. Higher aflatoxin levels were observed at 90% RH although AFB2 was not detected at 14% and 15% MC while AFG1 was not detected at 14% MC. The mean AFB1 content from all the treatments is shown in Table 1.

Table 1: Mean AFB1 contamination from all treatments in µg.kg-1

T_°C	RH_%	MC_%				
		14	15	16	18	20
20	60	0.8^{d}	1.23^{d}	1.17^{d}	1.53^{d}	1.9^{d}
30	60	0.3^{d}	1.07^{d}	2.13^{d}	2.1^{d}	2.43^{d}
20	90	3.93^{d}	37.3^{d}	80.1^{d}	400.53^{d}	733.7^{d}
30	90	4998.97^{c}	7540.0^{bc}	8338.23^{b}	11013.9^{a}	11179.67^{a}

Means within a row followed by the same letter(s) are not significantly different according to Duncan's multiple range test (P < 0.05).

Storage temperature significantly (P ≤ 0.05) affected aflatoxin production in maize. Aflatoxin levels were higher at 300C than at 200C at both 90% and 60% RH (Figure 1 and 2). The results are in agreement with findings reported by Al-Shikli et al. (2010). Aflatoxin production was also significantly affected by RH (P ≤ 0.05). Aflatoxin levels were higher at 90% RH (3.9 µg.kg-1 – 11179.7 µg.kg-1) than at 60% RH (0.3 µg.kg-1 – 2.4 µg.kg-1), which is consistent with the findings by Al-Shikli et al. (2010) and Pratiwi et al. (2015). A relative humidity of 90% provides sufficient water activity for the growth of A. flavus which then attacks the maize kernels. This results in the production of aflatoxins. At 60% RH, the water activity is below 0.65, which is the minimum water activity level necessary for microbial or fungal growth (Giorni et al., 2012). The growth of A. flavus is, therefore, impeded at 60% RH. The low levels of aflatoxin in maize kernels samples stored at 60% RH at both 20°C and 30°C suggest that these conditions can be used to store maize without severe aflatoxin contamination occurring.

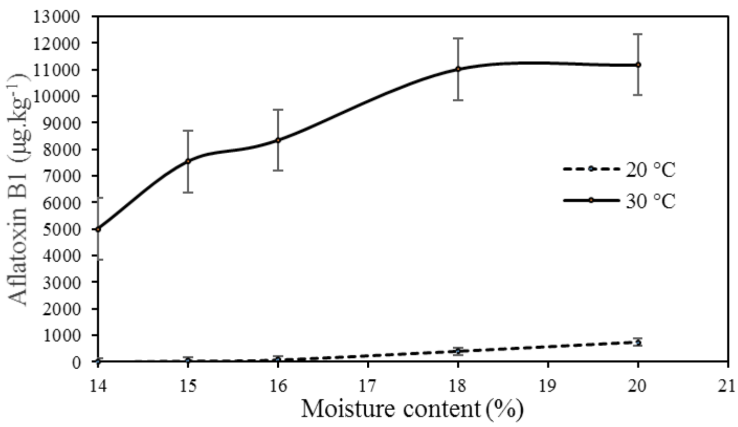

Figure 1: Aflatoxin levels at 90 % RH at both 20°C and 30°C

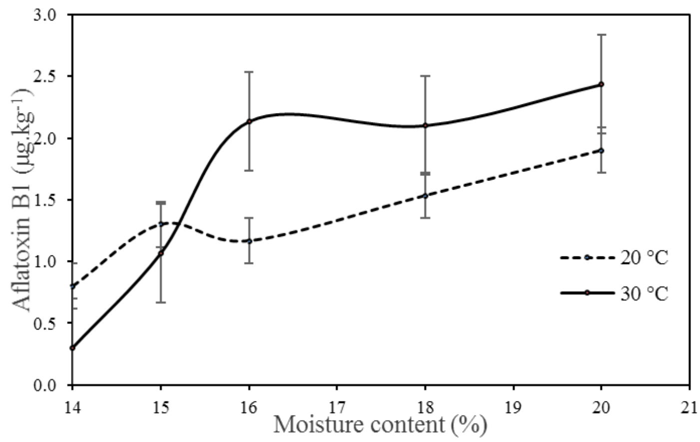

Figure 2: Aflatoxin levels at 60 % RH at both 20 °C and 30 °C

MC had no significant effect ($p \geq 0.05$) on the level of aflatoxin contamination in maize during storage. The interaction between temperature and relative humidity significantly ($p \leq 0.05$) influenced aflatoxin contamination of maize as well. However, two-way interaction of temperature and moisture content, relative humidity and moisture content, as well as the three-way interaction of temperature, relative humidity and moisture content had no significant ($p > 0.05$) effect on the level of aflatoxin contamination (Table 1).

Conclusion and Recommendations

Aflatoxin contamination was aggravated at a relative humidity of 90%, at typical ambient temperatures. The maize kernels stored at these conditions have extremely high levels of aflatoxin, thus not suitable for human or animal consumption. This study has shown that maize kernels stored at a relative humidity of 60% had AFB1 levels below 5 µg.kg-1, hence are safe for human consumption. Controlling aflatoxin contamination of maize during storage necessitates the development of simple storage facilities that can maintain the level of relative humidity below 60%. This study, therefore, recommends research into appropriate technologies that can be used to regulate the relative humidity in storage structures such as the inclusion of super absorbent polymers and desiccants in the design such structures.

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3006 Smallholder Oriented Approach to Post-Harvest Management for Groundnuts in Kenya: A Review

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Abstract
Smallholder farmers struggle to improve the post-harvest environment which includes poor infrastructure, challenging climate, rudimentary technologies and low capital. The review was carried out to argumentatively analyze critical steps during harvesting and storage of groundnuts that can maximally reduce post-harvest losses. The use of proper pre and post-harvest practices independently or in combinations have been shown to reduce moisture contents from above 21% to below 7% within seven days which guarantees reduction of post-harvest losses without significant loss in quality for more than 10 months.

Key words:
Food security, groundnut, post-harvest losses, smallholder farmers

Introduction
Groundnut (Arachis hypogaea) is an important oilseed and food crop rich in protein with high-energy value where developing countries account for nearly 95% of world production. Post-harvest food loss is one of the largest contributing factors to food insecurity, under-nutrition, and hunger across the developing world, directly impacting the lives of millions of poor. The greatest percentage of crop losses recorded are pre-farm gate, where poor harvest practices, including inadequate drying, processing, and storage of crops occurs. In Kenya, 20-30% of groundnut yield is lost during and after harvesting mainly because there is lack of adequate and appropriate information on the best and effective practices in post-harvest handling of the crop (Mwariri et al., 2005).

The current inefficiencies not only negatively impact household food security and income generation potential for smallholder farmers, but also represent a key limiting factor on available volumes of food for consumption and trade in food-deficit countries. Achieving zero hunger by 2030 will require a dramatic reduction in the amount food that is lost (FAO, 2009). By preventing post-harvest losses in food systems, the availability of food can be increased worldwide and more significantly in the Sub-Saharan Africa without requiring additional resources or placing additional burden on the environment. Being an oilseed, storage environment and handling procedures are of utmost importance and therefore specifically, the review outlines the most effective methods of drying groundnuts and highlights important conducts in the supply chain that ensures minimal post-harvest damages and losses to the crop.

Materials and Methods
The research makes use of literature reviews from primary journal articles, reports, academic theses and reference books globally. It summarizes findings from more than 19 reports found on this theme which were however found to be limited in circulation and some in content where post-harvest losses were only reported as percentages from survey studies.

Results and Discussion
Timely harvesting of groundnuts is the first key step for ensuring reduction in post-harvest losses where early harvesting leads to drop in oil content, aflatoxin contamination and shrinkage of seeds while late harvesting leads to difficulty in uprooting pods (Ntare et al., 2008). Groundnuts are mature when 70-80% of the inside of the pods shells have dark markings and the kernels are plump, with colour characteristic of that variety. It is important to shake the plant after lifting to remove excess soil from the pods because soil stuck to the pods lengthen drying period and induce development of unwanted fungal growth. The curing or drying stage and its interaction is the single most critical factor in establishing the best quality of groundnuts. Storing groundnuts with high moisture content (>8%) leads to mycotoxin formation and reduce seed quality for consumption, marketing and germination in cases of seeds (Okello et al., 2011). The process of curing or drying has not received much attention, especially in the developing countries, where the farmers lack education, quality consciousness or the proper facilities and knowledge (Kipkoech et al., 2007). There are different ways of drying the pods, some of which are better than others and it is particularly important to note that too much exposure of the pods to the sun can deteriorate seed quality and viability. Inverted windrows are used in the field where plants are laid in rows for 3-5 days to catch the wind and dry more quickly. Loose fluffy windrows permit good air circulation, which ensure uniform and fast curing of the pods. Large windrows have been shown to lose moisture more slowly as compared to the pods exposed to the sun in small, thin windrows (Costa, 2014). The plants can then be picked from the windrows and laid in thin layers using mats or other available dry surfaces for further 2-5 days. Mannouch et al. (2014) found that groundnuts dried from initial moisture content of 34.15% to final moisture content of 8.31% in three days by using thin layer dryers immediately after partial windrow drying. Building stacks or A-frames or cocks in different forms ranging from ordinary, ventilated, poled and ventilated poled stacks is another effective method of drying pods. The pods may either be scattered throughout the stacks or put on the stack centre or around the outside of the stack, depending on the area and the type of groundnut grown. The drying period in these stacks also varies, lasting from 10 to 15 days but in a few cases only two to three days. Platforms of various heights may also be built to raise the plants off the ground during curing and so reduce moisture damage in the bottom layer of pods and avoid damage. In Gambia stacks of groundnut plants are often put straight on to raised platforms immediately after harvesting. In Guinea after curing the plants in small stacks, local farmers sometimes put plants to dry in larger stacks on

raised platforms. The curing of pods on racks has been referred to in a number of countries, in Zambia to prevent termite damage to groundnuts during the curing period, a horizontal rack is used. The rack consists of crossed pieces of local wood 36 inches long, 18 inches apart and rose 18 inches off the ground. Plants hung on the rack are protected from termites and could be arranged so that the nuts are shaded from the direct rays of the sun. The moisture content of pods on the rack comes down from 21 percent to 6 percent during the first 7 days of curing. When the bundles are dried, the pods may be detached from the plants and spread in a thin layer under shade for further drying (Page et al., 2002). Well-dried pods rattle upon shaking and when pressed between thumb and index fingers it easily splits into two cotyledons or if the surface of the seed is rubbed hard a portion of the testa comes off. These drying methods have been shown to reduce postharvest losses by more than 25% compared to the traditional methods around the world. The use of these methods independently or in combinations have shown to reduce moisture contents from above 21% to below 7% within seven days which guarantees reduction of post-harvest losses without significant loss in quality for more than 10 months. Farmers should grade the crop before storage by removing residues, broken, damaged, poor and fungal infected groundnuts. Storage materials should be made of materials that allow air to circulate and stored in a well-ventilated, dry and cool place. Due to the high cost of insecticides and the increasing amount of pest resistance to insecticides, a strong focus should be on these good storage practices. Participating farmers in WFP's project in Uganda using traditional storage methods previously lost up to 60 percent within the first months after harvest. Through these outlined practices, post-harvest losses are reduced to less than 2 percent. In just one harvest, farmers are able to pay off their investments, and on average doubled their incomes as reported by Page et al. (2002).

Conclusion and Recommendation

Through dissemination of these effective and appropriate practices and technologies, there will be reduced post-harvest losses and thus the methods can lead to enhanced livelihoods and food security in the developing countries. The stated practices are therefore highly recommended to farmers in handling groundnuts immediately following harvesting to storage.

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3007 Postharvest Drying and Storage of Amaranth Seed Using Zeolite Beads and Effect on Seed Quality

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Abstract
Postharvest management of seed especially drying and storage is important. It determines quality of seed and ultimately crop production. Seed storage in tropical climates is a challenge because of high humidity. Amaranth is a popular vegetable in Kenya and most seeds are farmer saved. Seed drying and storage are some of the challenges farmers face. Zeolites (drying beads) is a newly developed technology that can dry and maintain low moisture content in seed when stored in hermetic containers. This study was conducted to determine the effect of zeolite beads on germination quality of amaranth seed when used for postharvest drying and storage. Zeolite beads and amaranth seeds were mixed and placed in three hermetic containers. A second set of amaranth seed placed in three small cloth bags but without zeolite beads was the control. The seeds were all placed in a storage location under room temperature. The design of the experiment was randomized complete design with three replicates. Seed samples were removed from the bags periodically at six months intervals and tested for germination for 24 months. After 18 months germination of seeds stored without drying beads were significantly lower than those stored with drying beads. Germination ability of amaranth seed stored with zeolite beads remained at above 54% during the storage period. Whereas the germination of seeds stored in bags reduced to 25% after two years. Results indicated that germination percentage of ALV seeds under zeolite storage were superior to those under the control.

Key words:
Amaranth, seed, germination, storage, zeolites

Introduction
During seed production proper post-harvest handling is critical to maximize yield and overall quality of the seed for future crop production (Chayan et al., 2010). Poor storage practices of seed can lead to tremendous losses resulting in subsequent poor plant growth and eventually low crop production Generally, the lower the temperature, relative humidity and moisture content, the lower the risk of seed losing its germination capacity and the longer the seeds can be safely stored (Catholic Relief Services, 2014).

Amaranth is one of the most important leafy vegetables and is rated among the ten most popular leafy vegetables in western Kenya. The major seed source is small scale farmers where it is found, sold in the markets or at farm gates in the informal system. Postharvest handling of amaranth seed is critical in order to maintain the quality. Experiences in African leafy vegetables, indicate that the viability of most farmers' seed is usually low because of the poor farm level storage conditions that predispose the seeds to rapid deterioration (Schippers, 2000).

Farmers use different storage structures with different levels of cost, capacity and effectiveness. Some of these are not sufficient thereby reducing germination percentage sometimes to as low as to only 25% (Catholic relief services, 2014). Basic knowledge on the key aspects of a good storage environment, including a proper storage facility, and the execution of pre-storage activities such as drying, will help farmers to meet appropriate conditions to maintain the quality and quantity of stored seed. When small-scale farmers implement good practices, they will be able to ensure safer seed storage and reduce losses. Storage challenges arising from high moisture content can be overcome by drying seeds to low moisture contents using inexpensive hermetic containers and drying beads®, a recently developed desiccant technology. Zeolites (drying beads®) are modified ceramic materials (aluminum silicates) that specifically absorb and hold water molecules very tightly, up to 20 to 25% of their initial weight. Seeds placed into a container with the beads will lose water because they remove water from the air to very low humidity environments. Water in the seed is transferred to the drying beads through the air without heating. Using drying beads®, seeds can be quickly and efficiently dried to safe storage moisture contents (UC Davis, 2013). Zeolites available in forms of powder, beans and pellets.This study was conducted to determine 1) the potential of drying beads® to dry and maintain low MC in amaranth seed for long term storage and 2) the effect of long storage on germination of amaranth seed

Materials and Methods

Drying amaranth seed
In 2014, Amaranth seeds were harvested at KALRO kakamega research centre, processed and sun dried for 3 days to remove surface moisture. Seed samples from this seed lot were randomly scooped and mixed to create a sample for investigation.

Reactivation of the beads
Zeolite beads sourced from CABI Africa were reactivated by baking using deep baking pans in an oven at 2500 C for 3 hours. This was to remove any moisture and ensure that the beads are dry. The beads were allowed to cool. The reactivated beans were placed in glass jars and sealed (UC Davis, 2013)

Measuring Bead moisture content
The reactivated Drying beads were weighed then placed over water and weighed after 24 hours to determine their initial capacity for water. The bead capacity was found to be 19%. The initial temperature and relative humidity of storage bags were 26.70 C and 69.3% respectively.

Estimating moisture content of seed

The initial moisture content of amaranth seeds was 13.3% and estimated using the Temperature/Relative humidity metre. The Temperature/Relative Humidity metre was placed with amaranth seed in a moisture proof container for a day and calculated using spread sheets for drying beads calculator (UC Davis, 2013).

Trial design

Amount of amaranth seed to be tested was 300 g. The bead quantity required for this amount of amaranth seed was 123 g for each container. The required amount of drying beads® and amaranth seeds were mixed and placed in hermetic containers. A second set of amaranth seed which was the control was placed in small jute bags but without zeolite beads. The seeds were all placed in a storage location under room temperature 240C. The design of the experiment was a randomized complete design with three replicates. Seed samples were removed from containers periodically at six months intervals and tested for germination for a total period of 24 months from 2013 to 2015. The final moisture content and relative humidity desired for amaranth seed was 6 % and 18 % respectively. The final relative humidity achieved was 16 % and moisture content 6%.

Germination tests

At the beginning of the experiment and subsequently during storage at intervals of six months, seed samples of about 400 was taken from each replicate. The 400 seeds were divided into four replicates of 100 seeds each and were arranged on moistened sterilized cotton wool placed in petri dishes. The germination test was conducted using the (ISTA, 1990) procedure. After four days, seeds were checked for germination and recordings done until the final count which was done on the 14th day. Germination % = (number of normal seedlings /total seeds used for germination)*100.

Data analysis

Data obtained were analysed using Analysis of Variance (ANOVA) technique. The treatment means were compared using the least square difference (LSD) at 5 % level of significance.

Results and Discussion

Results indicated that the germination percentage of ALV seeds under zeolite storage were superior to those under the control. The longer the seeds were in storage the better the drying beads® storage to the control. The initial seed germination at the start of the study was 56 % the germination of seed stored with drying beads after 24 months was 56 % and in the control it was 23 % (Fig 1). According to Das (2016), seed should be dried to 12 % moisture content to store for at least 2 years.

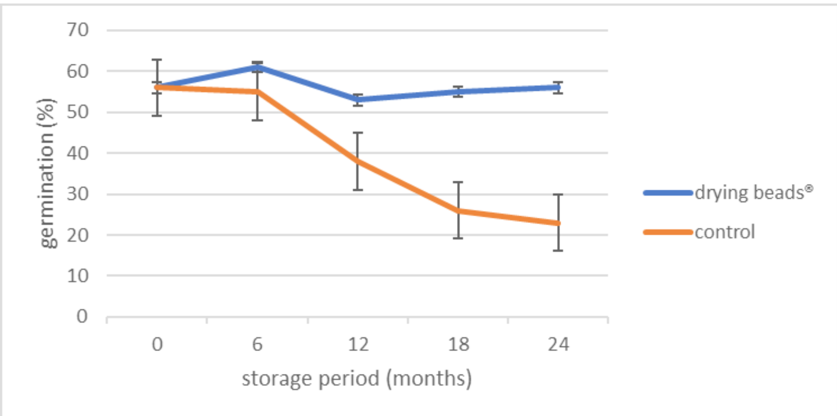

Figure 1: Germination of amaranth seed stored with drying beads® and without beads

On the first day of observation germination of amaranth seed was 56 %. During the second and third observation which is at 6 months and 12 months germination of seed stored traditionally continued to decline but was not significantly different from seed stored with drying beads (Table 1). At 18 months onward germination of seeds stored without drying beads were significantly lower than those stored with drying beads® (Table 1). Storage of amaranth seed using traditional methods should not be for more than one year. This finding is similar to Das (2016) who states that amaranth seed stored for more than one year showed decrease in germination percentage.

Table 1: Effect of storage methods on germination of vegetables Amaranth seed

	Germination %				
	0 months	6 months	12 months	18 months	24 months
Drying beads ®	56a	61.3a	53a	54.6a	56.9a
Control	56a	55.3a	38a	25.7b	22.6b
CV%	0	8.49	17.38	11.54	4.50

In this study, zeolite drying beads® desiccant dried the seeds sufficiently such that seeds could be stored for two years without losing viability. Germination ability of amaranth seed did not significantly change over time. Whereas for seeds stored in jute bags, the germination reduced by 50 % after two years.

Conclusions and Recommendations

The study conclusion was that seed storage with drying beads® retains germination over a long period of time and that Drying beads® are more effective in seed storage than the traditional methods used in this experiment. Storage of amaranth seeds should not be for more than one year if stored under ordinary conditions.

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3008 Influence of Moisture Content on Insect Pests and Mycotoxin Levels of Maize in Farms in the Northern Region of Ghana

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Abstract

Improvements in maize yield in Ghana are being eroded through postharvest losses. This study investigated postharvest losses of maize in Northern Ghana in order to identify mitigating measures and the study was conducted in six communities (Aduyili, Toroyili, Zamnayili, Diari, Pong Tamale and Savelugu) from October to December, 2015. Local storage systems used by small-holder farmers (granary (thatch), polypropylene storage bags and warehouse storage systems) were also assessed. Weight losses (%), insect damaged kernels (IDK), species and number of insects in samples, %IDK per 250 g of maize sampled and mycotoxin (aflatoxin and fumonisin) levels were determined. Results showed moisture contents of maize for pre-harvested and piled maize ears in all the communities were below 14%. There were no insect pests found in the pre-harvested maize but very few were found in the piled maize. However, maize weevil, Sitophilus zeamais Motschulsky, red flour beetle, Tribolium castaneum Herbst, and the rusty grain beetle, Cryptolestes ferrugineus Stephens were identified on maize in storage systems. Insect numbers were greater at the postharvest stage, with significantly more collected from the granary storage system than polypropylene storage bag which also had significantly more insect pests than the warehouse. Percent IDK in all six communities were generally low (<2%). Aflatoxin levels were lower at the pre-harvest stage but increased at the piling stage. Fumonisin levels were lower in all the stages. It is recommended that maize is dehusked and threshed right after harvesting to reduce the activities of microorganisms and hence aflatoxin levels.

Key Words:

Aflatoxin, food safety, , food security, fumonisin, postharvest loss

Introduction

Maize (Zea mays L.) is the third most grown cereal in the world after wheat and rice and principally used for human consumption and livestock feed (Lyon, 2000). Primarily, smallholder, low resource farmers produce maize under rain-fed conditions and it is well adapted to most of the ecological zones in Ghana including the northern savannah (MoFA, 2011). Ministry of Food and Agriculture (2011) estimated 84% of maize grown all over Ghana is in the middle–southern part (Brong Ahafo, Eastern and Ashanti regions) with the remaining 16% cultivated in the Northern Belt. According to Dzisi et al. (2007), the major constraints limiting maize production in Ghana are crop losses on-farm (5–10%) and postharvest losses (15–20%). Although maize production contributes significantly to the agricultural sector, postharvest maize insect pests are immensely responsible for food insecurity in sub-Saharan Africa (Osipitan et al., 2011). Insect infestation mostly starts from the field and is carried into storage. It is therefore prudent to intensify efforts to mitigate grain losses on-farm and during postharvest. Knowledge about factors that influence grain deterioration on-farm and in storage can instigate implementation of remedial measures to reduce postharvest losses. This study focused on establishing baseline data on moisture content, mycotoxin levels and insect infestation of maize in farms in Northern Ghana as basis for implementation of mitigating strategies.

Materials and Methods

The study was conducted in selected farms in and around Tamale which lies within longitude 0.8533 O W and latitude 9.4075 O N and located in Northern Ghana. Toroyili, Aduyili and Zamnayili communities in Central Gonja District, Pong-Tamale, Diari and Savelugu in Savelugu-Nanton District were selected for the study. Five farmers were selected from each community and pre-harvested maize and ears in piles of these farmers' fields were sampled for insect infestation, mycotoxin contamination and moisture content (MC). The effects of three storage systems — granary, polypropylene storage bags (PP bags) and warehouse — on stored maize were also assessed.

Ten ears of maize were collected from three sites from each field during harvest, manually shelled and mixed thoroughly. Moisture content and temperature of maize samples were taken using John Deere moisture meter (Manufactured by agraTronix™; Moisture Check Plus™, USA for Deere & Company; Batch SW08120). Maize samples were transported to the laboratory in a 17-liter Koolatron ® 12-V Compact Portable Electric Cooler (P75, Koolatron® Canada, Brantford, Canada). Aflatoxin and fumonisin levels in maize samples were determined using AgraStrip Total Aflatoxin (order #: COKAS1600A) and Fumonisin (order #: COKAS3000A) quantitative test kits respectively, provided by Romer Labs®. Insect pest species and their numbers and percentage insect damaged kernels (%IDK) were also determined. The number of discoloured kernels per 100 was also assessed. Gwinner et al. (1996) method was used to assess weight loss due to insect damage.

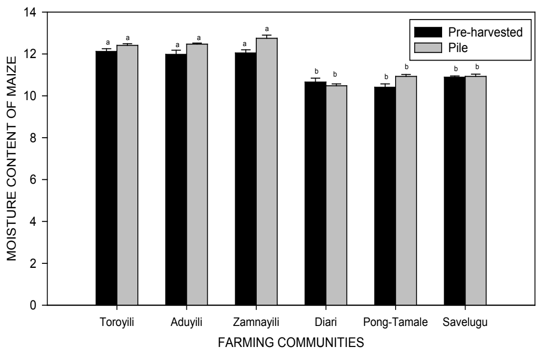
$$\text{Weight loss (\%)} = \frac{[(Wu\,x\,Nd)-(Wd\,x\,Nu)]}{Wu\,x\,(Nd+Nu)}\,x\,100$$

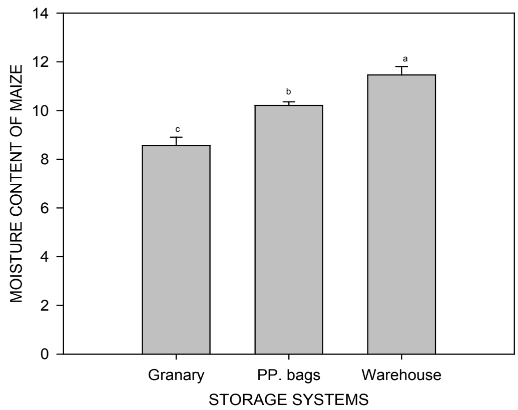
Where, W_u = Weight of undamaged grain, N_u = Number of undamaged grain, W_d = Weight of damaged grain, and N_d = Number of damaged grain.

Statistical analyses were performed with SAS Version 9.4 (SAS Institute, Cary, NC). Treatment effects were assessed using analysis of variance methods (PROC MIXED). Square root transformation was performed on insect damaged kernels (IDK) and numbers of live and dead insects whereas arcsine transformation of percent MC, IDK and weight loss was conducted before data analyses but untransformed data are reported.

Results

Results showed that moisture content had significant (P<0.05) differences among the farms with a range of 10.41–12.12% for pre-harvested to 10.93–12.75% for piled maize. Effects of the three storage systems on MC of maize were significantly (P < 0.05) different with mean MC of 8.57%, 10.21% and 11.46% for granary, PP bags and warehouse storage systems, respectively.





There were no insect pests in sampled maize at the pre-harvested stage; however, a mean of 1.67/250 g was recorded in the piled maize. These were mainly larvae of insect pests. Sitophilus zeamais, T. castaneum and C. ferrugineus were identified on maize in storage systems and their numbers were significantly higher in the granary storage system with a mean total number of 15.4/250 g, followed by PP bags with 9.0 and 3.5 for the warehouse storage system. Mean aflatoxin level of maize at the pre-harvest stage was about 13.13 ppb but rose significantly to 25.09 ppb at the piled stage. However, fumonisin levels were low — 1.10 and 1.16 ppm for pre-harvested and piled maize, respectively.

Table 1: Figure 5. Mean level of aflatoxin (ppb) and fumonisin (ppm) in maize at the pre-harvested and piled stages on-farm in Northern region of Ghana.

STAGES ON -FARM	Aflatoxin ± SEM	Fumonisin ± SEM
Pre-harvested stage	13.13 ± 0.59 a	1.16 ± 0.2 a
Piled stage	25.09 ± 1.19 b	1.10 ± 0.3 a

Table 2: Mean level of aflatoxin (ppb) in the granary, polypropylene storage bags and warehouse storage systems in Tamale, Northern region of Ghana.

STORAGE SYSTEMS	Aflatoxin ± SEM	Fumonisin ± SEM
Granary	11.28 ± 0.89 a	1.37 ± 0.36 ab
PP bags	13.25 ± 0.62 a	0.94 ± 0.26 bc
Warehouse	14.45 ± 1.06 a	2.21 ± 0.71 a

Discussion

Moisture content of maize in the Northern region of Ghana was below 12% on-farm. Aflatoxin levels were lower at pre-harvested stage (13.13 ppb) but increased at the piled stage (25.09 ppb) rendering maize unfit for human consumption. Data from the present study have shown that heaping maize on-farm increases aflatoxin levels in the maize. Therefore, heaping should be avoided and discouraged. The results also show that maize stored in warehouses harbour lower numbers of insects than when stored in the crib or PP bags hence warehouse storage practice must be encouraged.

Conclusion and Recommendation

Data from the present study has shown that heaping maize on the ground for some days before threshing and shelling increases aflatoxin levels in the maize, hence the practice should be discouraged and discontinued to help reduce aflatoxin levels and ensure safe food for consumers.

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3009 Population Dynamics of Stored Maize Insect Pests in Warehouses in Two Agro-Ecological Zones in Ghana

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Abstract
Understanding what insect species are present and their temporal and spatial patterns of distribution is important for developing a successful integrated pest management strategy for food storage in warehouses. Maize in many countries in Africa is stored in bags in warehouses, but little monitoring information is available on insect activity in these warehouses. The populations of major postharvest insect pests of maize were monitored at three different warehouses (MiDA, Gundaa and Wienco) in two regions in Ghana (Middle Belt and Northern Belt). The study was conducted from October 2015–July 2016, which represents a common maize harvest and storage period between the two regions. The most abundant insect pest found in the warehouses was Plodia interpunctella (Hübner), but other major pest species were recovered during the study. Sitotroga cerealella (Oliver) and Prostephanus truncatus (Horn) which are major pests on farms, were more likely to be captured in traps outside or at nearby farms than inside the warehouses. When recovered inside, they tended to be found in the receiving and cleaning areas. Sitophilus zeamais (Motschulsky) was commonly captured in the warehouses, but was more abundant in the Middle Belt warehouse. Our results identified the major species found during warehouse storage of maize and suggest that the importance of specific pest species may be different in warehouses compared to on-farm storage.

Key words:
Grain storage, monitoring, integrated pest management, pheromone trap, postharvest loss

Introduction
Maize (Zea mays L.) is the most extensively cultivated cereal in the world and a major staple in Africa (FAO, 2003). It is estimated that 10–40% of total damage to stored grains worldwide is caused by insect pests (Mathews, 1993), with most losses being postharvest. Safe grain storage is thus key to reducing postharvest losses. Most peasant farmers in sub-Saharan Africa use inexpensive storage structures such as mud and thatched rhombus, platforms, cribs, earthen pot, domestic or indoor storage such as plastic containers, gourds, earthen pots and metal containers (Adejumo and Raji, 2007). However, warehouses or storehouses are useful and more appropriate structures for food crop storage and protection because they enhance easy surveillance, treatment and transportation of grains (Gwinner et al., 1996) and allow regular inspections for insect infestation or fungal infection as well (Sallam, 2012). Grain storage has an ultimate goal of maintaining quality of produce and thereby ensuring sustained availability of food for a long period of time (Adejumo and Raji, 2007).

Most farmers in Ghana store their maize in granaries (cribs), polypropylene storage bags (PP bags) and warehouses. Very little information is available on the effects of warehousing on infestation and quality of maize in Ghana. The objective of this study was to determine the population dynamics of insect pests of maize in warehouses in the Northern and Middle Belts of Ghana.

Materials and Methods
This study was conducted in three warehouses in two towns in two agro-ecological zones in Ghana — Tamale (which lies within longitude 0.8533oW and latitude 9.4075oN and in the Guinea Savanna zone) and Ejura (which lies within longitudes 1o5′ W and 1o39′ W and latitudes 7o9′ N and 7o36′ N and located within the Transitional Zone or Middle Belt region). The Middle Belt has bimodal rainfall pattern allowing two cropping seasons of maize — major and minor cropping seasons. The study spanned October 2015–July 2016. The three warehouses were Gundaa, Wienco and MiDA, which had stacking rooms, where bags of maize grains were stacked on pallets, but Gundaa and Wienco warehouses had receiving and cleaning rooms as well.

Storgard II traps baited with pheromone lures were used to monitor the populations of flying insect pests inside and outside the warehouses. The pheromone lures were for Angoumois grain moth (AGM) (Sitotroga cerealella (Oliver), lesser grain borer (LRGB) (Rhyzopertha dominica (F.), larger grain borer (LGB) (Prostepahnus truncatus (Horn), red flour beetle (RFB) (Tribolium castaneum Herbst) and confused flour beetle (CFB) (Tribolium confusum Jacquelin du Val) and Indian meal moth (IMM+4) (Plodia interpunctella (Hubner). Dome traps were also deployed and used to monitor/capture crawling insects. Pheromone traps were placed in the warehouses between 25th September, 2015 and 25th July, 2016. The traps were suspended on the wall using steel hangers at a height of 1.83 m from the floor. Dome traps were placed on floors of warehouses between 25th January, 2016 and 25th July, 2016. There were 12, 15 and 18 traps in MiDA, Gundaa and Wienco warehouses, respectively (based on size of warehouse) and traps were separated 6 m from each other in each warehouse. Traps were checked biweekly (first collection on 11th October, 2015) and the number of each insect species found was recorded. In the case of the dome traps, insects captured every two weeks were recorded. The management of Wienco warehouse undertook routine treatment with Chloropyrifos–ethyl (Sunpyrifos®) in early May and late June and fogging with Deltamethrin in November, February and April.

Results

Results showed that S. cerealella numbers spiked to a mean of 12.11/trap in the stacking room on 25th October in Gundaa whereas numbers at MiDA and Wienco were 0–0.53/trap and 0–0.33/trap, respectively. A high number of S. cerealella (3.5/trap) was recorded in the receiving and cleaning rooms of Gundaa on 25th October but declined to zero afterwards (Fig 1 and Fig 2). Prostephanus truncatus collected in all the three warehouses ranged from 0–0.2/trap in the stacking rooms. In Gundaa, P. truncatus was found at a level of 0.11/trap only on 11th October. In MiDA, P. truncatus numbers were low (0–0.2/trap) throughout the sampling period. With regards to R. dominica, on 11th October, mean numbers of 1.44/trap, 1.42/trap and 0.67/trap were found in the stacking rooms of Gundaa, Wienco and MiDA, respectively. In the receiving and cleaning rooms, mean numbers of R. dominica per trap were 0.57–1.33/trap at the initial stage in Wienco (Fig. 1). Comparatively lower numbers of T. castaneum were recorded in stacking rooms in Wienco, Gundaa and MiDA with traps catching mean numbers of 1.03/trap, 0.78/trap and 0.8/trap, respectively. Tribolium castaneum numbers per trap increased from 11th October and peaked at 2.33/trap on 11th May. In Wienco, a higher mean number of T. castaneum (9.67/trap) was recorded on 25th November but declined to zero on 25th December. Gundaa had a sharp increase of P. interpunctella on 25th October and 25th July with mean numbers of 13.77/trap and 7.78/trap, respectively. A significant increase in P. interpunctella (34.36/trap) was observed in MiDA on 25th April and numbers peaked at 61.4/trap later. In the receiving and cleaning rooms, high numbers of 57.5/trap and 58/trap, respectively were recorded in Gundaa from 11th to 25th March. The most prevalent insect pests captured in the Dome traps were T. castaneum, S. zeamais and P. interpunctella. In MiDA warehouse, high numbers of S. zeamais were recorded with a mean of 10.42/trap in February, 2016. Tribolium castaneum numbers increased and peaked in May at 4.42/trap. In Wienco, <1.0 insect per trap was recorded for all the insect species except T. castaneum which had a mean of 5.25/trap on 11th July. High numbers of P. interpunctella (mean of 15.83/trap) were recorded on the 11th of March outside MiDA but numbers declined afterwards. Low numbers of T. castaneum were collected outside the Gundaa warehouse, and there was no S. cerealella found in traps. With regards to insect numbers outside Wienco warehouse, all the insect species were present with the exception of T. castaneum. Between 25th April and 11th July, P. truncatus, R. dominica and S. cerealella mean numbers found outside Wienco warehouse were 5/trap, 2.5/trap and 2.17/trap, respectively.

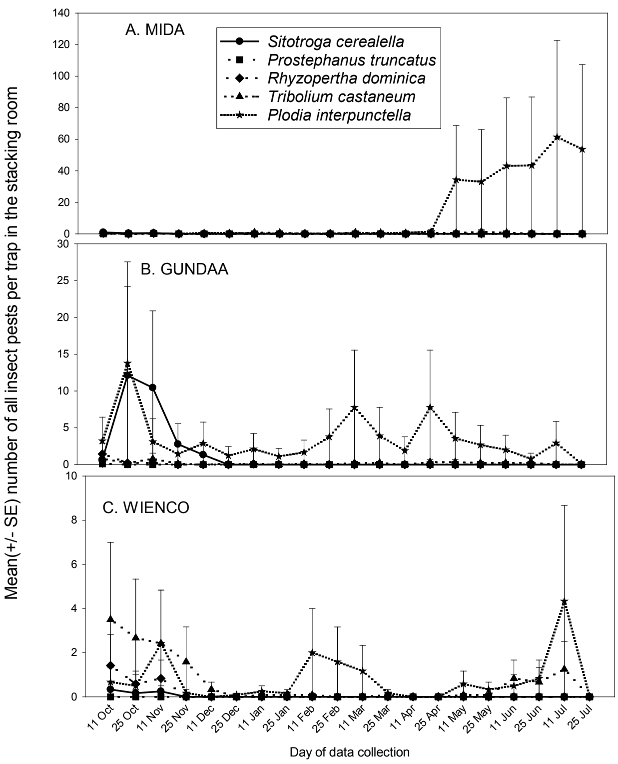

Fig. 1: Mean (± SE) number of all insect pest species per trap in the stacking rooms of the three warehouses.

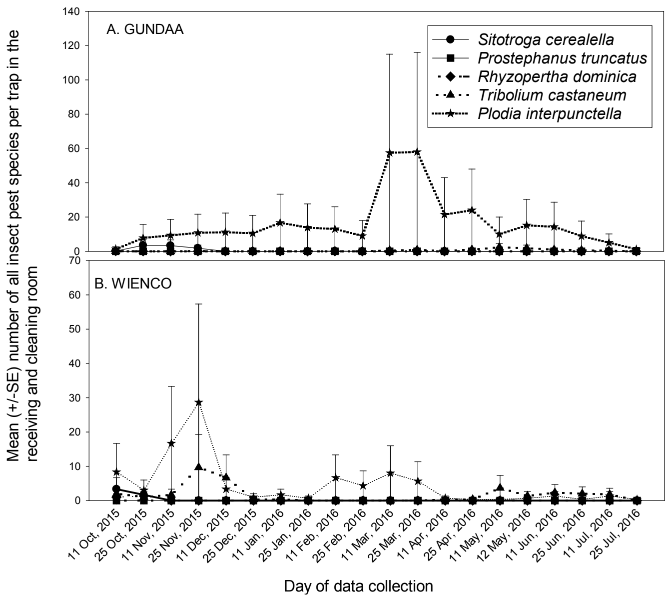

Fig. 2: Mean (± SE) number of all insect pest species per trap in the receiving and cleaning rooms of the three warehouses

Discussion

Our results strongly suggest most of the important insect pests of maize are present in areas where the warehouses are located but more research needs to be conducted over longer periods of time in more warehouses in order to elucidate insect seasonal abundance and movement in and outside the warehouses. Results of the present study show that both pheromone baited traps and dome traps need to be used to monitor flying and crawling insects to obtain reliable information on insect abundance in order to formulate appropriate integrated pest management decisions in warehouses.

Conclusion and Recommendation

It was evident from data collected that good sanitation practices and effective fogging and fumigation significantly reduced insect pest populations and therefore need to be incorporated into integrated pest management strategies for warehouses.

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30010 Moisture Content, Insect Pests, Mycotoxin Levels in Maize from Three Districts in the Middle Belt of Ghana

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Abstract
Moisture content, insect pest infestation and mycotoxin contamination of maize are challenges to food safety and security, especially in the tropics where maize is a staple crop. However, very little documentation is available on the impact of these factors on maize in Ghana. This study focused on post-harvest losses of maize by assessing grain moisture content, insect pests, and aflatoxin and fumonisin levels of maize on-farm and post-drying stages during the major and minor cropping seasons in the Middle Belt of Ghana. Data showed that maize moisture content decreased significantly from the field stage (17.2–19.0%) to the post-drying stage (12.4–14.2%). The mean grain moisture content was significantly higher in the major season (20.4%) than in minor season (12.5%). Sitophilus zeamais Motschulsky, Sitotroga cerealella Olivier, Cathartus quadricollis Guerin-Meneville and Carpophilus dimidiatus Fabricius were the dominant insect species that attacked maize on-farm in the Middle Belt of Ghana. Mean numbers of insects were significantly higher in the minor season (7.9 per 500 g) than in the major season (6.3 per 500 g), but in both seasons, higher numbers of insects were detected at the heaped stage (9.6 per 500 g) compared to the field and post-drying stage (≤ 6.8 per 500 g). Mean aflatoxin (ppb) and fumonisin (ppm) levels were significantly higher in the major season (29.1 ppb and 1.6 ppm) compared to the minor season (3.5 ppb and 1.0 ppm). Findings from this study can be used to help design more efficient management strategies to prevent on-farm losses of maize in Ghana.

Key Words:
Aflatoxin, food security, fumonisin, post-harvest loss

Introduction
Maize (Zea mays L.) is the most essential cereal in Ghana and is a staple for over 90% of the population (Anankware et al., 2013). Maize is consumed as a starchy base in a wide variety of porridges, pastes, grits and beer. In Ghana, annual maize post-harvest losses are estimated to be 5–70% (Amankwa, 2009). The major causes of maize post-harvest losses are high grain moisture content, physical environmental conditions and biological agents, mainly insect pests and moulds (Baidoo, Mochiah and Owusu-Akyaw, 2010). Maize post-harvest losses contribute to food insecurity and low farm incomes.

To date, very little information is available on the impact of the afore-mentioned factors on food security and safety in Ghana especially, on maize (AGRA, 2013). However, adequate knowledge of factors contributing to losses is required for implementation of mitigation strategies. This study focused on obtaining data on post-harvest losses of maize by assessing grain moisture content, insect pests, and aflatoxin and fumonisin levels of maize on-farm and at post-drying stages during the major and minor cropping seasons in the Middle Belt of Ghana.

Materials and Methods
The study was conducted in three principal maize growing districts located in the transitional ecological zone of Ghana, namely, Ejura district (located within longitudes 105′ W and 1039′ W and latitudes 7o9′ N and 7o36′ N) and Sekyedumase district (located within longitudes 7022′30″N and 1022′1.2″W and latitude 7.3750N and 1.3670 W) both in the Ashanti Region and Amantin district (located within longitudes 0°15′E and 0° 15′W, and latitude 7°N and 8°30′N) in Brong-Ahafo region. All the districts are in the Middle Belt of Ghana where rainfall distribution is bimodal allowing two maize cropping seasons. The study covered September to mid-October, 2015 and late-December, 2015 to mid-February, 2016 for maize samples taken for major and minor cropping seasons, respectively. Experimental design was a three factor (cropping season, district and sampling stage) factorial arrangement in a randomized complete block design (RCBD) with 2 x 3 x 3 levels (two cropping seasons — major and minor seasons, three districts — Ejura, Sekyedumase and Amantin districts, three sampling stages — field, heaped (ears) and post-drying stages). White maize varieties, Obaatanpa, Abelehi and Abrohoma, which are the most widely cultivated in the Middle Belt of Ghana were sampled from selected farms in each district during the major and minor maize cropping seasons. Samples were taken from 51 maize farms.

The three sampling stages were assigned to each randomly selected maize farm for a particular maize cropping season. The first stage was sampling mature cobs in the field before or during harvesting. The second stage involved sampling ears piled on the ground on-farm. The last stage was sampling post-dried grains after cobs have been shelled and grains sun-dried for storage or selling. Grain moisture content (%) and temperature (°C) were determined using a John Deere moisture meter (Manufactured by agraTronix™; Moisture Check Plus™, USA for Deere & Company; Batch SW08120). Maize samples were transported to the insect laboratory of the Department of Crop and Soil Sciences of the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana in a 17-liter Koolatron ® 12-V Compact Portable Electric Cooler (P75, Koolatron® Canada, Brantford, Canada) for mycotoxin analysis.

Insect pest species and numbers and percentage insect damaged kernels (%IDK) were also determined. The number of discoloured kernels per 100 was also assessed. Aflatoxin and fumonisin levels of sampled maize grain were determined. Mycotoxin (aflatoxin and fumonisin) analyses were performed using AgraStrip® Total Aflatoxin (COKAS1600A) and Fumonisin (COKAS3000A) quantitative test kits provided by Romer Labs®. Weight loss due to insect damage was assessed using the count and weight method.

$$\text{Weight loss (\%)} = \frac{[(Wu \, x \, Nd) - (Wd \, x \, Nu)]}{Wu \, x \, (Nd + Nu)} \, x \, 100$$

Where, W_u = Weight of undamaged grain, N_u = Number of undamaged grain, W_d = Weight of damaged grain, and N_d = Number of damaged grain.

Statistical analyses were performed with SAS Version 9.4 (SAS Institute, Cary, NC). Square root transformation was performed on insect damaged kernels (IDK) and insect numbers whereas arcsine square root transformation of percent MC, IDK and weight loss was conducted before data analyses but untransformed data are reported.

Results

Results showed that mean grain moisture content decreased significantly from a range of 17.2–19.0% on-farm to 12.4–14.2% at the post-drying stage. The mean grain moisture content in the major season was 20.4% and was significantly ($P<0.0001$) higher than the 12.5% in the minor season. During the two cropping seasons, moisture content ranges of 10.2–23.9%, 12.7–26.2% and 9.2–24.0% were recorded in Ejura, Sekyedumase and Amantin districts, respectively. Minor season mean grain temperature of 32.1°C was significantly higher than that of 29.8°C in the major season. Significantly higher temperature was recorded at the heaped stage (31.1°C) than at the field (30.1°C) or the post-drying stage (30.6°C). In general, temperatures were similar in Sekyedumase (31.3°C) and Amantin (30.9°C) but temperature was significantly ($P<0.05$) lower in Ejura (30.5°C).

Maize weevil, Sitophilus zeamais Motschulsky, Angoumois grain moth, Sitotroga cerealella Olivier, square-necked grain beetle, Cathartus quadricollis Guerin-Meneville and corn sap beetle, Carpophilus dimidiatus Fabricius were the most abundant insect species that attacked maize on-farm in the Middle Belt of Ghana. Mean total numbers of insects were significantly ($P<0.05$) higher in the minor season (7.9 per 500 g) than in the major season (6.3 per 500 g), but in both seasons, higher numbers of insects were detected at heaped stage (9.6 per 500 g) compared to field and post-drying stages ($\leq$ 6.8 per 500 g). Percentage insect damaged kernels (%IDK) was significantly ($P<0.05$) lower at field stage (0.4%) than at both the heaped and post-drying stages; %IDK was statistically similar for these latter two stages ($\geq$0.6%). However, mean %IDK recorded in both seasons were below the 5% threshold set by Ghana Standard Authority (GSA) for commerce. Mean weight loss ranges of 0.09–0.10%, 0.12–0.18% and 0.13–0.15% were recorded at field, heaped and post-drying stages, respectively. Percent grain discoloration was significantly ($P<0.05$) higher at the heaped and the post-drying stages ($\geq$1.7%) than field stage (0.8%).

Discoloration was significantly higher in the major season (2.0%) compared to the minor season (0.9%). Mean aflatoxin level (ppb) was significantly ($P<0001$) higher in the major season (29.1 ppb) than in the minor season (3.5 ppb). Ranges of 3.0–25.4 ppb, 3.4–45.5 ppb and 3.1–46.8 ppb were detected at field, heaped and post-drying stages, respectively. Similarly, mean fumonisin (ppm) levels were significantly ($P<0.05$) higher in the major season (1.6 ppm) compared to that in the minor season (1.0 ppm). The recorded levels of fumonisin at field, heaped and post-drying stages were all below the 4.0 ppm limit set by The US Food and Drug Administration (FDA).

Discussion

Grain moisture content was higher in the major season compared to the minor season, possibly due to greater and more intense rainfall in the major season. The major season harvest overlaps the rainy beginning of the minor season and harvest in the minor season also overlaps the dry portion of the year. The observed high grain moisture content in the major season prior to storage suggests that most farmers did not use proper drying management techniques or do not have access to effective and efficient drying equipment. The detection of more insect pests in heaped cobs (ears) could be attributed to emergence of new adults from eggs laid on ears prior to harvest and the warm humid conditions within and around heaped cobs (ears) that potentially supported insect activities. Post-harvest activities such as threshing of cobs, cleaning and winnowing of maize grains might have reduced insect numbers at the post-drying stage. The observed grain weight loss suggests that insect feeding activities on grains translate directly into kernel weight loss. The higher numbers of insects detected at the heaped stage, high grain moisture content and warm-humid weather conditions in the major season might have supported the production of high levels of aflatoxin and fumonisin in the latter.

Conclusion and Recommendations

The present study has shown that insect pest infestation and mycotoxin contamination begin in the field and subsequent grain moisture and temperature may influence the magnitude of losses due to these factors after harvest. Aflatoxin and fumonisin levels were considerably higher in major season than in the minor season, especially when the harvested ears were heaped on-farm. Therefore, it is recommended that farmers harvest maize at physiological maturity and dry immediately to reduce insect pests and mycotoxin risks. Piling of maize on-farm should be avoided and discouraged.

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30011 Efficacy of Filter Cake Against Sitophilus granarius and Rhyzopertha dominica in Stored Wheat

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Abstract
Silica based inert dusts are becoming eco-friendly alternatives to control stored grain insect pests due to environmental and health concerns associated with chemical use. A study was conducted to determine the efficacy of filter cake (a silica-based inert dust) on combined populations of Sitophilus granarius and Rhyzopertha dominica in stored wheat. Filter cake dust of <0.4 mm particle size was admixed with 500 g of wheat seed to provide nominal rates of 10000, 7500, 5000, and 2500 ppm (mg/kg), while the control treatment consisted of wheat seeds that were untreated. The bioassay was carried out using a liter-sized plastic jars in completely randomized design with three replications. Experiments were maintained at 23.1±1.7oC and 61.0±4.3% relative humidity. Mortality data were collected at three, seven, and fourteen days after treatment. Results indicated that mean mortality rate at three days after treatment ranged from 41.3 to 70.0% in S. granarius and 73.3 to 93.3% in R. dominica. Average mortality rate of S. granarius at 14 days after treatment was 84.0 to 98.7%, whereas that of R. dominica was 98.3 to 100%. The present results show that filter cake dusts can be used to control the species under study. It is, therefore, recommended that filter cake has potential in protection of wheat from S. granarius and R. dominica infestations in storage.

Keywords:
Filter cake, inert dust, Rhyzopertha dominica, Sitophilus granarius, wheat

Introduction
Silica based inert dusts are becoming eco-friendly alternatives to control stored grain insect pests due to environmental and health concerns associated with chemical use. Different researchers have studied the efficacy of various inert dusts such as diatomaceous earth formulations, wood ash and sand against maize weevil (Sitophilus zeamais) under Ethiopian conditions (Tadesse & Basedow 2005; Demissie et al. 2008). Demissie et al (2008) evaluated a material namely Filter Cake (a factory by-product) and found that it is effective against the maize weevil at rate of 1% or higher. Filter cake consists of kaolin (8.889%), SiO2 (39.39%), H2O (48.178%), and others (3.548%). A recent result from scanning electro-microscope showed that the product is composed of CaCO3, SiO2, NaAlSi3O8, FeS2, Al2O3, and K2O (Tadesse and Subramanyam, 2017, Unpublished data) with considerable concentrations of SiO2. However, reports on efficacy of filter cake against other storage insect pests than S. zeamais are rarely available. Efficacy of the inert dust at lower doses also needs investigations since applying at rate of >1% (10000ppm) may be too high since commercial formulations of the diatomaceous earth are normally used at rates as low as 3500ppm (0.35%) (Shah & Khan 2014). This study, therefore, was initiated to investigate the efficacy of filter cake against combined populations of Sitophilus granarius and Rhyzopertha dominica in wheat seeds.

Materials and Methods
Test insects of Sitophilus granarius were collected from farmers' stores in Ofla district, Tigray, Ethiopia, at altitude of about 2509m above sea level and geographic position of N12o30.939' E039o30877' in early June, 2016. Approximately 200 live adult insects of different age and sex were recovered from wheat grain samples and placed in 1liter plastic jar filled with around 200g of disinfested wheat grain. The jar was then covered with cotton fabric for rearing under room condition at College of Agriculture and Environment Sciences, Bahir Dar University, Ethiopia. Original insects were then removed after 15 days (assuming that adequate number of eggs could have been laid during the due time). Additional disinfested grain was added to plastic jars to avoid food limitation to the growing insects. Progenies with age of about three to six weeks were collected and used for the bioassay during end of September, 2016. Adult insects of Rhyzopertha dominica were recovered during end of August 2016 from certified seed samples purchased from the Ethiopian Seed Enterprise, Bahir Dar Center. Around150 to 200 adults were reared in plastic jars filled with 200g of disinfested wheat grain under similar conditions with that of granary weevil. Older adults were not removed in the case of lesser grain borer. Only live and active adults (about one to two weeks old) were collected and used for the bioassay in combination with granary weevil during end of September, 2016. Temperature and relative humidity of the room during the period between July and end of September was recorded in hourly interval using Hobo® temp/RH data logger, Onset® Computer Corporation, USA, and the average room temperature was about 23.1±1.7oC and 61.0±4.3% relative humidity. Wheat seed samples were sifted and disinfested through refrigeration at 5oC for two weeks. Grain samples were acclimatized for 48 hours at room conditions of 23.1±1.7oC temperature and 61.0±4.3% relative humidity. Damaged grains were removed and only intact grains were used for the experiment. Grain sample of 12.5% moisture content was divided into five portions of 1500g weight to receive five filter cake treatments (10000ppm, 7500ppm, 5000ppm, 2500ppm, and 0ppm/control). Filter cake dust which passed through 0.4mm meshes was administered at respective rates on each of 1500g grain samples. Filter cake dust and grains were homogeneously mixed with spoon. A 500g of treated wheat was then placed in 1000ml plastic jar covered with woven cotton fabric. Adult Sitophilus granarius and Rhyzopertha dominica insects of different age and sex were used for this experiment. From individual species, 50 and 20 insects, respectively, were placed in each of the jars. Jars were slightly moved forward and backward for 5 seconds to facilitate entrance of insects into the grain mass. The jars were then placed in the laboratory under ambient conditions, with 23.1±1.7oC temperature and 61.0±4.3% relative humidity, in completely randomized design with three replications. Insect mortality was examined at 3, 7, and 14 days after treatment. Dead insects were removed at every time of counting. All live

insects were returned to the jars until the end of data collection i.e. 14 days. Daily temperature and relative humidity were recorded every hour. Insect mortality was examined at 3, 7, and 14 days after treatment. Dead insects were removed at time of counting. All live insects were returned to the jars until the end of data 14 days.
Mortality data were corrected based the following equation provided by(Rosenheim & Hoy,1989):

$$Pcorr = 1 - \left(\frac{(1-T)(1-K)}{1-C}\right)x100 \text{ and } K = \left(\frac{Var(C)t\hat{}2}{(1-C)\hat{}2nc}\right)$$

Where, Pcorr=corrected proportion of dead adults, T=mortality in treated grain and C=mortality in untreated grain, nc=number of replications used for estimating C, and t=value of t distribution n_c-1 degrees of freedom at =0.05. Percentage data were arcsine transformed using the equation:

where r is the mortality rate.

One way analysis of variance and mean separation were carried out using the GLM Procedure of The SAS System (Version 9.0). Mean separation employed the Ryan-Elinot-Gabriel-Welsch Multiple Range Test (REGWMRT) using the transformed data and means were reversed to percentage data using the equation: $\mathrm{asin}(\sqrt{r})$ where t is the transformed mean.

Results and Discussion

Analysis of variance showed that there was statistically significa $100 * \sin(t)^2$ P<0.05) among treatments for mortality of Sitophilus granarius at 3 and 14 days after filter cake treatment (Table 1). Differences in mortality of S. granarius were statistically not significant among various rates of filter cake after 7 days. However, the coefficient of variation was very high for mortality measured 3 days after treatment. For Rhyzopertha dominica, average adult mortality rates for all concentrations of filter cake were statistically similar (p>0.05) at 3, 7, and 14 days after treatment. The coefficient of variation at 3 days after treatment was high showing that the observations could be less reliable.

Table 2: Mean mortality (%) and analysis of variance. Means followed by the different letters are significantly different at 5% level of significance.

Filter Cake Concentration (ppm)	Sitophilus granaries			Rhyzopertha dominica		
	Days After Filter Cake Treatment					
	3	7	14	3	7	14
10000	70.0	95.3	98.7	93.3	98.3	100.0
7500	62.7	91.3	98.7	80.0	95.0	100.0
5000	52.7	85.3	90.7	78.3	93.3	100.0
2500	41.3	74.0	84.0	73.3	93.3	98.3
Mean	56.7	86.5	93.0	81.3	95.0	99.6
F-value	21.05	3.59	9.40	2.53	0.89	1.00
R-Square	0.888	0.573	0.779	0.487	0.25	0.273
CV%	5.64	11.84	6.87	15.86	10.3	4.19
P-Value	0.00	0.07	0.01	0.13	0.49	0.44

Treatment of wheat seed with filter cake resulted in average mortality of 56.7%, 86.5%, and 93.0% at 3, 7, and 14 days after treatment, respectively on granary weevil. Mean mortality of S. granarius at 3 days after filter cake treatment ranged from 41.3% to 70.0%. Lowest mortality rate was recorded at 2500ppm filter cake treatment. At 7 days after treatment, almost 95.3% of S. granarius adults were dead at filter cake rate of 10000ppm while the mean mortality rates at all levels of filter cake treatment were statistically similar. Decreasing filter cake concentration 10000ppm to 2500ppm reduced mean mortality of S. granarius by 21.3%. However, mean mortality of 74.0% at 2500ppm of filter cake concentration can be of a considerable effect.

Mean mortality of S. granarius adults was as high as 98.7% at 14 days after treatment with both 7500ppm and 10000ppm filter cake dust (Table 1). Earlier report by Demissie et al. (2008) indicated that Filter Cake dusts at rate of 1% can achieve 100% mortality of S. zeamais at 15days after treatment. Difference in mean mortality between highest and lowest concentrations of filter cake treatment was around 14.7%. Halving filter cake concentration resulted in 90.7% mortality at this time. Only 84.0% mean mortality rate was recorded at 2500ppm filter cake concentration.

R. dominica exhibited more average mortality rate as compared to that of S. granarius. Average mortality rates of 81.3%, 95.0%, and 99.6% were recorded at 3, 7, and 14 days after treatment. Increasing filter cake concentration usually increased mean mortality rate. At 3 days after treatment, mean mortality rate ranged from 73.3% to 93.3%. This range was narrowed to 5.0% and 1.7% at 7 and 14 days after treatment, respectively. At 7 days after filter cake treatment, the mean mortality of R. dominica adults was around 95.0%, which was higher than that of S. granarius by 8.5% for the same time. At 14 days after treatment, filter cake concentrations between 5000ppm and 10000ppm resulted in 100% mortality in R. dominica adults. It was observed that R. dominica can be controlled at lower rates of filter cake, which is in agreement with previous findings on diatomaceous earth (Kavallieratos et al. 2015).

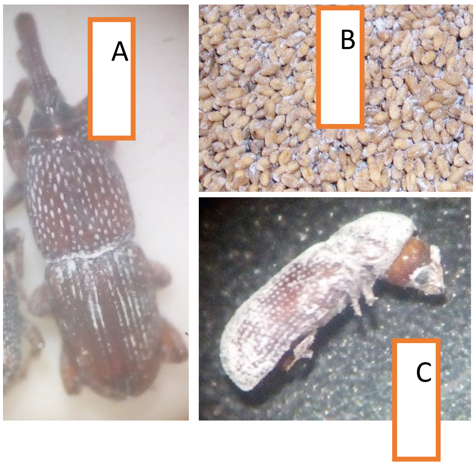

Fig. 2: Dead adults of Sitophilus granarius (A) and Rhyzopertha dominica (C) recovered from wheat grain treated with 10000ppm filter cake (B) at 3 days after treatment. Dust particles adhered to insect bodies with relatively higher density on R. dominica.

Conclusion and Recommendations

The present study revealed that the filter cake dust is effective on Sitophilus granarius and Rhyzopertha dominica. Filter cake dust may adhere to the cuticle of insect body (Figure 1) and cause impairment of water balance in a similar manner that observed in other silica based products(Malia et al. 2016). Reducing filter cake rate of application up to 5000ppm (0.5%) did not show any significant reduction in effectiveness after 14 days, in both species. However, the study was carried out on adults of different ages and further studies should be carried out to understand the efficacy on newly emerged progenies. Moreover, wheat samples used in this investigation have uniform moisture content (12.5%), hence, effects of higher moisture contents (as experienced in on-farm stores) are not yet understood. Given that the present scenarios are maintained, it is recommended that filter cake can be used against S. granarius and R. dominica in stored wheat.

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30012 Acoustic Survey and Detection of Pests in Kenya's Grain Storage Facilities

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Abstract
Grain production by Kenyan farmers, an important resource for their food security, faces constant challenges from pre- and post-harvest conditions favorable to rapid growth of insect populations. Currently, Kenya must import grain to meet consumption needs; however, if losses due to insects in storage facilities could be reduced, significant reductions in grain imports could be achieved. A review of current grain resources available in Kenya indicated that its grain production has increased over the last decade, but storage capacity has remained constant, with continued losses of up to 20-30% due to inadequate control of postharvest insect pests. Early warning of pest infestations can help managers reduce postharvest losses by enabling them to target and eliminate infestations before they increase to economically damaging levels. Since acoustic methods have been successfully used previously for early detection of infestations, an acoustic survey was conducted in selected maize grain stores in storage facilities in five Kenyan counties, Nairobi, Nakuru, Nyeri, Kirinyaga and Kiambu. Stores visited during the survey exhibited significant presence of Sitophilus zeamais Motschulsky, Prostephanus truncatus Horn and Tribolium castaneum Herbst. It was demonstrated that the use of acoustic technology can help managers identify and target infestations within their warehouses, enabling them to reduce postharvest losses.

Key words:
Acoustic detection, Kenya grain storage, pitfall traps, postharvest insect pests, postharvest losses

Introduction
Kenya has developed a Strategic Grain Reserve to store sufficient grain for release into markets if supplies fall below typical levels of consumption (Murphy, 2009). The government dedicates funds every year to ensure there is backup maize that can be released in an emergency. Strategic grain reserves play a vital role in ensuring Kenyan food security.

Kenya experiences an estimated 20-30% postharvest loss of staple grains, which poses great challenges to the country's food security and economic development (George, 2011). Prostephanus truncatus Horn (Coleoptera: Bostrichidae), Sitophilus zeamais Motschulsky (Coleoptera: Curculionidae), Tribolium castaneum Herbst (Coleoptera: Tenebrionidae) and Sitotroga cerealella Olivier (Lepidoptera: Gelechiidae) are the major maize pests in Sub Saharan Africa. Postharvest losses significantly endanger the livelihoods of stakeholders across the value chain by reducing valuable incomes and profitability.

Managers of bulk storage facilities frequently fumigate with phosphine gas; however, some postharvest pests have been developing resistance (Opit et al. 2012). In many facilities, gas tightness is not complete and fumigation needs to be augmented with additional tools. Routine monitoring and timely inspection of grains enables removal of infestations before they cause economic damage. Common monitoring methods make use of visual inspections in and around storage facilities, examination of grain samples, measurements of temperature changes in bulk grain, and widespread placement/inspection of insect traps (Toews et al. 2012). More often than not, this monitoring is not completely effective because of hidden infestations of larvae. However, acoustic detection (Mankin et al. 2011) is a promising technology which can detect hidden larval infestations and advise store managers on timing and targeting of grain preservation efforts.

An acoustic and pitfall-trap survey of storage facilities in Kenya was conducted to assess whether acoustic technology could be used effectively by warehouse managers to detect insect infestations in their early stages and reduce economic losses. A second objective was to compare the detection ranges and background noise discrimination capabilities of two different insect acoustic detection systems.

Materials and Methods

Recording sites
Recordings were collected from 90-kg maize grain bags in June 2016 from five grain storage facilities. Preliminary visits were conducted to gain consent to participate in the acoustic survey. These sites had similar, subtropical highland climatic conditions, with slight variations in altitude: Nairobi 1795m, Thika 1631m, Sagana 1762m, Kiganjo 2161m, and Nakuru 1850m. Each grain store had several grain stacks, exhibiting various levels and types of infestation at the time of the survey. Visual inspection for infestation was carried out to identify representative stacks and 12 90-kg bags were drawn randomly from the surface of the stack for acoustic recordings.

For each of the 12 selected bags non-pheromone Storgard WB Probe II traps (pitfall traps) were set up to collect insects in the grain. The traps were retrieved 2-3 hrs later, at the end of the acoustic recordings, and their contents taken to the laboratory for identification and counting.

Two sets of insect acoustic detection equipment, "imc", and "AEC" were used. The imc equipment included a 0.5" microphone (Model 378B02, PCB Piezotronics Inc., NY) attached to a preamplifier system (imc C-SERIES, CS-3008-N, imc Meßsysteme GmbH, Frankfurt, Germany) as described in Njoroge et al. (2016). The AEC equipment included a 16-cm-long x 6-mm diam stainless steel probe attached to a sensor–preamplifier module (model SP-1L, AEC Inc., Sacramento, CA) connected to an amplifier (AED-2010, AEC Inc. Sacramento, CA), leading to a digital audio recorder (model HD-P2, Tascam, Montebello, CA). The recording procedures were as described by Mankin et al. (2011). Records of 3 min each were collected over a 5-d period from a total of 60 different bags simultaneously with both systems in order to compare their detection ranges and background noise discrimination capabilities in the warehouse environment.Since some stores were located in very noisy environments, recordings were made when noise was reduced and while monitoring with headphones.

Automated classification

Recordings were band-pass filtered between 1 and 10 kHz and pre-screened using Raven Pro 1.5 Beta Version software (Cornell Lab of Ornithology, New York, United States) to remove high- and low-frequency background noise. Prescreening entailed playback, oscillogram, and spectrogram analysis. Two spectral profiles and a bird-noise profile were constructed for each of the imc and AEC data respectively, using the custom-written insect signal analysis program, DAVIS. (Mankin et al. 2011). The sound impulses in each imc or AEC recording were least-squares matched by DAVIS against each of these profiles and assigned to the profile type of best fit. DAVIS classified impulse trains containing >6 and <200 impulses that matched insect sound profiles, as insect bursts in each recording (Mankin et al. 2011). Times and types of each burst were saved in a spreadsheet for statistical analyses. Rates of bursts, were calculated for each profile, and totals calculated as the sums of the separate values for each profile (Njoroge et al. 2016).

Results and Discussion

Adults and/or larvae of at least 2 species of postharvest insect pests were present in all stores visited thus making it possible to collect recordings with different numbers of each or either species present (Table 1) under varying conditions of wind, bird noise, and machinery noise. Prostephanus truncatus and S. zeamais were present in 4 out of 5 store locations, while T. castaneum was present in all 5 store locations surveyed.

Table 1: Analysis of variance of counts of insects captured and identified at each site (Mean ± SEM)

Numbers of insects captured					
Species	Kiganjo	Nairobi	Nakuru	Sagana	Thika
P. truncatus	37.69±13.80a	0.25±0.25a	0.89±0.54a	0.57±0.42a	0.00±0.00a
S. zeamais	6.23±5.82b	20.42±6.71b	24.56±8.70b	0.00±0.00a	0.25±0.25a
T. castaneum	39.08±7.37a	39.42±4.75c	27.11±7.64b	5.86±1.74b	12.50±1.84b
Other species	4.07±0.78b	0.08±0.08a	0.56±0.44a	0.00±0.00a	0.00±0.00a
Mixed larvae	7.54±1.75b	0.00±000a	3.67±1.09a	0.14±0.14a	0.42±0.42a

Sound impulses were detected in all stores. All bags tested were identified as infested based on the total rates of insect sound bursts exceeding a detection threshold of 0.02 burst/s previously established in Mankin et al. (2008). The two equipment detected sound bursts at different rates in different bags due to differences in the positions of the insects relative to the sensors as well as differences in the range of detection. The microphone detected insects over approximately 25-cm distances from the top of the bag, while the AEC sensor attached to a probe, enabled detection of insects up to 25-cm distances along its 16-cm length (Kiobia et al. 2015). This is seen, for example, in comparisons among bags at the Kiganjo site (Fig. 1A) where the rates of bursts detected by the microphone were proportional to rates detected by the AEC, although the regression (calculated using SAS Proc GLM) was not statistically significant (Table 2). However, there was a statistically significant regression of the sum of the P. truncatus and S. zeamais counts on the AEC burst rates (Fig. 1B, Table 2), possibly because both methods were sampling approximately the same volumes within the bags.

Table 2. Parameters for linear regression of combined counts of P. truncatus and S. zeamais on the rates of bursts detected by A) AEC, and B) imc acoustic systems, and C) linear regression of imc burst rate on AEC burst rate for 12 maize bags tested at Kiganjo

Parameter	Model		
	A) count on AEC rate	B) count on imc rate	C) imc on AEC rate
Model (Error) SS	13355 (22385)	11387 (2435)	2.0374 (1.3282)
Root MSE (r^2)	47.3133 (0.3737)	49.3486 (0.3186)	1.1524 (0.1330)
F (P > F)	5.97 (0.0347)*	4.68 (0.0559)	1.53 (0.2438)

SS, sum of squares; MSE, mean square error; df = 1, 10; statistically significant values, P < 0.05 are marked by asterisk.

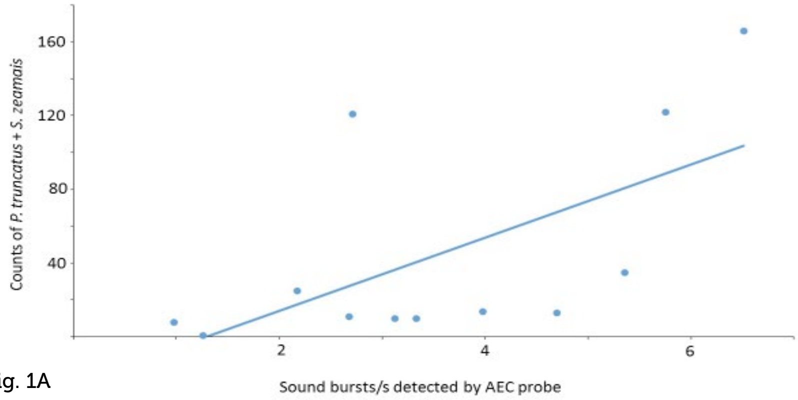

Fig. 1A

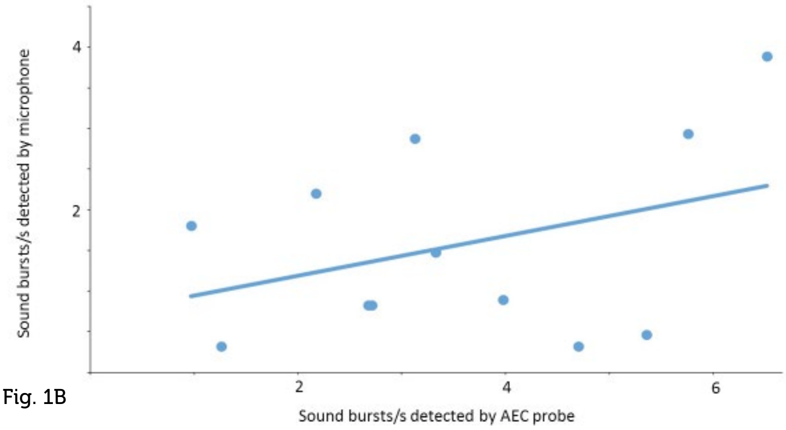

Fig. 1B

Fig 1 (A) Comparison of rates of sound bursts from 12 bags in recordings from the imc microphone and the AEC probe. Solid line indicates the linear regression of microphone sound burst rates on AEC probe sound burst rates (B) Comparisons of total counts of P. truncatus and S. zeamais with rates of sound bursts detected by the AEC probe in 12 bags. Solid line indicates the linear regression of insect counts on AEC probe sound burst rates.

Conclusions and Recommendations

Acoustic assessments of insect infestation in Kenyan warehouses correlated well with pitfall trap assessments and have the advantage of providing early detection of larval infestations. Knowledge of early infestation can assist warehouse managers in maintaining strategic grain reserves with scarce resources. Improved monitoring combined with innovations such as hermetic storage bags may enable reduced reliance on grain imports.

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30013 Postharvest Practices and Losses in Grains: A Case Study of Six Farm Settlements in Oyo State, Nigeria

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Abstract
Postharvest losses remain a major problem in sub-Saharan Africa despite interventions by governmental and international bodies. Information update on postharvest practices most especially among small-holder farmers is necessary in order to assess current practices. A pilot study was designed to collect information from grain farmers in 10 farm settlements in Oyo State, Nigeria to evaluate post-harvest practices out of which six (Ijaye, Ilora, Eruwa, Iresaadu, Ipapo and Ogbomosho) have been surveyed. Each farm settlement comprises 80–100 lead-farmers who employ other farmers and labourers. Forty farmers from each location who were identified as lead-farmers, were interviewed using structured questionnaires administered during a focused group discussion. Threshing, drying, storage practices and facilities used were considered. Maize threshers without blowers were found in all settlements. Threshing without blowing implies that maize taken into storage is not sufficiently clean thereby making it attractive to insects. Sun-drying of maize in open spaces expose grains to re-wetting by rain, defecation by birds and animals as well as dirt from the surroundings, thereby leading to early deterioration. Dryers, graders and modern storage facilities which would ensure proper processing were not available. About 90% of farmers reported significant postharvest losses, up to a third of harvest. Lack of adequate storage facilities compels farmers to use wrong and risky methods of keeping insects and rodents away from grains. Adequate information dissemination to farmers on proper practices was lacking and this lack of research-based knowledge transfer in hard-to-reach agrarian communities must be addressed for Africa to achieve food security.

Keywords:
Farm settlements, food security, postharvest losses, storage facilities, threshers

Introduction
Agriculture is a major sector of many economies including Nigeria where it contributes more than 30% of the total annual Gross Domestic Product (GDP) and over 70% of the non-oil exports (Olayemi et. al., 2012). In Nigeria, cereals play an important role in the agricultural sector, accounting for 55–60% of subsistence farmers' output and it forms the main diet for households both in rural and urban areas (Tahir, 2014). However, postharvest losses remain a major problem in sub-Saharan Africa despite interventions by governmental and international entities. Recent estimates indicate that food production will need to grow by 70% in order to feed the world population which is projected to reach about 9.725 billion by 2050. However, postharvest losses constitute a threat to attaining global food security. As the human population continues to grow and food demand increases, there is need for sustained effort in increasing production and reducing losses along many commodity value chains (Adejumo, 2012). In order to increase the availability of grains for food and feed, diligent efforts towards good handling practices must be established across each stage of the postharvest value chain. Amentae et. al., (2016) reported that in the food value chain, some of the major factors leading to losses are ineffectiveness and inefficiencies of postharvest management practices. Kummu et. al. (2012) noted that by improving postharvest practices, half of the food losses could be prevented thereby making it possible to feed an estimated one billion extra people. Therefore, the main objective of this study was to carry out an assessment of postharvest practices especially in drying, threshing, storage and pesticide application among smallholder farmers which may be contributing to grain losses.

Materials and Methods
A pilot study was designed to collect information from grain farmers in 10 farm settlements in Oyo State, Nigeria in order to evaluate post-harvest practices. These farm settlements were chosen purposely because they were established by the Oyo state government and they all have agricultural extension agents attached to them. Six farm settlements (Ijaye, Ilora, Eruwa, Iresaadu, Ipapo and Ogbomosho) have been surveyed so far. Each farm settlement comprises 80–100 lead-farmers who employ other farmers and labourers. A total of 240 respondents (40 from each location) who were identified as lead-farmers, were interviewed using structured questionnaires administered during a focused group discussion. Maize cultivation cuts across all farm settlements in the study and farmers in Southwestern Nigeria have two cropping seasons per year. Therefore, maize was used as a reference crop.

Results and Discussion
About 83% of respondents were male with approximately 40% having non-formal education and over 63% have been farming for over 20 years. Just about 20% of farmers surveyed were younger than 40 years in age. Barely 2% reported being self-sufficient (not financially constrained) in financing their farming activities while about 93%

were affected by lack of finance as agricultural lending facilities from financial institutions are still very difficult to secure. Open sun drying was the prevalent method for grain moisture reduction before and after threshing. The absence of dryers on all farms visited give the farmers no other choice but to leave their maize on the stalk for about 15 to 30 days after maturity to dry. Over 82% of the lead farmers reported having insect infestation right from the field before harvest. Limited use of post-harvest mechanization in storage facilities (silos) was observed. Processing and storage facilities installed when the farm settlements were established are in a state of disrepair (Figures 1 and 2). Maize is harvested and de-husked manually after which it is stored in cribs where it is subjected to further air-drying. The maize crib and earthen/mud-walled structures were found to be widely adopted by farmers for storing un-threshed maize. Over 95% of respondents threshed using locally-fabricated maize shellers which have no blower for winnowing/cleaning chaff away from threshed grains. A few still threshed using sticks, mostly for domestic consumption. Even though maize threshers were found in all settlements visited, blowers, dryers, grain graders and other modern postharvest handling and storage technologies which would ensure that maize is processed and stored properly were not available. The implication of this is that maize taken into storage is not sufficiently clean thereby making it attractive to insects. Moreover, there is inefficient use of time judging from time intervals among threshing, manual winnowing (mostly by women) and bagging. Direct measurements indicate that it takes about 13 people (comprising 1 thresher operator, 2 loaders—who bring maize from the store to the threshing floor, 2 labourers packing threshed maize to the bagging area, 3 women winnowing threshed maize, 2 women removing corn cobs from the threshing floor, and 3 men bagging and transporting bagged maize to the store) 9 hours to thresh about 2.5 to 3 metric tonnes of maize. A multi-purpose thresher of sufficient capacity incorporated with a blower can perform the same task within 3 h with fewer personnel, at most 6 workers comprising 2 thresher operators, 2 labourers bringing un-threshed maize and 2 transporting bagged maize. The practice is slightly different if maize is threshed immediately after harvest and is found to be wet (~ $\geq$15% MC). Such maize is sun-dried on tarps using any available open space. This practice exposes maize to re-wetting by rain, defecation by birds and animals as well as dirt from the surroundings. Several methods were used by farmers to determine the moisture content of harvested maize. Such practices included crude methods such as biting kernels, sound test, and visual observation presented in Table 1.

Table 1: How farmers determine moisture content of maize

Moisture content determination	Frequency	Percentage
Biting kernel	45	18.8
Sound of kernel when shaking or turned	16	6.7
Moisture meter	3	1.3
Visual observation	101	42.1
Number of days dried	8	3.3
*Others	2	0.8
More than one method (moisture meter, biting kernels,	60	25.0
Not specified	5	2.1
Total	240	100.0

*Other methods such as the salt test

About 90% of the farmers reported that they experienced substantial postharvest losses, up to a third of total harvest due to rodent, insect and mold damage. About 82% of them were able to link a general lack of adequate storage facilities with these losses which in turn affect their productivity and profitability. Inadequate processing facilities was identified by about 58% as influencing their postharvest losses arising due to kernel damage or unnecessary delays in processing. Similarly, close to 87% identified insect infestation during storage, poor road networks, and financial constraints as major problems. Moreover, the high risk of losses due to stored product insect pests compels 90% of the farmers to apply field pesticides on stored grains despite the threat to human health. Direct observations indicated that storage facilities (most especially cribs) were poorly maintained. Over 63% of the farmers were unaware of molds which cause aflatoxin contamination or how to prevent infestation, while 50% were unaware of aflatoxin threat to humans and livestock. Rodents were identified as the pests causing most damage during storage at the farm level followed by insects. These pests sometimes reduce the quality of harvested produce from food grade to feed grade. Most farmers keep their harvest for 1–9 weeks and over 95% of the respondents used rat poison in their stores, a practice which they acknowledged is dangerous, but was inevitable. According to 66% of respondents, agricultural extension officers visit farms regularly. However, most visits by extension agents were described as casual. Extension visits organized specifically for knowledge transfer are few and far between. Moreover, it was noted that the regular visit of extension workers do not have much effect on some of the postharvest practices of farmers because some of the farmers still use wrong methods to preserve and store grains. Apart from extension agents, farmers typically receive knowledge and training from other farmers, mass media such as radio and television, NGOs, farm input suppliers and "trial and error". However, it is worth pointing out that more than half (57%) of the farmers visited have received formal training on crop processing and storage at one point or the other.

Conclusions and Recommendations

The practices of farmers were evaluated across 6 farm settlements in Oyo State, Nigeria. Their practices specifically in harvesting, threshing, drying and storage were found to be similar and technologically low. Harvesting was manual, threshing was time consuming and laborious while drying wet maize before storage was unhygienic. The process of getting maize dried adequately before threshing is also time wasting. Threshing operations can be improved significantly through access to more efficient machines. Due to lack of access to adequate storage facilities, farmers were using wrong and risky methods of keeping insects and rodents away from their grains. A considerable amount of resources go into enhancing cultivation of crops but such efforts have limited impact if postharvest handling of crops is not given priority. Adequate information dissemination to farmers was lacking and this obvious lack of current research-based knowledge transfer in hard-to-reach agrarian communities must be addressed if Africa is to achieve food security. In light of this, capacity building, both for agricultural extension agents and farmers alike must be given priority. Periodic training on proper practices will go a long way to change farmers' mind-sets and help to improve practices in postharvest grain management. Moreover, financial assistance towards replacing dilapidated facilities and acquiring suitable grain handling and processing equipment should be made available to farmers.

Figure 1: A disused silo fitted with a blower at Iresaadu Farm Settlement

Figure 2: A disused multi-purpose thresher at Eruwa Farm Settlement

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Sub Theme 4

Capacity Development Including Training, Research and Extension Programs

4001 Bibliographic Search on Postharvest Losses of Perishables and Food Waste in Brazil

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Abstract
Although discussions on postharvest losses of fresh perishables and food waste in Brazil have increased in recent years, there are relatively few scientific papers on both subjects. A bibliographic search was performed with Google Scholar, SciELO database (Scientific Eletronic Library Online) and CAPES Portal of Periodicals using the terms postharvest losses (PHL) ("perdas pós-colheita) and food waste (FW) ("desperdício de alimentos") in Portuguese to know what has been published so far. In Google Scholar, 46,100 records were obtained for FW and 16,100 for PHL, and only 48 and 24 records, respectively, when the two terms are searched together in the title. At the SciELO database, the search in all indexes resulted in 22 scientific papers for PHL and 14 articles for FW. Most of the records of Google Scholar are grey literature, such as newspapers articles, editorials, academic papers (theses, dissertations), abstracts, reports and technical documents published only in Portuguese. Research on FW is dispersed in subareas, such as Health, Nutrition, Consumer Behavior, Organic Residues Management. Research on PHL is basically carried out by professionals linked to Agriculture, Food Sciences and Rural Economics and aimed at reducing losses by applying specific technologies or studies on increased costs caused by losses. So far, FW and PHL tend to be considered as distinct subjects in Brazil, lacking more comprehensive publications considering both areas together, as currently regarded by the international scientific community.

Keywords:
Losses, food, fruits, publications, vegetables, waste

Introduction
Although discussions on postharvest losses (PHL) of fresh produce and food waste (FW) in Brazil have increased in recent years, there are relatively few scientific papers on both subjects. Since the 1970´s, there has been a great deal of interest in adapting and developing technologies to reduce postharvest losses and increase shelf life of perishables. Research institutes and universities were involved in research projects and have produced many publications on the subject, including measurement of postharvest losses. In 2015, two reviews on postharvest losses were presented as abstracts at the First International Congress on Postharvest Loss Prevention held in Rome (Péra et al., 2015; Henz, 2015).

Losses along the value chain of perishables have been reduced in some ways because of the modernization of marketing, distribution and logistics by retailers, particularly by supermarkets which currently account for more than 70% of domestic supply of fresh produce. However, more in-depth discussions about food waste are relatively recent in Brazil, intensified since the launch of the Zero Hunger program in 2003. The theme has been much discussed in the national press lately, with several television programs and articles in newspapers and magazines. Brazilian society tends to be consumerist and has typical attitudes of food wastage in all social classes, including the poorest (Porpino et al., 2015). Fehr & Romão (2001) determined that biodegradable portion accounted for 66.6% of household garbage, composed by 86.6% of scraps and 13.3% of lost food. A "Good Samaritan" bill to encourage donations of food and grocery products has been discussed at the Congress since 2016 (Peixoto & Pinto, 2016). Currently, organic waste is a sanitation problem in Brazil because of open-air dumps in many municipalities.

Apparently, food waste has not been arousing much research interest as compared to postharvest losses because there is not much scientific bibliography available on the subject in Brazil. So the objective of this paper was to make bibliographic searches in available databases in Brazil to know what had been published in PHL and FW to check the interest by the scientific community for each subject.

Methodology
A bibliographic search was performed with Google Scholar (in Brazil known as Google Acadêmico: https://scholar.google.com.br), SciELO database (Scientific Eletronic Library Online: www.scielo.org) and CAPES Portal of Periodicals (www.periodicos.capes.gov.br) using the terms postharvest losses ("perdas pós-colheita") and food waste ("desperdício de alimentos") in Portuguese. At Google Scholar, idiom was set to Portuguese (Brazil) and searches were performed by decade and later on with the two terms in the title, excluding patents and citations. At SciELO website, searches were made in the Brazilian collection of journals using the terms "food waste" and "postharvest losses" in all indexes (author, year, periodical, abstract, title, funding agency) in the "integrated mode". At "CAPES Portal of Periodicals", searches were performed with the two terms in the title and also on the subject ("and").

Results and Discussion
In Google Scholar, 42,100 records were obtained for "food waste" and 16,600 for "postharvest losses", reduced to only 48 and 24 records, respectively, for searching the two terms in the title. At the SciELO database, the search resulted in 22 references for PHL and 14 for FW for the two terms in all indexes using the integrated search mode. Seven references for PHL and five for FW were found at CAPES Portal for searches with at least one term in the title (Table 1).

In Google Scholar, classification by relevance resulted in 1,950 records for food waste, covering different topics, such as waste management, centesimal composition and alternative food use. At the bottom of the results page of Google Scholar, the "related searches" terms for FW were "Brazil", "restaurants", "hospital facilities", "data", "schools", "hunger", "Food and Nutrition", "reduction", and "evaluation". For PHL, classification by relevance yielded 2,060 records, and the "related research" terms were "Brazil", "fruits", "vegetables", "evaluation", "reduction", "data", "transportation", "cereals" and "alternative technologies".

Searches in SciELO and CAPES Portal of Periodicals produced similar results, with more references on PHL as compared to FW. Most of the papers published on PHL were about specific topics, such as handling systems, postharvest diseases and mechanical injury, or about the application of postharvest technologies in fruits and vegetables, such as refrigeration and packaging, controlled/modified atmosphere (AC/AM), minimally processed products, MCP-1, use of edible coatings and waxes, physical and chemical treatments. The articles were published in eleven Brazilian journals of Agricultural Sciences, Horticulture and Rural Economics and Sociology between 1981 and 2016. For FW, 14 scientific papers were found in eight different Brazilian journals of Health, Nutrition, Environment and Agriculture listed in SciELO. Most of the articles were about centesimal composition, physical and chemical characterization, evaluation of food waste in institutional restaurants and waste management. There was a significant growth of records for the two search terms by decades at Google Scholar, particularly after the 2000s (Table 2). For FW, records ranged from 635 (1970s) to 14,600 (2010s) and for PHL ranged from 11 (1970s) to 9,430 (2010s). From the 2000s, there was a sudden increase in the number of records for both FW and PHL. There are some explanations for this fact: (a) popularization of internet and increased availability of eletronic documents in PDF and "html" formats, as opposed to hard copies in libraries in the previous periods of time; (b) "food" alone is a more powerful term in broad searches as compared to "postharvest" or "losses"; (c) most of the records are generic publications, often related to only one of the search terms. Most of the records yielded by broad searches using Google Scholar are grey literature, such as newspapers articles, editorials, academic papers (thesis, dissertations), abstracts, reports and technical documents published only in Portuguese. The largest number of records in Google Scholar for FW compared to PHL can also be explained by the impact and comprehensiveness of the term in searches across all areas of knowledge. PHL is more closely related to Agricultural Sciences, Economics and Management while FW is linked to Health, Nutrition and Food Sciences, areas with a larger number of scientific journals and postgraduate courses in Brazil. Since the 2000s, there is growing interest and awareness on food waste because of governmental programs on food security and apparently less interest on PHL, yet not reflected in scientific papers.

Conclusions

There are relatively few scientific papers on FW and PHL published in Brazil, most of them in Portuguese. In contrast, most of the publications available can be considered as grey literature. Google Scholar broad search was fast but required additional review because it retrieved all sort of grey literature, such as books, news articles, pdf and html texts, thesis, dissertations, technical publications. Publications on FW are dispersed in many subareas, such as Health, Nutrition, Consumer Behavior, Organic Residues Management. This is one of the main reasons for finding publications in Brazil. Research and publications on PHL are basically carried out by professionals linked to Agriculture, Food Sciences and Rural Economics and aimed at reducing losses by applying specific technologies or studies on increased costs caused by losses. So far, FW and PHL tend to be considered as distinct subjects in Brazil, lacking more comprehensive publications considering both areas together, as currently regarded by the international scientific community concerning Food Losses and Waste (FLW).

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4002 Systematic Review of the Measurement of Postharvest Losses in Perishables in Brazil

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Abstract
Postharvest losses (PHL) of perishables emerged as a problem in Brazil since the 1960´s. Since then, many publications on PHL have been produced nevertheless just a few are known and used as references in both national and international publications. Thus, the objective of this paper was to document Brazilian publications on measurement of PHL of perishables. Bibliographic searches on measurements of PHL were conducted using available databases in Brazil, such as SciELO and Google Scholar, and the Embrapa´s library system. More than 100 scientific papers, reports and technical documents on PHL were found and individually examined. Studies reporting losses caused by postharvest diseases, mechanical damage and/or resulting from the use of technologies were not included. Forty-one publications were selected by title, objective and scope and categorized according to their measurement method (surveys/interviews or quantitative) and measured losses (physical, qualitative, and/or economic). Brazilian publications on PHL were categorized into three major groups as (1) estimates/interviews with questionnaires; (2) measurement/quantitative methodology; and (3) economics/logistic studies. Most of PHL evaluations carried out in Brazil applied surveys and/or interviews as measurement method and presented loss results as physical or percentage. Studies applying quantitative methods usually reported results as qualitative loss, such as diseases, physical damage and appearance changes, as well as physical or percentages. Any of the Brazilian experiences in measuring PHL can potentially be replicated in Africa, depending on the context, budget and interest. The quantitative PHL methodology and the economic/logistics studies are more science-based and therefore recommended.

Keywords:
Estimations, measurement, postharvest losses, surveys

Introduction
Postharvest losses (PHL) of perishables emerged as a problem in Brazil since the 1960´s, when the country underwent a fast urbanization process. Since then, many publications on PHL have been produced, nevertheless just a few are known and used as references in both national and international publications. The HLPE (2014) recommends undertaking four parallel mutually supportive tracks to reduce globally the impact of food losses and waste (FLW), and the first one is improve data collection and knowledge sharing. Kitinoja and Kader (2015) gathered the existing information on measuring PHL of perishables in developing countries into a single document to be used as a basis for future research and method development, with just four Brazilian citations, three of them in Portuguese. Henz (2017) published a review on PHL publications in Brazil, including some of the results shown here. Thus, the objective of this paper was to document Brazilian publications on measurement of PHL of perishables to make them available to the international community working with the subject, according to the recommendation of the HLPE on improving data collection and knowledge sharing.

Methodology
Searches were made for documents in the collection of the Embrapa's library and through Google Scholar and SciELO journal database. More than 100 publications on PHL have been found, including scientific articles, technical publications, research projects, reports, academic papers (theses, dissertations, others), reviews, books and book chapters, and congress abstracts. Documents were individually analyzed and selected according to their scope and main objective focusing on postharvest losses estimates and measurements. Studies reporting losses caused by postharvest diseases, mechanical damage and/or resulting from the use of some specific technologies were not included.

Results and Discussion
Forty-one publications were selected by title, objective and scope and categorized according to measurement method applied (surveys/interviews or quantitative) and how losses were measured (physical, qualitative, and/or economic). Most of PHL evaluations carried out in Brazil applied surveys and/or interviews as measurement method and presented loss results as physical or percentage. In these studies, losses are categorized into predetermined causes by the interviewer. Studies carried out applying quantitative methods usually reported results as qualitative loss, such as diseases, physical damage, appearance changes, and also as physical and/or percentage. A significant number of studies on PHL in Brazil are related to economic losses in marketing and transportation, with mathematical models to estimate the impact of losses on produce prices and costs.

Estimates
Most of the studies can be considered as subjective estimates because they rely on structured questionnaires to obtain the data, strongly influenced by the first estimates carried out in the 1970s by SUDENE, a governmental development agency for the Northeast Region. Data on losses were obtained through interviews with professionals responsible for trading fruits and vegetables in the wholesale markets and street markets. PHL were categorized by the interviewer in the following causes: (a) delay occurred between produce buy and sell; (b) poor product quality (initial quality); (c) inadequate packaging; (d) inadequate storage; (e) poor transportation; (f) adverse weather conditions; (g) other causes (SUDENE, 1971). Several subsequent surveys in Brazil were carried out following this methodological approach. Ueno (1976) and Tsunechiro et al. (1994) did surveys on PHL in 42 fruits and vegetables in supermarkets, groceries and street fairs in São Paulo city at two distinct periods (1973/74 and 1991). Ueno (1976) considered that most of the losses occurred in supermarkets because produce suffered additional handling and packaging and a product correction factor was calculated to replace the losses. Tsunechiro et al. (1994) found 10.2% as average loss, and considered that reducing losses could increase trade margins due to additional costs for retailers.

Measurement of losses

There are relatively few publications based on measurements, here understood as mass or weight measurement of the discarded part, as opposed to estimates based on questionnaires or interviews. A pioneer research project on measurement of PHL was carried out with carrot, tomato and sweet pepper in Brasilia-DF (Lana et al., 1999). The first paper with this method was published by Lana et al. (2002) reporting losses in carrot categorized in two types of samples, called "Initial Quality" (just purchased) and "Discard" (not sold). Losses in carrot ranged from 10% to 18%, and the main causes were mechanical damage, root defects and root wilting. Many other papers were published following the same methodology.

Research Projects

There are few hard copies of research projects proposals or final reports on PHL of perishables in Brazil available in libraries. The following two were selected because of their relevance:

1) "Research on postharvest practices and development of a method to analyze losses of perishables" (Mukai & Kimura, 1986): the objective of the project was to identify postharvest handling practices of five vegetables (tomato, potato, onion, cabbage, carrot) at farmers, wholesalers and retailers in Minas Gerais State to study the losses and then establish strategies to reduce losses. The estimates of losses for the five vegetables were variable, depending on the commercialization stage (wholesale or retail) and period of the year (summer or winter);
2) "Evaluation of postharvest losses of horticultural crops in the State of São Paulo" (Carvalho, 1992): The project proposal describes the state of the art on the subject at that time, highlighting the scarcity and precariousness of the information available in Brazil, with a high degree of uncertainty in the estimates (Carvalho, 1992). A sampling based on statistics and a qualitative PHL measurement was proposed. Apparently, this project was not executed.

Economics and logistics

Since the 1970s, many studies on economics and logistics related to postharvest losses of perishables have been published in Brazil. Economy: Brandt et al. (1974) studied the commercialization and economic consequences of PHL of tomato, sweet peppers, lettuce and cabbage grown in Manaus, Amazonas State. Average PHL of 15% were determined for tomato; 11% for lettuce and cabbage; and 10% for sweet peppers. The marginal propensity to losses and yield elasticity were calculated. Resende (1979) identified and analyzed the causes and effects of physical losses in the commercialization of tomato (31.14% loss) and cabbage (26.55% loss) in Minas Gerais. The net social cost of the losses reached 25.8% and 27.5% for tomato and cabbage, respectively. Farmers were more disadvantaged than consumers in terms of wellfare state, configuring losses in marketing as income transfer.

Logistic studies: Caixeta Filho (1999) published a case study on losses in the transport of fruits and vegetables in São Paulo, Brazil. Scenarios were constructed by the application of mathematical models taking into account the adoption of technologies that potentially could reduce the losses of tomatoes and pineapples at the CEAGESP, the largest wholesale market in Brazil. Wholesalers were the main players in the chain and had oligopoly power, but seemed unwilling to adopt technologies that could increase costs. An updated version of this model was presented at the First International Congress on Postharvest Loss Prevention in 2015. In 1996, Costa & Caixeta Filho published a case study on losses in transport and marketing of tomatoes in the state of São Paulo involving three segments (farmer, broker and retailer), with estimated losses of 10% in transport. The consumer was impaired by absorbing the price increase caused by the reduction in the quantity offered.

Conclusions

Brazilian publications on PHL can be categorized into three major groups: (1) estimates/interviews with questionnaires; (2) measurement/quantitative methodology; and (3) economics/logistic studies.
Any of the Brazilian experiences in measuring PHL can potentially be replicated in Africa, depending on the context, budget and interest.
The quantitative PHL methodology and the economic/logistics studies are more science-based and therefore recommended.

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4003 Stored Grain Protection and Management Capacity Building in Nigeria – Review of 7 Years of Experience

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Abstract
The state of know-how and personnel capacity to manage grain stocks through the grain value-chain is one of the understated aspects of capacity building to reduce post-harvest losses in Africa. Most of the time, emphasis is placed on the provision of technologies that aid in improving quality and reducing losses during grain handling and storage, with little emphasis on training of personnel. This abstract reviews seven (7) years of training in stored grain protection and management provided to the industry in Nigeria as part of a USAID funded project through a cooperative agreement with USDA-Foreign Agricultural Service and three Land-grant universities (Purdue University, University of Kentucky and Oklahoma State University) in the USA. About 500 personnel that include agricultural extension agents, operation managers of grain storage complexes/warehouses, millers, university faculty, research institution scientist, farmers, equipment fabricators and university students have been trained in Nigeria on grain post-harvest handling, stored grain protection and management using two curricula. The curricula were designed to target storage and handling on-farm in local storage barns and small warehouses, and storage in bulk in large silos and in bags in large warehouses. Impact assessment conducted by the International Institute of Tropical Agriculture (IITA) in Ibadan and feedback from participants indicates that outcomes such as improved sanitation, reduced pesticide use, and reduced worker exposure to pesticides have been observed in facilities whose managers' took part in one or more of the trainings offered. The overall quality of grain delivered by suppliers to processors from trained grain merchants has improved.

Keywords:
Capacity building, post-harvest technology, stored grain management, training

Introduction
The United States Department of Agriculture (USDA) – Foreign Agriculture Service (USDA-FAS) program on "Technical Support to the Nigeria Capacity Building Program on Stored Commodities" was developed in response to the world food crisis of 2008. The world food crisis caused by several factors such as low levels of grain and oilseed stocks, high oil price and high price of input was a cause for concern in many countries. Some reports such as a 2008 World Bank report (Mitchell, 2008) attributed some of the rising food prices to the increase in biofuels in the US and EU, which increased the demand for commodity grain and oilseeds used in biofuels. The fallout of the food crisis was especially felt in developing countries in Africa that saw price hikes and scarcity, which caused civil instability with riots on the street. In November 2009, a two-week in-country assessment was embarked upon by three experts in post-harvest engineering technology and stored-products protection from three different U.S. land-grant universities to assess the state of grain storage systems and practices in Nigeria (Ileleji et al., 2009). The team of university faculty assessed grain storage facilities at the farm, state, and national level with the ultimate goal of determining short-, medium-, and long-term activities to be implemented in order to provide food security for Nigeria and the region. A major finding of the assessment trip that led to the design and implementation of the capacity building program on stored grain management was that basic proper stored grain management practices were lacking at all levels (federal, state, and on-farm), and the implementation of training in Nigeria at all three levels will help mitigate the problem. The goal of this paper is to outline the background of the capacity building effort, the state of infrastructure (both structures and know-how) of the stored commodity grain industry in Nigeria, program implementation, its impact to date and plans ahead.

Methodology
Capacity Building Effort in the Grain Commodity Sector 2009 in-country assessment of grain storage in Nigeria

Storage at the Federal level
National Storage Policy and Food Security: Food storage at the federal level was under the management of the National Food Reserve Agency (NFRA) now Strategic Grains Reserves (SGR). SGR facilities are used for storing the major staple foods purchased from farmers during periods of abundant supply at harvest; the food is then released gradually into the market during periods of scarcity in order to stabilize food prices. These food staples include grains – maize (corn), sorghum (guinea corn), millet, soybeans, and paddy rice, which are primarily produced in the northern Nigeria. In 2009, SGR owned 13 - 25,000 MT (Fig. 1) storage complexes with a total capacity of 325,000 MT. Today SGR has 33 silo complexes, adding 20 new silo complexes around Nigeria with a total capacity of 1,025,000 MT, bringing the total storage capacity at the strategic reserve program to 1.325 million MT. Unfortunately, the utilization capacity of these facilities has been only 5%.

Storage at the State Level

State Buffer Storage Facilities (SBSF): Grain storage at the state level is used as a buffer stock to alleviate scarcity during lean periods of grain supply or during shortages due to drought or some other reason. SBSF grain is usually stored for no more than a one-year period (more likely for as short as 4 or 5 months), and may sometimes be stored for as long as two years. State buffer storage facilities (SBSF) primarily consist of flat storage warehouses. However, some states have a combination of both cylindrical steel silos and warehouses. In general, the SBSF appear to be older and poorly managed than NFRA facilities.

Fig. 1. Location of SGR-FMARD storage complexes in Nigeria (2009).

Storage at the Farm Level

The on-farm storage visited was in northern Nigeria. In northern Nigeria, on-farm storage is in rhombus (Fig. 2). A rhombus is a locally constructed storage structure made of either corn stalks or mud and hold about between 1,200 - 1,500 kg of grain, i.e. 50 to 60 bundles of grain sorghum. Dry un-threshed sorghum heads are hauled in bundles (4 bundles ≈ 100 kg) for storage in rhombus. The structure is cylindrical in shape and elevated above the ground on cement blocks or sticks to prevent ground moisture from contact with the dry stored grain.

(a) Rhombuses made of corn stalks. (b) A rhombus made of mud

Fig. 2. Storage structures known as "rhombus" used for grain storage at the farm level.

Strategies used to implement training

The original team consisted of US land-grant universities who designed the training program to address issues across the various aspects of the grain value chain from on-farm storage and handling practices to bulk storage at the processor level. Two training workshops were designed; the first on stored grain management for on-farm and small warehouses, and the second on stored grain management for large warehouses and bulk storage in silos. The first is to train agricultural Extension agents, grain merchants and farmers, while the second is for warehouse and silo managers, grain operations personnel and warehouse receipts collateral managers. The workshops involved lectures and hands-on exercises such as use of grain samplers and moisture meters, sensors, insect identification, phosphine fumigation, and problem solving. The training also involves the tour of a grain market for the on-farm and small warehouse management, and a silo complex for the large facility management course, where instructors walk through the implementation of best practices for stored grain. These methods have increased knowledge acquisition by participants. As the program evolved, a research component to support our training was initiated in 2016 in order to generate data to support training applicable to Nigeria. The research components pursue stakeholder-driven research questions, which then generate material for the training. Most importantly, local universities and national research institutions involved their students and interns to implement these researches, thereby building capacity within the system. In the fifth year, the team actively involved four personnel from two institutions in Nigeria: the National Stored Products Research Institute (NSPRI) and the University of Ibadan. The involvement of these institutions is building capacity within the system to sustain the effort in training the workforce to support local, regional and export of high-quality grains and oilseeds.

Conclusion and Recommendations

Around 500 personnel have been trained in 11 workshops organized and held in four different locations (Makurdi, Akure, Abuja, Ibadan) in Nigeria. Impact assessment conducted by the International Institute of Tropical Agriculture (IITA) in Ibadan and feedback from participants indicates that outcomes such as improved sanitation, reduced pesticide use, and reduced worker exposure to pesticides have been observed in facilities whose manager(s) took part in one or more of the trainings offered. One company reported a cutback in pesticides and associated annual expenditures by 100% by implementing integrated pest management (IPM) strategies learned in our workshops. Faculty (lecturers) from Nigerian universities who have attended our training have reported positive feedback from the use of our training materials in their undergraduate and graduate courses on grain post-harvest management. The extension agents trained in 2015 reported training over 20,000 farmers in their locality. The capacity building effort has made an impact on stored grain management in Nigeria. Feedback from participants and participating companies and our personal visits with them show that they are implementing what has been learned in the workshops. Effective monitoring and evaluation is key to measuring impact. Our long-term plans are to transform the curricula into a professional development course for stored grain managers and local extension agents, which will be delivered nationwide by a consortium of local experts.

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4004 Farmers' Awareness and Adoption of Improved Grain Storage Technology in Western Kenya

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Abstract
Maize is the staple food for over 90% of the Kenyan population. Postharvest losses of grain maize, ranging between 20 and 36%, reduce quality and volume of maize available for consumption and trade. Many initiatives have promoted improved grain storage technologies including metal silos, and hermetic bags. The objectives of this study were to: evaluate households' sources of information on grain storage; assess adoption levels; and establish drivers to adoption of improved grain storage technologies. Data were obtained from a random sample of 613 households in Western Kenya using a questionnaire and analyzed by descriptive statistics and multinomial logit model. Results show that 48% of the households were aware of grain storage technologies mainly through government extension agents (66%) and other farmers (20%). In contrast, 27% adopted some improved post-harvest management technologies, especially hermetic bags (28%) and metal silos (0.5%). Low adoption of metal silos was mainly attributed to high initial costs of acquisition, whilst the relatively high adoption of hermetic bag was due to its low cost. Age and education level of the household head and number of contacts with agricultural extension agents had significant positive influence the adoption of hermetic bags. However, quantity of maize grain produced had a negative significant effect on adoption of hermetic bags and positive significant effect on adoption of metal silos ($p<0.05$). We recommend that more effort be devoted to awareness creation on improved grain storage technologies and reduction of the cost of metal silos in order to improve the adoption.

Key words:
Adoption, maize, losses, multinomial logit, postharvest

Introduction
In sub-Saharan Africa (SSA), Postharvest Losses (PHL) of maize (Zea mays) grain are estimated at 18 percent of total production, mainly due to poor storage (Obayelu, 2014). The PHL through deterioration of the grain quantity and quality that occurs between the time of harvest and the time it reaches the consumer, leads to loss of nutritional and monetary values as well as limited access to particular market segments. Hence, PHL is a widely recognized constraint along grain value chains across Africa (Obayelu, 2014; Affognon et al. 2015). Maize is the staple food for over 90 % of the Kenyan population. For this reason, a large part of harvested maize is stored on-farm to guarantee supply between harvest seasons. The on-farm storage mainly comprises traditional storage structures such as traditional cribs, gunny bags and baskets that are prone to invasion by agents of stored food losses including insects, rodents (Nukenine, 2010) and molds.

The PHL of maize grain are particularly acute in Kenya, with estimates ranging between 20 and 36 percent, which is well above that of SSA region. The losses drastically reduce the volume of maize available for consumption and trade (KAVES, 2014). Low awareness or poor knowledge of good postharvest practices and technologies by farmers has been pointed out as one of the challenges to be overcome if a meaningful reduction of postharvest losses is to be achieved (Affognon et al. 2015). In view of high grain PHL, many initiatives have been made to promote improved grain storage technologies including metal silos, hermetic bags and use of chemicals to replace inefficient traditional methods. The adoption of improved postharvest technologies is believed to be low. However, farmers' awareness of improved post-harvest storage technologies, rates of adoption and the causes of the adoption or non-adoption are not fully understood. Minimizing post-harvest losses through efficient post-harvest handling, storage and marketing can tremendously contribute to reducing production volumes needed to feed a growing population, resulting in improved food and nutrition security and increased incomes as envisioned in Kenyan development blue print, the Vision 2030.

The objectives of this study were toi) Evaluate households' sources of information on grain storage; ii) assess adoption of improved grain storage technologies; and iii) establish factors that influence the adoption of improved grain storage technologies.

Methodology
A combination of random and purposive sampling techniques were applied to identify the study sites and individual respondents. Siaya and Kakamega Counties were purposively selected based on their maize-legume production potential. A multi-stage sampling procedure was used to select the study sub-Counties, Wards, Villages and households A random sample of 613 households comprising 494 and 119 male- and female-headed households, respectively, were selected from the villages and interviewed during the 2015 long rain season. The interviews were conducted by trained enumerators using a pre-tested and revised structured questionnaire. Data were collected regarding farm and household characteristics, maize grain production, awareness and practice of grain storage practices, and reasons for choices of post-harvest storage technology. Data were analyzed by descriptive statistics and multinomial logit model using STATA version 12 computer package.

Results and Discussion:
Results show that 48 percent of the households received grain storage information from multiple sources. Of those who received the information, the main sources were government extension agents (66 %), other farmers (20%) and radio (12%) (Figure 1).

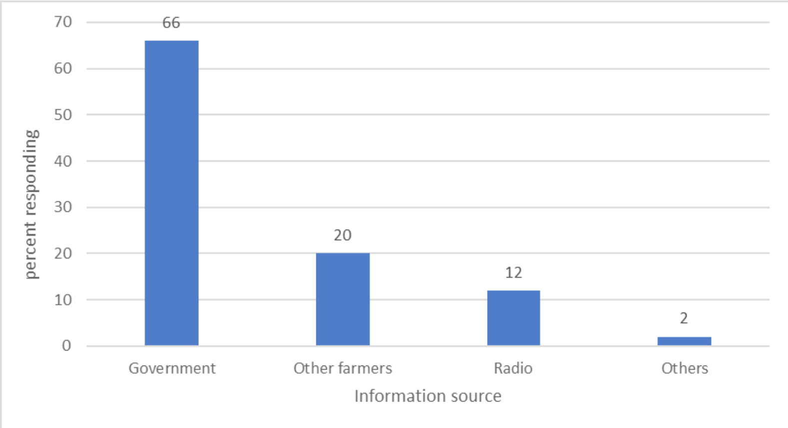

Figure 1: Main sources of grain storage information in Western Kenya

Regarding the adoption of the post-harvest technologies, only 28% used the hermetic bags, and 0.5% applied metal silos compared to 48% who still used gunny bags. Overall, only 27 percent adopted some improved post-harvest management technologies. Previous studies (e.g., Murage et al. 2012) show that other farmers or neighbours are an important means of spreading technological information. However, the quality of information is often poor, especially for knowledge intensive technologies such as post-harvest storage. This calls for more intensive trainings and provision of support training materials (e.g., leaflets) to enhance their information delivery. Moreover, Kaminski and Christiaensen (2014) have reported that training on grain storage and protection technologies that created awareness and knowledge did not necessarily result in lower storage losses as farmers who received training incurred similar magnitudes of postharvest losses as those farmers who did not receive the training. This suggests that the farmers did not apply the knowledge acquired during the training. Household and storage technology characteristics especially costs, ability to keep off rodents and other pests influenced the adoption. Low adoption of metal silos was mainly attributed to high initial costs of acquisition, whilst the relatively high adoption of hermetic bags was due to low cost of acquisition. Household characteristics such as age, education level of the household head and number of contacts with agricultural extension agents had significant positive influence the adoption of hermetic bags. However, quantity of maize grain produced had a negative significant effect on adoption of hermetic bags and positive significant effect on adoption of metal silos.

Conclusion and Recommendations

The study concludes that awareness is only a necessary condition for improved postharvest management. This is because of the 48% of households received that information on maize grain storage mainly from government extension agents, other farmers and radio, whilst only 27 percent adopted some improved post-harvest management technologies. Factors that influenced the adoption varied by improved storage technology. The low adoption of metal silos was mainly attributed to high initial costs, whilst the relatively high adoption of hermetic bags was due to low initial costs. Households whose head was elderly and had more education and which more contacts with agricultural extension agents had higher probability of adopting hermetic bags. Moreover, households that produced lower quantities of maize per season were more likely to adopt of hermetic bags, whilst those that produced more quantities of grain maize per season had a higher probability of adopting metal silos.

We recommend that more effort be put in promoting post-harvest management technologies to reach a large proportion of farmers. More investment is required to enable farmers to access improved costly post-harvest technologies such as metal silos. The price of metal silos are relatively high in the context of the low financial capacity of most smallholder farmers. The key stakeholders in the agricultural sector should engage the Kenyan Government for tax waivers on the metal sheets, which constitute the major component of the metal silos cost. This combined with policies that encourage subsidy on initial acquisition of metal silos, availability of the silos on credit basis through the engagement of micro-finance institutions and catalyzing farmers to form groups that can help them save funds and buy materials for making silos in bulk will be of paramount importance. Overall, improving grain output markets is necessary to provide incentives to facilitate commercialization of proven post-harvest management technologies. For this to happen, post-harvest promoters need to provide credible evidence on efficiency and economics of different post-harvest storage technologies.

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4005 Development of a Low-Cost Moisture Meter for the Grain Trade

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Abstract
A low cost meter was developed as part of a USAID funded Feed the Future project headquartered at Kansas State University to reduce post-harvest loss (PHL) of grains and is referred to as the PHL moisture meter. It actually measures the temperature (T) and relative humidity (RH) of the air space between grain kernels and calculates the equilibrium moisture content (EMC) to determine grain moisture. The meter was built and evaluated in laboratory studies in the U.S. and field tested in Ghana and Nigeria. Meter accuracy was compared to two commercial meters: (a) John Deere Chek Plus-SW08120 grain moisture tester and (b) bench top DICKEY-john GAC®2100 Agri meter. The portable JD meter is a low cost meter by developed country standards (~US$250, 2016 price), whereas the GAC2100 benchtop moisture meter is a USDA-GIPSA-approved tester that is highly regarded in the US grain trade and has been used for many years. Laboratory studies indicated that the PHL moisture meter requires approximately six minutes to make a measurement due to the time required for the probe tip and sensor to equilibrate to the air within the grain mass. Field tests have shown the accuracy of the PHL moisture meter was comparable to that of the GAC2100 moisture meter for maize below 15% MCwb. Measurement differences averaged over many readings showed a positive offset of 0.45% for the PHL meter relative to the GAC2100, whereas the John Deere SW08120 moisture meter was found to have an offset of 2.37% MCwb.

Keywords:
Aflatoxin mitigation, food security, grain moisture, storage, postharvest loss

Introduction
A team comprised of agricultural engineers and entomologists have recently been working in West Africa to assess grain drying and storage systems with the aim of reducing post-harvest losses, which are reported to be between 20 and 30% (CYMMIT, 2013). Many of these losses occur at the farm level, where the vast majority (60% to 70%) of grain in Africa is stored (FAO and INPhO, 1998), and can be attributed to poor drying and storage conditions. Additionally, farmers lack access to an affordable, reliable instrument to quickly and accurately measure grain moisture, which is a key factor in determining grain quality and storability. Our observations revealed that very few farmers and merchants have access to moisture meters, primarily because of the high cost.

Traditional (free) ways of estimating grain moisture rely on crude methods such as biting into grain kernels or shaking a handful of kernels to hear them rattle. However, maize that is not properly dried can lead to problems during storage, reduced storage life, insect and mold problems, and (worst case) aflatoxin contamination and associated health concerns, especially in warm, humid regions and seasons. Thus, a low-cost moisture meter would clearly help farmers determine when grains were well dried and ready for the market or storage. Moreover, a reliable meter is the first step in helping farmers protect their crop from mold and insect contamination and subsequently provide their families and local markets with safe, high quality grains. Accurate moisture measurement can also help merchants select which grain lots will most likely store well and which lots to reject from farmers until they are dried further. For these reasons, the need for a low cost moisture meter for developing countries has been promoted by the authors to reduce post-harvest loss of grains. The PHL meter utilized in this study report is fully described by Armstrong, et al. (2017). It was first demonstrated to an international audience during a poster presentation at the First International Congress on Postharvest Loss Prevention in October, 2015 in Rome, Italy (McNeill, et al. 2015).

Methodology
The PHL moisture meter actually measures the temperature (T) and relative humidity (RH) of the air space between grain kernels or seeds directly via a small digital sensor located in the tip of a tubular probe that can be inserted into a bag of grain or bulk grain (Figure 1). These values are then used in existing equilibrium moisture content (EMC) equations programmed into the meter's microcontroller to determine grain moisture. Specifically, the dry basis moisture content (MCdb) is calculated using the Modified Henderson equation (ASABE, 2005) using coefficients that have been previously defined for various grain types. Other EMC equations can be implemented as necessary. A handheld reader connected to the probe by a standard phone wire provides a convenient user interface which displays the temperature (C), relative humidity (%), and moisture of maize, soybean, sorghum, wheat, paddy rice, and chickpea (%wb).

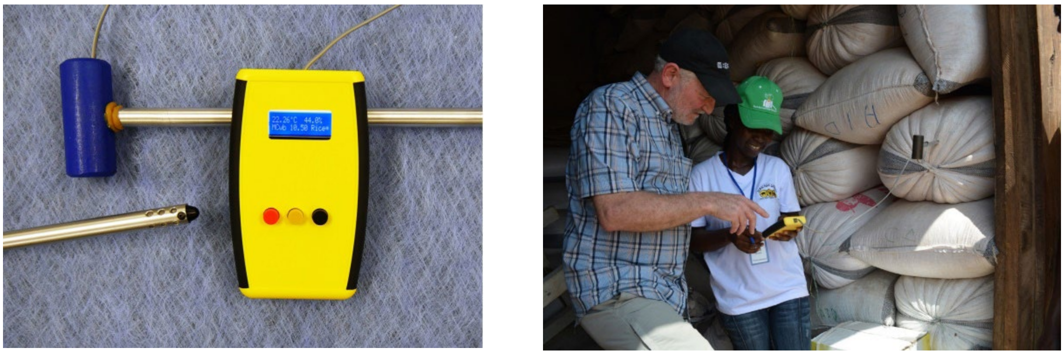

Figure 1. The PHL meter (on left featuring the probe, tip with sensors, and readout device) is used to measure grain moisture in a market stall in Ejura, Ghana (on right).

The primary benefit of the PHL moisture meter is it's relatively low cost when compared to other types of meters. The electrical components and materials costs for the PHL meters were $USD 85, excluding labor. The primary expense initially was for the sensor ($USD 28), which is accurate and replaceable but this price has since fallen to $USD 5. A more complete description of the electronic components is given in Armstrong, et al. (2017).

In a well-controlled laboratory study at the USDA-CGAHR facility in Manhattan, KS, the PHL meter accuracy was compared to two commercial meters: (a) John Deere Chek Plus-SW08120 grain moisture tester and (b) bench top DICKEY-john GAC®2500 Agri meter. The portable JD meter is a low cost meter by developed country standards (~US$250, 2016 price), whereas the GAC2500 benchtop moisture meter is a USDA-GIPSA-approved tester that is highly regarded in the US grain trade and has been used for many years. Laboratory studies indicated that the PHL moisture meter requires up to six minutes before temperature, relative humidity and grain moisture measurements should be recorded due to the time required for the probe tip and sensor to equilibrate to the air within the grain mass.

Following initial evaluation, the PHL meter has been used to monitor changes in maize moisture when stored in bags in market stalls (Fig. 1) and small bulk tanks in the Middle Belt of Ghana. The PHL meter has also been used to monitor changes in maize moisture for different storage systems (traditional polypropylene [PP] bags and PICS® bags [hermetic storage]) during a 10 month period in grain storehouses in Ibadan and Ilorin, Nigeria. Interestingly, these monitoring sites are near the same latitude so have similar environmental conditions. Data loggers (HOBO Pro v2, Onset Computer Corporation, Bourne, MA, USA) were used at all locations to record temperature and relative humidity levels inside and outside the warehouses on one hour intervals.

Results and Discussion

A laboratory comparison was made between the PHL moisture meter and GAC2500 for maize between 10% and 20% MCwb over a temperature range of 8 to 32 C. The results showed a greater error for the PHL meter at higher moisture levels and higher temperatures (Armstrong et al., 2017). However, the increase in the error is attributed to two sources, as the sensor has a higher error at high RH levels (Uddin et al., 2006) and the EMC equation is increasingly sensitive to small changes in RH above 90% RH.

A field comparison of measurements with the JD SW08120, PHL and GAC 2100 (earlier model of the GAC 2500) moisture meters at three different maize markets is shown in Table 1 (30 samples per meter). Comparing averages reveals the PHL meter is in closer agreement with the GAC 2100 (0.13% MCwb) than the JD SW08120 (2.27 % MCwb). Thus, an offset should be applied to measurements taken with the JD SW08120. The meter has the ability to store this value.

Table 1. Average moisture content readings obtained on December 15, 2016 with JD, PHL and GAC 2100 moisture meters. Readings were obtained from 10 bags (3 replicates per bag per meter) located at the specified maize markets

	Measured Moisture Content, %wb		
Location	JD SW08120	PHL	GAC 2100
Amatin	13.1	10.3	10.1
Ejura	14.4	12.6	12.5
Sekyedumase	14.5	12.7	12.6

Average monthly temperatures inside and outside the storehouse at the Eleekara market near Ibadan, Nigeria (HOBO data) are plotted along with average temperatures within the 6 PP and PICS® bags (PHL meter data). The metal roof on this structure contributed to temperatures inside the warehouse and grain bags that were slightly higher than ambient temperatures throughout the period. Differences in average grain temperatures between the types of bag used were less than 1.20C.

Preliminary results of the observed changes in maize moisture (PHL meter data) indicated that grain held in PP bags gained moisture from February to September (from 8.7 to 13.8 %wb), as shown in Fig. 2, then lost moisture the remaining three months (to12.7 %wb). In contrast, maize inside the PICS bags gained much less moisture from February to October (9.2 to 10.4%wb). However, maize samples from oven moisture tests revealed that these changes were lower than corresponding values recorded with the PHL meter (from 0.4 to 2.8%). This difference was unexpected and requires further investigation.

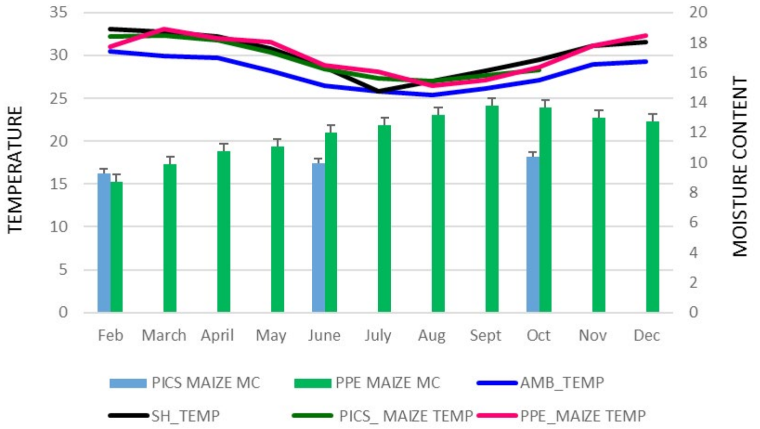

Figure 2 (graphic form). Average temperatures inside and outside a grain storehouse near Ibadan, Nigeria and average temperature and maize moisture levels within six polypropylene (PP) and PICS® bags from February to December, 2016.

Conclusion and Recommendations

The PHL moisture meter described in this report provides a reliable, convenient and relatively low cost method to measure the MC of maize and a number of other crops and is well suited for measuring bulk grains such as that in bags or silos. Because it utilizes equilibrium moisture relationships by measuring the temperature and relative humidity to predict the MC, measurements may take up to six (6) minutes. The PHL meter has been successfully used in field tests in Nigeria, Ghana and Kenya to monitor grain stored in bags and bulk containers and the environment during drying processes. Approximately 35 units have been distributed for use by service providers in villages, grain markets, university researchers, and a few privately funded researchers. Rigorous field tests in Ghana showed that the accuracy of the PHL moisture meter was acceptable compared to the GAC 2100 with a standard error of prediction of 0.57% MCwb. However, laboratory tests that included high moisture maize revealed that the PHL moisture meter underestimated maize moisture content. The John Deere SW08120 moisture meter measurements were found to have a considerable offset (2.27% MCwb) when compared to the GAC 2100 measurements. However, this offset (once known) can be applied to maize moisture measurements to give similar results as the PHL and GAC 2100 moisture meters. The current version of the PHL moisture meter design utilizes common and relatively simple electronic and mechanical components that a small local business could manufacture and assemble. A new model is presently being constructed to incorporate Bluetooth communications to allow a smart device to act as the user interface, which could eliminate some components and possibly lower the cost as well as allow easier software upgrades to the meter, such as adding new EMC coefficients for different grains.

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4006 How are Crop Post-harvest Loss Estimates for Sub-Saharan Africa Obtained? A Review of Approaches Employed

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Abstract
Reliable and consistent post-harvest loss (PHL) estimates are required to identify where interventions are needed. However, estimates differ considerably between studies and databases, especially region-wide estimates; making the extent of loss uncertain. This study reviews methodologies used to provide the magnitude of crop PHL in Sub-Saharan Africa with the aim of understanding how estimates are obtained. The procedures of 2 databases, 2 region- wide studies and 45 micro-level studies, which provided loss estimates in the last decade (2005 – 2015), were reviewed. Findings show that micro-level studies are the most crucial in providing region-wide loss estimates, as they form the basis for consolidations in region-wide studies and the development of conversion factors/ profiles used for databases. However, these micro-level studies are scarce due to both outright unavailability and a more crucial case of consequential unavailability, resulting from poorly documented procedures and inappropriate statistical analysis/ reporting. Consequently, consolidations and conversion factors/ profiles rely on some studies which are not recent, thereby overlooking the dynamic nature of PHL. Majority of the micro-level studies reviewed lacked thorough documentation of procedures, failed to report variability measures, or failed to indicate clearly which variability measure was reported. To provide reliable and updated estimates for the region will require avoiding consequential unavailability by improving documentation and reporting in micro-level studies.

Key words:
Assessment methods, micro-level, post-harvest loss, region-wide, sub-Saharan Africa.

Introduction
Reliable and consistent post-harvest loss (PHL) estimates are important to identify priority areas for both private and public interventions to reduce these losses. However, estimates of food biomass loss provided for Sub-Saharan Africa (SSA) vary considerably between databases and between studies. For example, loss estimates differ between the Food and Agricultural Organization's (FAO) food balance sheet (FBS) and the African Postharvest Loss Information System (APHLIS) databases. The 2011 maize losses for Ethiopia, Burkina Faso, Kenya and Zimbabwe estimated by APHLIS are 3.75 times higher on average than those reported by the FBS of FAO. For SSA as a whole, estimates by FAO (6.4 percent) do not sound alarming, while the corresponding 17.8 percent loss figure reported by APHLIS is high enough to justify political action to address the African PHL problem. The focal question is: how are these and other loss estimates obtained?Understanding approaches used in loss assessment for crops helps to highlight the possible reasons for variations in estimates and define the context in which they can be referenced, while discussing possible ways of improving them.

This study focuses on: 1) Reviewing the approaches utilized for crop PHL estimation in regional studies/ databases and micro-level studies (studies which provide estimates for specific points or processes in the marketing chain in specific locations) for the period 2005 to 2015, and discussing the context in which resulting estimates can be referenced; and 2) Outlining possible ways of improving the consistency of estimates.

Methodology
The procedures of 2 databases, 2 region- wide studies and 45 micro-level studies were reviewed. Procedures for the FBS and APHLIS loss estimations were obtained from the FAO and APHLIS websites, respectively, while a search for other accessible studies providing region-wide and micro-level assessments was conducted in databases –Elsiever, Science Direct, Wiley online library and Google scholar. Studies were also tracked from the reference list of related articles. We screened resulting literatures based on two criteria. First, in consideration of the dynamic nature of PHL, we restricted selection of both region-wide and micro-level studies to those conducted in the last decade (2005-2015), and secondly, for micro-level articles we selected those which conducted surveys or used primary data for PHL assessment. Methodologies of the selected articles were first reviewed for detailed documentation and procedures for loss assessment, and then classified into approaches. A further review was conducted for detailed statistical reporting of results.

Results and Discussions
Region-wide estimates were observed to be derived. The derivation is either through the use of loss profiles/ conversion factors or the consolidation of estimates from micro-level studies, making these micro-level studies an important factor in obtaining consistent and reliable regional PHL estimates. However, some of the micro-level studies used date as far back as the 90´s. Also, computing procedures vary considerably among regional databases and studies, which is a likely reason for the stark difference in estimates. At the micro-level, studies reviewed also employed varying approaches –subjective assessment (55.5%), direct assessment (22.2%), trials (13.3%), simulations (20%), and rapid assessment (2.2%). This implies the high use of guesstimates in providing quantitative PHL estimates at micro-levels in the last decade, which will consequently apply at the regional level, if the dynamic nature of PHL is to be considered during estimation.

Two major problems observed for region-wide studies and databases are scarcity and consequential unavailability of micro-level studies. The scarcity is due to an imbalance in micro-level loss assessment reports across agricultural commodities, value chain levels and countries. For example, despite the importance of legumes and root/tubers in SSA, only 6.7% and 11% of reviewed studies focused on these, respectively, for both quantitative and quality losses; more studies focused on fruits and vegetables.

As such, availability of micro-level estimates is skewed for commodities and unofficial estimates or data sharing are relied on. Conversely, consequential unavailability is due to a lack of properly documented procedures and appropriate statistical analysis and reporting, and increases the probability of exclusion of these studies as data sources for reliable region-wide computations. For example, Affognon et al., (2015) appraised the methodological quality of studies and also screened for variability measures (VM) in selecting studies. In most studies reviewed, VM are excluded or not clearly reported. Of the reviewed micro-level studies, over 60% reported means without VM or the possibility of computation. About thirty seven percent (37.5%) of the reports with VM did not indicate which was being reported –standard deviation or standard error. Furthermore, most studies which used the subjective assessment approach lacked thorough documentation of procedures for both the sampling and estimation phases of loss assessment, which is crucial for assessing methodological quality and usability in providing region wide estimates.

Conclusion and Recommendations

Region-wide PHL estimates are obtained from micro-level studies with the use of different methodologies. Although developing a consistent methodology, which can be accepted as a unified method, for both estimating region- wide PHL and developing conversion factors/ loss profiles might be needful, it is not sufficient in improving estimates because the quality of estimates provided by whichever procedure can only be as good as the quality of the data used. As such, the departure point for consistent and updated PHL estimates requires reliable and sufficient micro-level studies and reports. First, more frequent investigation periods and balanced research across agricultural commodities would be important as regular and balanced repetition of PHL measurement would reflect its dynamic nature and provide a basis for comparing estimates over time and across improved strategies. PHL is not expected to be static; improved technological and infrastructural factors, as well as changing environmental conditions occur over time and should be considered. Secondly, a high reliance on the subjective assessment approach though beneficial in qualitative and monetary loss assessment, is problematic in quantitative loss assessment where records are absent and there is an interaction of memory and perceptions. Understanding and addressing issues resulting in the high use of this approach is crucial in providing reliable quantitative PHL estimates. Finally, appropriate statistical analysis and reporting is crucial in ensuring the reliability and usability of micro-level estimates.

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4007 Qualitative Discussion About Reducing Grain Postharvest Loss With Logistical Platforms in Ghana, West Africa.

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Abstract
Farming without storage that stops grain postharvest and input loss suffers critical problems like aflatoxin contamination. The objective of the study was to understand why the spread of inputs, and stationary surplus grain storage have failed to reduce PHL. Qualitative comparison methods identified roadblocks in Africa as scientific monitoring and poor storage that do not allow reduction of PHL to significant levels. The results of the discussion concluded with recommendations that it is PHL that is expensive, not assets like Mobile metal grain storage that awards rights to democratize food chain decisions, so two farms may be managed to achieve agriculture's triple-bottom-line and Foreign exchange reserves.

Key words:
Grain, storage, postharvest loss, triple-bottom-line

Introduction
Farming is about harvesting as much as possible from land use, fertile soil, blue water (ecosystem services), and choosing sustainable practices that protect harvested food from being wasted. If stored correctly, "staples, pulse, and legume" (grain) surplus produced by farming pay for "health care, school fees and peace-of-mind" (net benefit). Surplus quality has utility as "sustained nutritional choices, ecosystem services, and profit" (triple bottom-line), "reduce imports and increase exports" for Foreign exchange reserves.

Of course, not all farm production is achieved equally and so it is impossible to lump all postharvest loss together. Some postharvest loss is of fruits, vegetables, and meat (dense nutrition) and some is dry, high calorie and protein grain. However, grain provides most of the calories that power animal and human hard labor to "plant, grow, harvest, thresh, clean, dry, aggregate, store, monitor and process" grain and densely nutritious food. At farm level, especially in the field, many factors that influence postharvest loss are environmental. For example, biotic problems like fungi, insects, rats, birds, or abiotic problems like groundwater, flooding, wildfire and theft are difficult or impossible to control without effective grain storage.

Historically African Postharvest Loss means Sub-Saharan Africa (SSA) grans are contaminated during storage by fungi that produce aflatoxin. Aflatoxin "increases morbidity and mortality" (IARC, 2016) and small-scale grain growers cannot safely consume or market surplus for net benefit. Although solutions that stop fungi and other problems are available "the value of solutions are not always equal to the exposure they get" (SIANI, 2015).

Without storage, growers are disadvantaged and forced to sell early or suffer significant postharvest loss (Lipinsky, 2013). Opportunistic traders know growers are forced to sell early, and set low prices. Low prices reduce the net benefit of hard labor, ecosystems and production inputs like "Esoko (sms information), Fasiba (virtual market), AgriCorp (education), Oikocredit (micro-finance), Area Yield Index Crop (insurance), Hello Tractors and Solar powered irrigation (mechanization), ICRISAT (improved varieties), IFDC (fertilizers), Push-Pull cropping and Plastic pest management" and other process improvements like commodity marketing. The result is that, the disadvantaged grower may experience "market failure" (Jones, 2011) after selling grain raw, and then buying similar grain back at a higher price. Or, if the grower attempts to gain the advantage by controlling assets that store grain in sack, airtight plastic bag or metal can, they may "challenge the tradition" of patriarchs (Bott, 2005). Development confronts postharvest loss with production packages that temporarily increase gross grain production. If development experts realized that grain Postharvest and input Loss (PHL) is an integral part of the whole system (Boa, 2016), the new 'golden age' of agronomy could improve the process and increase net benefit from the triple-bottom-line and Foreign exchange reserves (Pearce, 2016).

Simply, farming without storage that stops PHL suffers critical problems like aflatoxin contamination. For example, it might not be true, that in food-scarce conditions, PHL like aflatoxin in food is still better than no food at all (Lindahl, 2016). Justifiably, many current calls for innovation refer specifically to grain storage, as there are few healthy outcomes if inputs are wasted and labor requires consuming aflatoxin with calories (Mendoza, 2016).

Our objectives were to understand why the spread of inputs, stationary "grain distribution and logistical infrastructure and virtual markets" (GDLI) for surplus have failed to reduce PHL. Understanding why "losses are most critical in developing countries" (Kumar, 2017) would help "development experts guide WFP action, ICRISAT improvement, FtF innovation and GIZ intervention" (research, outreach) for example.

Materials and Methods
The three qualitative comparison methods were:
1. Evaluating the scientific rigor used to assess GDLI by organizing, reviewing, and comparing research and outreach literature
2. Ground-proof mobile GDLI by observing adaptive learning at 4 locations
3. Identifying any potential roadblocks to reducing PHL by adopting mobile GDLI.

Results and Discussion

Qualitative results are relevant as scientific monitoring and improvements to GDLI reduce PHL to insignificant in areas that send Africa staggering amounts of nutrition (Juma, 2016). The key results suggest net benefit is being ignored as reviews and assessments of primitive or institutional GDLI (Kaminski, 2014) exchange scientific rigor for "Stationary Warehouse Prejudice" (Adjei, 2017). Examples of Stationary Warehouse Prejudice are reviews like Kumar (2017) that ignore that sealed systems need additional GDLI and plastic must be recycled before it is chemical free. Another example is how the WFP "Global Postharvest Knowledge Center" (Rierson, 2017) ignores that refugees are tenure-insecure. The last example is MIT's "Comprehensive Initiative on Technology" (2016) that merely evaluates the end-user-cost per unit stored (Amaizz, 2015), and assumes that all GDLI listed were full for the same period and therefore provide similar net benefit. Replacing Stationary Warehouse Prejudice with scientific rigor, would illuminate the cost of recycling, handling and additional GDLI per unit per number of months stored, improve grower net benefit, agriculture's triple-bottom-line, and foreign reserves.

Potential roadblocks to PHL reduction are:

- Aflatoxin challenge that plagues African farmers, other agri-entrepreneurs, and governments, is ignored (Francis, 2016).
- Poor GDLI built by growers from local materials, is limited by the condensation caused by day and night temperatures that allow some abiotic problems to flourish in sealed systems. Local materials used do not protect grain in sacks from problems and primary processing wears plastic quickly and soon bags need recycling. Airtight metal cans built by local artisans are hard to handle if they are large enough to store surplus cost-effectively.
- Purchase price of stationary metal GDLI is major obstacle for growers. However, metal GDLI can be effective as the maintenance cost is very low and the cost per unit stored decreases with increases in size.
- Development production packages that merely raise gross production, without addressing PHL. Often the temporary support includes institutions that create GDLI for average local production, forgetting how averages are rare and PHL drives the degradation of ecosystems. Many institutions attempt to exclude opportunistic traders and include growers by implementing warehouse receipt systems (WRS). However, if the WRS GDLI is "distant or does not scale or accomplish pest monitoring for cost-effective and judicious management" (unresponsive), it is soon a rusting monument to PHL.
- Agribusiness profits from PHL in that this reduces the food supply thus creating a demand for inputs to produce more food. In fact, SSA agribusiness sees little profit in the preservation of food once it is produced (Wilson, 2016) and often lobby for research assessments and outreach agendas that create demand for inputs. These assessments and agendas ignore how agricultural intensification or extensification is soon limited by ecosystem degradation.

For developing economies, degraded ecosystems, mean that water and soil are less likely to mitigate drought, pests or sustain yields. Ultimately roadblocks mean incentives to produce surplus grain lack substance and soon investors are concerned about inputs that do not produce global quality. The results are staggering. "Africa imports 83% of the food it consumes, though it holds nearly 50% of the land available worldwide" (Juma, 2016). On the other hand, PHL reductions "increase food availability without further use of land, water, and other agricultural production inputs" (APHLIS, 2015) thus, leading to more sustainable systems.

A pilot navigated through Ghana's agricultural business environment and observed adaptive learning that suggested mobile metal GDLI (Figure 1.) addresses the needs of tenure-insecure growers. Ground-proofing at 4 of many locations (Figure 2.) observed rights shifted control to growers, away from patriarchs wielding land-tenure, opportunistic traders setting prices or institution that are unresponsive (Easterly, 2016). African farmers "who notice their maize is damaged by pests or fungi, take measures to reduce these problems" (Hell, 1999). Initially mobile GDLI can be leased to offset end-user-cost, then at harvest it breathes to mitigate condensation, rises above rats and groundwater so storing is optimal and reduces the hard labor of primary processing at markets. GDLI with mobility to scale at problem control points is optimal for tenure-insecure SSA growers and soon the net benefit of marketing quality surplus compensates for the lease or purchase price.

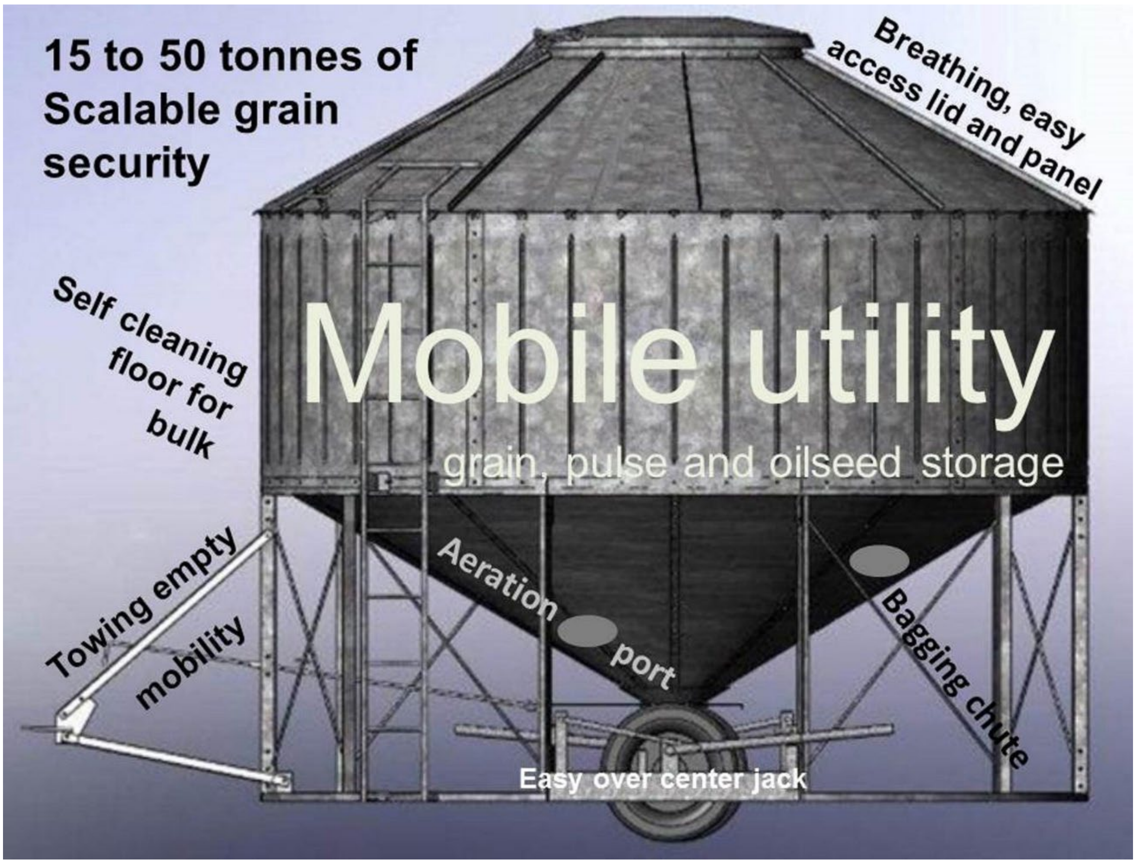

Figure 1. Mobile metal grain distribution logistical infrastructure has utility to store surplus
Source: Unknown and modified by author

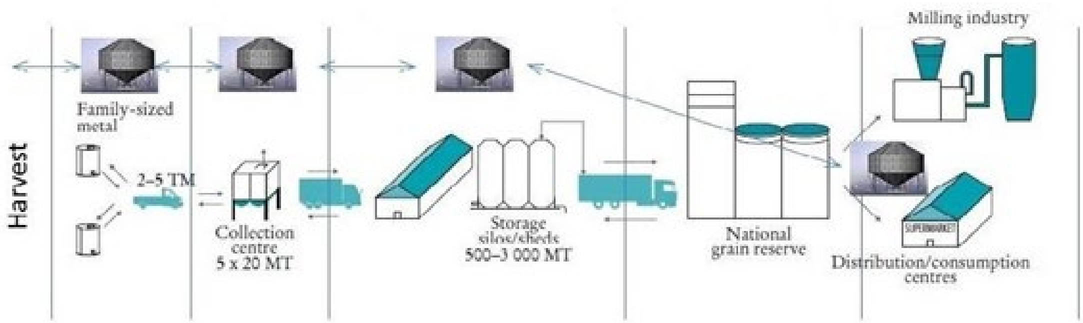

Figure 2. Mobility lets growers optimize GDLI for their net benefit at many locations.
Source: FAO 2015 D. Mejla and modified by author

Conclusion and Recommendation

Any discussion will conclude it is PHL that is expensive, not optimal GDLI as "amidst decades of grain net benefit increases in other parts of the world, current SSA grain agriculture stands out as less mechanized, low-net-yielding, and insecure" (Juma, 2016). Mobile metal GDLI awards rights to democratize food chain decisions, so policy progresses and growers set, or modify, their own goals, so two farms with identical climates and soils may be managed with different aims to achieve a different mix of net benefit (FAO, 2015) and:

- cost-effective and scientific pest monitoring procedures permit judicious adjustments to the timing, choice, and intensity of control actions; timely chemical pest control measures, in grain storage, which are often not only the cheapest but also the most reliably efficacious of the possible options (Proctor, 1994).
- agriculture's triple-bottom-line benefits the people in an inclusive manner, and drive sustainable practices for managing natural resources and minimizing environmental degradation (UNEP, 2015).
- less imports and foreign exchange expenditures. The converse follows logically, that quality surplus improves exports for net foreign exchange (Welsh, 2016).

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4008 Willingness to Adopt Plastic Crate by Actors in the Tomato Value Chain in Nigeria

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Abstract
Tomato is the most widely consumed fresh vegetable in Nigeria. Tomato presents distinct problems of both transportation and packaging because it is much more perishable than other vegetables. The objective of the study was to investigate the awareness and willingness of stakeholders in the tomato value chain to adopt a new packaging container (plastic crate), as against the conventional traditional woven basket. Plastic crate was introduced to the market in Kwana Garfan and transported to Mile 12 Lagos. A structured questionnaire was administered to obtain information from the stakeholders (that is, dealers, brokers, retailers, truck drivers and loaders). The awareness level for plastic crate was averagely low but most stakeholders believed that plastic crate was more appropriate in tomato handling. Dealers were not ready to accept the responsibility for the cost of transfer, saying retailers should be responsible (66.7%) for tomatoes purchased with plastic crate. On the other hand, 72% of the interviewed retailers accepted responsibility for transferring tomatoes into plastic crates upon delivery. Alternative containers considered appropriate for subsequent transactions were raffia basket, plastic bags and carton box. With economic consideration, 85.7% and 15.4% of the dealers and retailers, respectively, believed that it would increase their income while 39.1% of loaders believed that it would increase cost of loading. In general most stakeholders were willing to adopt plastic crate.

Key words:
Adoption, wwareness, affia basket, plastic crate, willingness

Introduction
Tomato is the most widely consumed fresh vegetables in Nigeria. The country is second largest producer of tomato in Africa (FAO, 2013). The concentration of production is in the northern part of the country due to ecological specialization. As a result, there exist an active local trade between the cities in the north and south. Tomato presents special problems of both transportation and packaging because it is more perishable than other vegetables because it is more perishable and tender (Mohammadi-Aylar et al., 2010). Tomatoes are consumed as complementary foods and in smaller qualities than staples, but they are a significant source of nutrition for substantial portions of the Nigerian population. Tomatoes are important as a valuable source of food minerals and vitamins, principally vitamins A and C in the daily diet (Pardee, 2008).

Transportation, no doubt, constitutes a phase in the postharvest system (hence, value chain) of tomatoes in Nigeria where mechanical damage is particularly high. The gravity of widespread loss in the transportation of packaged tomatoes in the country has become a complex postharvest problem in the tomato value chain. In the horticulture sector, the vision for systemic transformation is to introduce new packaging material for international best practices in the distribution of tomatoes to reduce postharvest losses and increase incomes for the actors across the value chain. In Nigeria, the traditional woven baskets that are used to transport tomatoes frequently cause fruit spoilage. Hence, there is a need to introduce new packaging and packing materials comparable to international industry standards, where plastic crates are used for long distance distribution of tomatoes. The objective of the study was to investigate the awareness and willingness of stakeholders in the tomato value chain to adopt a new packaging container (plastic crate), as against the conventional traditional woven basket.

Materials and Methods
The study was carried out in Kwana Garfan in Kano state (the biggest tomato collection centre in Nigeria) and Mile 12 international Fruit and Vegetable market, Lagos state (delivery market). For the purpose of this study, plastic crate was introduced to the market in Kwana Garfan and transported to Mile 12 Lagos. The filled plastic crates were allowed to pass through the normal transportation process. A structured questionnaire was administered to obtain information from the stakeholders including dealers (wholesalers), brokers, retailers, truck drivers and loaders). Dealers, truck drivers and loaders were interviewed at the collection centre while brokers and retailers were interviewed in the delivery market. Data collected from respondents were analysed, using descriptive statistics.

Result and Discussion
The awareness level for plastic crate was averagely low with truck dealers being the lowest 20% and truck drivers 56.5% highest. Dealers (100%), retailers (100%) with brokers (64.3%), drivers (80%), and loaders (78.3%) believed that plastic crate was more appropriate for tomato handling. On willingness to adopt, all the dealers, retailer, drivers, 91.3% of loaders and only 42% brokers were willing, with different degree of willingness ranging from "willing" to "highly willing". Dealers were not ready to accept the responsibility for the cost of transferring tomatoes, saying retailers should be responsible (66.7%) for tomatoes purchased with plastic crate (33.3%) while 72% of the interviewed retailers accepted responsibility for transfer into plastic crates upon delivery, containers considered appropriate for subsequent sales transactions were wooven basket (62.5%), plastic bags (25%) and carton box (12.5%). Economically, 85.7% and 15.4% of the dealers and retailers, respectively, believed that it would increase their income while 39.1% of loaders believed that it would increase cost of loading. In the delivery market, tomatoes in plastic crates were sold faster than those in baskets because of the good quality. Concerning plastic crate ownership, 50% of the dealers, were willing to own the plastic crates and the remaining 50% pre-

ferred renting the plastic crates, while for the retailers, plastic crate 91.9% of the retailers prefer owning the plastic crate while the remaining 9.1% prefer to rent plastic crates. 53.3% (dealers) and 66.7% (retailers) believed that association will be most appropriate for distributing or renting the plastic crates for the reasons that the association controlled the major activities in the market and had direct access to the dealers. 46.7% and 16.7% of dealers and retailers respectively preferred private dealers such as the one currently handling basket distribution. Of the dealers, 66.7% intended to acquire the plastic crates with their personal funds. 20% wished to purchase through cooperative, 6.7% through loans and 6.7% through Government aid. The major challenges perceived by the stakeholders in adopting plastic crate includes:

i. The tomatoes in the plastic crate should be full, since the retailer deals not only in quality but also in quantity.
ii. The size of the plastic crate should be bigger (40-50 kg was recommended).
iii. The tomatoes should be sold with plastic crates.
iv. They were not sure of the price of the plastic crate but if it was high it would affect their willingness in using plastic crate.

Conclusion and Recommendations

It was generally noted that the tomato dealers (especially the large-scale dealers) were very willing to adopt plastic crates but the acceptance of the intervention was mainly in the hands of the actors, that is, dealers and retailers, in the delivery market (Mile 12). The dealers were concerned more about the size of the plastic crate, while the retailers were not particularly concerned about the packaging material but rather the quality and quantity of the contained tomatoes. To hasten adoption, there is need for setting of specifications for any newly introduced packaging containers (such as plastic crate and fiberboard cartons) in consultation with the stakeholders-growers, transporters, handlers and traders.

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4009 Agricultural Service Delivery: Strengthening Private Crop Protection Service in Southern Ethiopia

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Abstract
Agricultural extension service is one of the institutional supports that has a key role in provision of sound advice, education and ensure transfer of knowledge and skills to famers to stimulate agricultural development. Mabeza-Chimedza (2000) described agricultural service to include the variety of services and goods which are provided by various institutes for farmers to supply seeds, fertilizer, credit, machineries, product services, other technologies, information and trainings. In the Ethiopian extension system, the crop extension packages include food crops, post-harvest activities, inputs for improved seed and fertilizers (Carlssonet al., 2005). Large scale crop protection service is totally implemented by Ministry of Agriculture. At present smaller scale farmers, however, are responsible for purchasing pesticides unless the situations are threatening for food security of an area or region at larger scale (Abate, 2006; Abate and Fenta, 2003). The practice of using agro-chemicals to reduce crop loss by individual farmers without formal training and linkage with ministry of agriculture is described as informal crop protection services (ICPS). There is less involvement of private sector in crop protection service which calls for strengthening of the service through training, input supply, monitoring and evaluation of the service. Private crop protection service (PCPS) refers to crop protection service provided by trained farmers to use agro-chemicals and bio-pesticides with support from International Livestock Research Institute (ILRI) managed project for input supply and linked with service from the office of agriculture.

Introduction
Pre and post-harvest crop loss is one of the major bottlenecks to increased crop productivity and grain quality in Ethiopia. Estimate shows a crop loss from 30 to 50 % (EIAR, 2009; Abesha, 2006; Simane, 2004) at national level which is similar to the crop losses in the study area, Halaba special District in the Southern Ethiopia. There are several major national challenges in agricultural service delivery. First, there is no service provider so far licensed to work as part of the private sector in crop protection. Second, although guidelines and legislation on pesticide exist, they have not been enforced effectively (EIAR, 2009) even today. Third, pesticide use by the smallholder farmers in Ethiopia is extremely low. Recent increase in use of pesticides in the country is associated with the expansion of the floriculture industry. Ethiopian agriculture is dominated by smallholder farmers and majority of the farmers lack both resources and knowhow (on safety and chemical toxicology) and do not use improved agricultural technologies (including crop protection) (Abesha, 2006; Abate, 2006). The average annual import of pesticides for the last seven years is about 1100 tons. Fourth, pesticides are distributed to smallholder farmers through formal and informal retail outlets (Simane, 2004) where the private sector also plays a role. The objective of this study was to document lessons gained share experiences and develop strategies for strengthening private crop protection service (PCPS). The study describes crop protection in the area, shows how to promote private sector involvement through strengthening PCPS with multiple actors. It also shows role of developed service from economic, socio-technical and environmental point of view. The study shows how to transform existing crop protection service delivery to reduce crop loss with a support of private sector to address the need of smallholder farmer.

Materials and Methods
The study was conducted at Halaba Special District, located at 310 Km South of Addis Ababa and 85 Km South West of Hawassa, the capital of South Nations Nationality and Peoples Regional State (SNNPRS). The District is located at 70 17' N latitude and 380 06' E longitudes. Three key steps were taken to strengthen the crop protection service. First, assessing existing crop protection services (Informal Crop Protection Service, ICPS). Second, targeting and building capacity of eleven farmers to serve as private crop protection service (PCPS) providers. Third, service provision for two crop seasons in 2007 and 2008 and assessment of service. The study methods included questionnaires (key informants, focus group), service ranking, temporal service comparison and Strength, Weakness, Opportunities and Treats (SWOT) analysis. Temporal evaluation (pre and post service) of the service was also undertaken with the community in the study area. Indicators were used to examine sustainability, merits, and demerits of PCPS. Socio-economic benefit was analyzed using field data collected in two cropping seasons in 2007/8.

Results and Discussion
The study showed that the PCPS in 2007/2008 crop seasons benefited 1104 households (HH) on 1707 ha of land in 19 Kebeles Associations (KAs). The estimated PCPS direct off-farm income was 194 USD/season/ service provider. The estimated average yield increase due to PCPS was 2.9 quintal/ha with an estimated indirect financial benefit of 197 USD/season/customer. The total community financial gain from reduced crop loss was 327,752 USD during the growing seasons. The benefit of the service in terms of reduced crop loss and corresponding yield increment was equivalent to 4609 quintal/service area. Post service assessment shows reduced crop loss, increase access to service and frequent monitoring by OoARD. The merits of PCPS are use of bio-pesticides, safe use of agro-chemicals, use of protective devices and better linkage of service providers with OoARD. Service assessments show higher demand, positive perception, and better attitude for the PCPS compared to the existing informal crop protection services (ICPS).

Conclusions and Recommendations

Complementing existing ICPS through strengthening of PCPS can address the problem of crop loss while contributing to existing crop extension program and encouraging private sector involvement. Strengthening ICPS was possible by using trainings, demonstration, promotion, visits and strengthening partners linkage. Government role lies in support of coordination, monitoring, evaluating and certifying of PCPS. The project managed by ILRI demonstrated role of PCPS in strengthening public extension as reflected in public perception, positive attitude towards the service and sustainability of the service based on business model. Future direction should focus on developing service guidelines, indicators and setting a direction to certify service providers. The study recommends piloting and scaling up the service in additional areas as a new approach for improving agricultural service delivery and reducing the major crop loss related bottlenecks to increased crop productivity in Ethiopia.

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40010 Community of Practice (CoP) on Food Loss Reduction: A Global and Dynamic Platform for Solutions Sharing.

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Abstract
The complexity of food losses issues and their importance on food security require a global and comprehensive approach to understand their major causes and to identify and promote appropriate and feasible solutions in different geographic areas and contexts. A Community of Practice (CoP) on food loss reduction was designed and launched in October 2014 in the framework of UN Food and Agriculture Organization (FAO), the International Fund for Agricultural Development (IFAD) and World Food Programme (WFP) joint project titled "Mainstreaming food loss reduction initiatives for smallholders in food deficit areas" funded by the Swiss Development and Cooperation Agency. The CoP on food loss reduction serves as a global convener and an integrator of knowledge related to post-harvest loss reduction. It offers a platform to facilitate linkages and information sharing amongst stakeholders and relevant networks, projects and programs. The CoP website shares information, relevant news, events, online discussions, resources, and links to partners. In early 2017, members have expressed their interest in accessing the CoP for getting information on News, Events, Resources and technical expertise. More can be done to attract the participation at Forum discussions. It is recommended that in its continuation the CoP offers more resources and exchanges, in addition to English version. More contributions in French and Spanish should be generated for reaching out a wider community of practitioners. Food loss reduction practitioners should be further encouraged to support the CoP global commitment to address post-harvest losses toward the achievement of SDGs by 2030.

Key words:
Community of practice, food loss reduction, knowledge sharing, networking & partnerships

Introduction
The complexity of food losses issues and their importance in food security require a global and comprehensive approach to understand their major causes and to identify and promote appropriate and feasible solutions in different geographic areas and contexts. The levels of losses depend on the level of development and the efficiency of food supply chains, the categories of foods and their nature (perishable vs. nonperishable products), and agro climatic conditions. FAO stated that one third of the world food production is lost or wasted. Food loss is considered as "decrease in quantity or quality of food" reflected in nutritional value, economic value or food safety of all food produced for human consumption but not eaten by humans. Food waste is intended as part of food loss and refers to discarding or alternative (non-food) use of safe and nutritious food for human consumption all along food supply chains (FAO 2014). The level of losses and waste for cereals was estimated to reach 30%, dairy products 20%, fish and seafood 35%, fruits and vegetables 45%, meat 20%, oilseeds and pulses 20% (SAVE FOOD global initiative on food loss and waste reduction 2017). Grain losses alone in sub-Saharan Africa are worth potentially $4 billion a year and could meet the minimum annual food requirements of at least 48 million people (FAO 2011).

The same report highlights that "significant volumes of grain in developing countries are lost after harvest, aggravating hunger and resulting in expensive inputs—such as fertilizer, irrigation water, and human labor—being wasted. Losses in quality and quantity occur during harvest and postharvest operations. Losses in quality lead to a loss in market opportunity, economic and nutritional value; under certain conditions, quality issues due to inappropriate handling can cause a serious health hazard if linked to consumption of aflatoxin-contaminated grain (The World Bank 2011)" In addition, food loss and waste also have considerable environment impact. "The later a product is lost or wasted along the supply chain, the higher the environmental cost, as impacts arising for instance during processing, transport or cooking, will be added to the initial production impact" (FAO 2013).

Methodology
There is a need to share widely the existing knowledge on food loss reduction in order to disseminate and promote the solutions that are feasible in a given context based on the major causes identified. Food loss assessments have been carried out in different supply chains in different countries for this purpose. Such assessments of the causes and appropriate solutions need to be carried out to ensure the feasibility and the sustainability of the solutions to be recommended and promoted in different contexts. "Technical causes may include harvesting methods; handling procedures, drying techniques and moisture levels (in the case of grains); types of storage or lack thereof; filth or contamination; attacks by rats, birds, and other pests; insect damage; and infestation by food-borne pathogens.

Governance-related causes can include poor sales, procurement, storage, marketing and distribution policies or practices; absence of mechanisms for dealing with cash flow needs (such as warehouse receipts systems; WRS); mismanagement or malfeasance in handling grain stocks and associated financing; or difficulty in dealing with the ownership, control, and payment aspects of grain storage and price stabilization programs" (FAO 2013). The FAO global report on food loss and food waste highlights that "the causes of food losses and waste in low-income countries are mainly connected to financial, managerial and technical limitations in harvesting techniques, storage and cooling facilities in difficult climatic conditions, infrastructure, packaging and marketing systems. Given that many smallholder farmers in developing countries live on the margins.

In 2013, FAO and partners carried out a survey to assess the needs and how to facilitate exchange and networking of the expertise generated in the recent decades on post-harvest handling (PHL) and food loss reduction, and mobilized resources to meet these needs. As a result, a Community of Practice (CoP) on food loss reduction (Community of Practice in food loss reduction 2017) was designed and launched in October 2014 in the framework of the UN Food and Agriculture Organization (FAO), the International Fund for Agricultural Development (IFAD) and World Food Programme (WFP) joint project titled "Mainstreaming food loss reduction initiatives for smallholders in food deficit areas" funded by the Swiss Development and Cooperation Agency. The project aims to improve food security and income generation opportunities through reduction of food losses in supported food grains and pulses value chains.

By mobilizing the individual strengths of the three agencies, the joint project has significant impact and influence in stimulating Member Countries to take action to reduce food losses and is expected to be a model for future collaboration and up-scaling of the UN Rome-based agencies (RBA) collaboration. It will contribute both to the Sustainable Development Goals (SDGs) for improving food security, reducing hunger, poverty and food loses and to the Zero Hunger Challenge launched in June 2012 by UN Secretary-General Ban Ki-moon, which includes zero loss or waste of food as one of its elements. All the three RBA are committed for the realization of this global agenda and the project gives an opportunity to strengthen their collaboration.

Results and Discussion

The Community of Practice (CoP) on food loss reduction serves as a global convener and an integrator of knowledge related to post-harvest loss reduction. It offers a platform to facilitate linkages and information sharing amongst stakeholders and relevant networks, projects and programs. The CoP website shares information, relevant news, events, online discussions, resources, and links to partners. It is a dynamic platform that facilitates information sharing and coordination. In getting involved, registered members become also part of the global mobilization of stakeholders to help reduce food losses and waste. Registered members are also members of the SAVE FOOD global initiative on food loss and waste reduction.

The published News and Events items refer to CoP members' activities, projects and programmes and are developed and published in three languages (English, French, and Spanish) for disseminating information and reinforcing partnerships between the members. News and Events include conferences and training opportunities. It is a means to share any new development in the PHL reduction discourse, updated information and insights, and for providing and facilitating access to capacity building opportunities.The CoP disseminates information on post-harvest food loss reduction solutions that have been produced and piloted by different stakeholders and partners e.g. by FANRPAN, and on related policies.

The Multimedia section of the website offers links to videos and animations, which illustrate solutions and applied methods for reducing food losses in different areas of intervention with the aim of sharing knowledge and expertise through the different media and languages. Given the fact that storage is a major critical loss point along cereals and pulses value chains, a joint section of the CoP Resources was developed with the Natural Resources Institute of the Greenwich University, and it provides access to a catalogue of grain storage techniques for easy access of practitioners as developed by NRI/Greenwich University.

Overall, the CoP shares and facilitates access to updated resources and information on PHL, including on economic, environmental, gender, and nutritional analyses, as well as support to the development of policy and regulatory frameworks that are conducive to FLR. To this aim, several links to FAO and non-FAO publications tackling these issues are made available in the different sections of the platform.

In addition, through the online discussion Forum a mapping of post-harvest management projects managed and/or implemented by the CoP members was undertaken through the compilation of a dedicated form. The results allowed for producing an interactive map that is being updated on a regular basis available online. It is key tool for coordination and optimization of resources for stakeholders from the public and the private sectors who are seeking information on ongoing PHM and food loss reduction activities and interventions in a given country or area, as well as for project development and investment purposes.

Enriched with updated information on a regular basis, the CoP has over 600 registered members worldwide and has recorded an average of 1500 hits per month for a total of 11,500 visits up to December 2016. In being members, experts are informed on projects and programs on food loss reduction and post-harvest management, participate to online moderated discussions in the CoP Forum, and stay tuned on relevant news and events. This allows experts, students, researchers looking for PHL solutions to be aware of the existing options that are offered around the world for reducing PHL, and being connected with providers from the private sector. In fact, the CoP counts as registered members a variety of different actors from national and international organizations such as universities, private sector, UN agencies, agricultural services, producers' associations, research centers and NGOs (Figure 1).

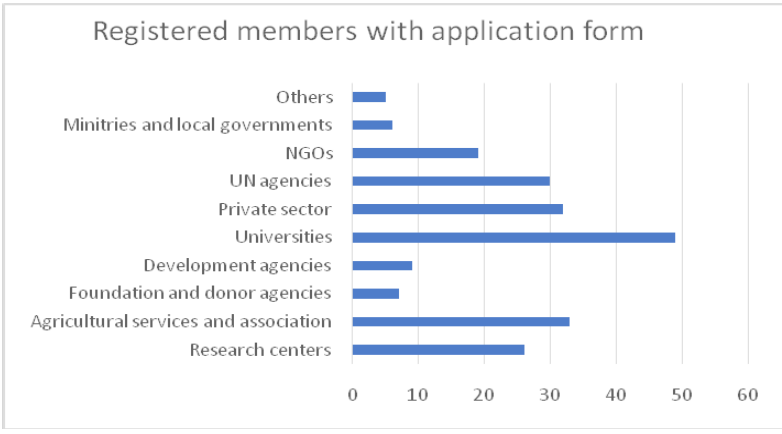

Figure 3 - CoP on food loss reduction registered members as of December 2016

Conclusion and Recommendations

In early 2017 an online survey administrated to all the registered members of the CoP expressed their feedback on the usability and efficiency of the Community of Practice. Members have confirmed their interest in accessing the CoP for getting information on News and Events, Resources and technical expertise. More can be done to attract the participation at Forum discussions, given the fact that, in addition many members responded that have not been using the Forum at all. Others expressed that they only read the Forum discussions if the topic is of interest for their work.

It is recommended that in its continuation the CoP will offer more resources and exchanges, in addition to English language.. More contributions in French and Spanish have to be generated for reaching out a wider community of practitioners, especially due to the fact that mainly francophone experts perceive this issue as an obstacle for benefiting from the CoP. Furthermore, food loss reduction practitioners should be further encouraged to support the CoP global commitment to address post-harvest losses toward the achievement of SDGs by 2030.

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40011 Effect of Improved Practicess on Food Grain Losses and Income of Vulnerable Household in Kebbi, Sokoto and Federal Capital Territory in Nigeria.

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Abstract
The study examined the effect of improved practices on postharvest losses and income of vulnerable households in Kebbi, Sokoto and Federal Capital territory, Nigeria. A multi-stage random sampling was used to select 350 respondents from two communities in Bwari Local Government area of Federal Capital Territory, two communities from two local government areas of Kebbi state and eight communities from four Local government areas of Sokoto State as sample size for the study. Primary data was collected through the use of detailed questionnaire and data generated was subjected to inferential and descriptive statistics. Results indicate improved practices has an increasing effect on mean income of respondent by shifting the intercept upward but a decreasing effect on postharvest food grain losses by shifting the intercept inward. Respondents derived their income from sales of maize, rice, millet, cowpea and sorghum grains. Identified improved practices were the use of PIC bags, adopting improved varieties of planting materials such as TZSRY and TZRW variety of millet, maize and sorghum which matures in 60-75 days and 100 days as against unimproved variety which matures in 90-120days and the use of fertilizer. The challenges observed were, lack of mixers, sealing peeling, grinding, bagging and labeling machine, platform for drying, filters, basins, pestles and mortals, chemical for storage and PIC bags. Nine causes of grain losses were identified while eight stock management practices were used to prevent losses but stock management practices adopted were traditional.

Keywords:
Food loss, improved practices, income, Nigeria

Introduction
Everywhere in the world, there is a constant concern for the vulnerable households. The British Department of Fund for International Development (DFID) implemented a protracted relief program worth several millions of sterling pounds to support the vulnerable household in Zimbabwe (Augustine and Peter, 2007) and the United State Agency for International Development pumped in several relief packages worth millions of dollars to assist the same less privileged categories in Nigeria. World Bank, JICA, USAID, FAO, USAID, CRS, ADB among others have been in the vanguard of providing support for vulnerable household over the years and they are still not relenting on their effort.

Agriculture is expected to provide relief for the vulnerable household through provision of food, employment and security, reduction in the prevalence of poverty, promotion of self-sufficiency, and reduction in crime rate and breaks the chain of vulnerability in every society but the current economic downturn in Nigeria severely impoverished many households. The distribution of Bokoharam displaced in North-eastern Nigeria, violent political climate and inflation caused by an unpredictable rise in domestic fuel price made critical farm input inaccessible to food grain farmers in Northern Nigeria which further dampens the hope of less privileged farmers. Vulnerable households in Sokoto, Kebbi and FCT are faced with so many challenges: poor farming practices and lack of critical farm inputs such as fertilizer improve seedling and access to credit. China utilizes about 74% of world nitrogen while the whole of Africa utilizes only 4% and Nigeria utilizes less than one 1% (Daddari 20015). Nitrogen is the limiting nutrient in most soils in our Country most especially in Northern Nigeria. The average street price of a 50-kilogram bag of fertilizer is 5,500 Naira ($37), compared to 2,000 Naira ($13) for subsidized product (Marcela & Michael, 2011). Fertilizer and agricultural tools/implements, which are essential for agricultural development, have a zero import duty. Several agencies such as United State Catholic Relief Services (CRS), Diamond Development Initiative (DDI), Fadama III, MARKETS II, International Fund for Agriculture (IFAD), Sokoto and Kebbi Agricultural Development Programs (ADP) among others have been working in Sokoto, Kebbi and FCT to provide support to the vulnerable households. These organisations provide support in terms of training the farmers on best practices, supply of improve seedling, provision of storage and processing facility and other interventions to increase the productivity of food grain: maize, millet, sorghum, cowpea farmers over the years. What are the effect/ impact of this support services on food grain production by vulnerable households? Any positive changes? It is therefore important to assess the current production practices of vulnerable households so as to determine where the farmers are, where they should be and the direction in which support services should go. The study is therefore designed to assess the current production practices of vulnerable farmers in FCT, Kebbi and Sokoto states in Nigeria.

Catholic Relief Services (CRS), in partnership with Mercy Corps, the Catholic Caritas Foundation of Nigeria (CCFN), and the Federation of Muslim Women Associations of Nigeria (FOMWAN) is implementing Feed the Future Nigerian Livelihoods Project. Feed the Future Nigeria Livelihoods Project is a 5 year program with support from the United States Agency for International Development (USAID) and cost share from CRS and partners. Feed the Future Nigeria is implemented in rural communities in Northern Nigeria's Sokoto and Kebbi states, and the Federal Capital Territory (FCT), and is a multi-sector approach that is assisting 42,000 very poor households grow their agriculture production, incomes, and improve nutrition. The project is strengthening community and government systems to support these gains. The foundation of Feed the Future Nigeria Livelihoods Project approach is agriculture-led growth. The project improves agricultural production and productivity of selected crops and livestock already being produced and uses a market oriented approach to diversify production. Key interventions will increase targeted households, use of sustainable production skills, appropriate agricultural inputs and promote improved production, post-harvest handling and storage practices through training, demonstrations and trials.

The research question is: What is the effect of improved practices on vulnerable household income? What is the impact of innovation on postharvest food grain losses in the study areas? The study provided answer to the research questions.

The paper examined the effect of improved practices on income and postharvest losses of vulnerable household using analysis of co variance model of regressing. The specific objectives are to identify the causes of postharvest losses: estimate the effect of improved practices on income and postharvest food grains losses and identify stock management practices used to reduce postharvest losses in the study areas and make recommendations on how to improve current practices that reduce postharvest losses and impact positively on food security and rural dweller livelihood.

Materials and Methods

Multi-stage random sampling technique was used to select 350 respondents in CRS target areas in Abuja, Kebbi and Sokoto States in Nigeria Primary data were collected through the use of detailed questionnaire and focus group discussion. Descriptive and inferential statistics such as analysis of co variance regression models were applied to data collected.

Result and Discussion

The Vulnerable households had access to various improved practices through the effort of various nongovernmental organisations such as DDI,USAID ,CRS, IFAD,ADP and World Bank assisted programmes(FGD). These organisations provide access and training on usage of improved practices . Vulnerable households were trained by DDI and CRS on usage of PIC bags developed by Purdue University and made it available for millet, sorghum and cowpea storage. Early maturing and high yielding varieties of seed and raising such seedling for commercial production and the use of fertilizer were practices introduced to farmers. The vulnerable Households (VHHs) cultivated high yielding early variety of millet, rice and sorghum which matures in 60-75/80/90 days and the local which matures in 90/100-120 days. About 87.98% cultivated 90/100-120 days variety.

The HHs had access to limited improved varieties such as TZSRY and TZRW via NGO. Few Kebbi and Sokoto Fadama farmers cultivated the short 100days maturing variety of rice. Limited processing: drying, grinding threshing and milling to remove the outer layer of grains and flours for tuwo preparation. The majority relied on mud made rhombus which can store for twelve months representing 73.31%. Grains are stored in bags after harvesting in a cool dry place. 100,000 metric tonne grain storage is currently located in Kebbi State and similar facility is available in Sokoto and FCT. The VHHs representing 54.55% had no knowledge of latest processing and storage technology while 6.15% were uncertain about new development on latest storage techniques. About 82.11% relied on existing old storage practices. The respondents did not use the new innovations such as PIC bags because of t lack of awareness, money to buy, poor access to extension agent and new equipment and innovations. Identified pressing need of VHHs on postharvest handling and storage were lack of facilities such as peeling, grinding machine, bagging and labeling machine, platform for drying, labeling machine, filters, basins, pestles and mortals, insecticides and pesticides for storage, PIC bags

Causes of Postharvest Loss in Food Grains

Identified causes of losses among the vulnerable household were lack of storage facility, finance, pest and diseases, autolysis, poor handling, rainfall and mould, lack of platform for processing, expensive cost of preservatives and transportation problems leading to losses. Lack of acceptable storage facility ranked first accounting for 79.17% of respondents

Effect of Adoption of Improve Practices on Food Grain Losses

Adoption of improved practice has decreasing effect on physical food grain losses among the vulnerable households. The differential intercept shift the constant downward from 2.940 to 2.918 indicating that the average rate of post-harvest losses decreases with the rate of adoption of improved practices such as the use of PIC bags, improved variety of seedling and fertilizer. Although the coefficient was not significantly different from zero but the relationship between the two variables is very important because it indicates that adoption of improved stock management practices has the likelihood to reduce post-harvest losses in the studied areas which is in agreement with a priori expectation of the study. The sign indicates that the more the vulnerable households adopts improve practices the higher the likelihood of loss reduction in food grain production in the study areas. The Effect of Adoption of Improve Practices on Income of VHH. Improved practices identified among the vulnerable households were introduced through international agency such as DFID, USAID, CRS, World Bank and local NGO such as DDI among others. These international organisations introduced improved technology such as the one developed by Purdue University popular PIC bag for food grain storage. Also improved varieties of cowpea, millet and other grains were introduced to farmers to improved performance. Adoption of improved practice has increasing effect on mean income of farmers by shifting the intercept upward. The intercept increased from -1.260 to -1.255 indicating a positive impact of improved practices on mean income of vulnerable households. The introduction of adoption as dichotomous variable increases the average income of vulnerable household indicating that farmers with improve variety of seedling has the capacity to generate higher income.

Conclusion and Recommendation

The study established that adoption of improved practices such as the use of PIC bags, seedling and fertilizer had increasing effect on mean income but a decreasing effect on average postharvest losses among the vulnerable households. A negative interaction was observed between postharvest losses and improved practices It is recommended that farmers should be encouraged to adopt more recent advancement in technology that will impacts positively on income and negatively on postharvest losses thereby improving the livelihood of vulnerable households in the study.

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40012 Expanding the African Postharvest Losses Information System - APHLIS+

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Abstract
The 2008 food crisis led African food security programs to seek a more accurate understanding of the magnitude of postharvest losses of staple food crops. The African Postharvest Losses Information System (APHLIS) was launched in 2009, bringing a rigorous knowledge management approach to cereal postharvest losses (PHL). The relevant scientific literature was used to build profiles of the PHLs occurring along value chains of nine cereal crops, by country and province for 37 sub-Saharan African countries. APHLIS provides estimates of PHL figures where direct measurements are not available. A network of African experts input data specific to the season and province on influential factors such as weather during harvesting, crop production figures, proportion of grain stored on-farm versus marketed, and for maize the presence of the larger grain borer. An algorithm combines the PHL profile with the seasonal data, to calculate a modified estimate of PHLs along the value chain for each province. APHLIS produces outputs as losses tables and maps presenting PHL data by % weight loss, tonnes, or loss density. These science-based loss estimates are available at www.aphlis.net. The systems' transparency allows the quality of the estimates to be evaluated. A downloadable calculator enables users to input production figures and fine-tune seasonal factors to produce loss estimates for their specific location. Work has begun on APHLIS+, which is expanding to include: root, tuber, and legume crops; financial and nutritional PHL estimates; risk warning systems; and an improved user-interface.

Key words:
Financial and nutritional losses, postharvest loss estimates

Introduction
The 2008 food crisis caused development agencies involved in improving food security across sub-Saharan Africa to realise they needed a more detailed and accurate understanding of the level of postharvest loss of staple food crops occurring (World Bank et al., 2011; Hodges & Stathers, 2013). Different types, amounts and causes of loss happen during the different postharvest activity stages. In cereals and pulses, this might include: some grain being left behind in the field at harvesting, or infested by insect pests, or dampened during unseasonal rains resulting in mould growth, or spilt during transport to the home; poor weather conditions during sun-drying may lead to insufficient drying and high losses, or roaming livestock may consume portions of drying grains left unguarded; poor handling during threshing, shelling or further drying can lead to scattering, contamination with soil and stones, and grain breakage; and poor storage hygiene and infestation by pests can cause further losses (Hodges et al., 2014). Few studies exist that have measured the cumulative weight losses occurring at each postharvest stage along the supply chain.

The African Postharvest Losses Information System (APHLIS) was developed and launched in 2009, to bring a rigorous knowledge management approach to cereal postharvest losses (PHL). Further work now includes expanding the approach to other crops and widening the focus from weight losses to also consider the impacts of postharvest losses in quality.

Methodology
In creating APHLIS, the relevant cereal PHL scientific literature was critiqued and used to build PHL profiles for nine cereal crops (maize, sorghum, millets, rice, wheat, barley, oats, teff, and fonio), pulling together the most reliable knowledge which existed on losses, interconnections and causes of loss along the postharvest parts of the value chains.

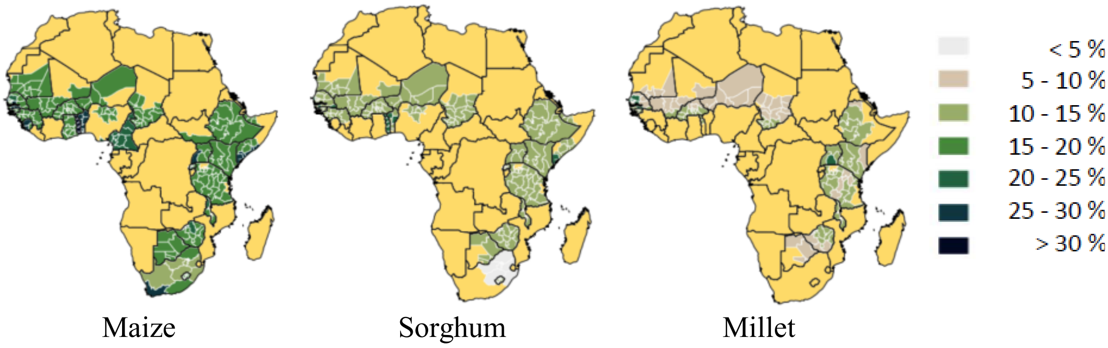
A network of experts from across sub-Saharan Africa collected and inputted data specific to the season for each province within their country on factors which influence PHL. These data include the weather during crop harvesting, cereal production figures, the proportion of grain kept for farm storage versus that marketed within the first three months after harvest, the number of harvests, the scale of farming, and in the case of maize the presence or absence of the larger grain borer pest (Prostephanus truncatus) which can cause storage losses to double.

An algorithm was used to combine the PHL profile for each crop with the seasonal data for the focal location, to calculate a modified estimate of PHL at each stage of the value chain for the specific local circumstances.

APHLIS is being expanded to include PHL estimates for other important food security crops, information on the value of the PHLs in financial and nutritional terms, and risk warning systems for key postharvest loss causing factors.

Results
APHLIS currently provides estimates of the magnitude of PHLs by cereal crop, by country and by province for 37 sub-Saharan Africa countries. Providing valuable evidence-based estimates of cereal PHL figures where direct measurements of PHL are not available.

The outputs can be produced in the form of losses tables and maps presenting postharvest loss data by % weight loss, tonnes, or loss density (MT/km2) (Figure 1). APHLIS additionally provides users with a downloadable calculator enabling them to input cereal production figures and fine-tune the seasonal factors to produce loss estimates for their specific focal area. These science-based loss estimates are available through the open access APHLIS website www.aphlis.net. The system has been designed to be transparent enabling the user to drill down into the data to see how each estimate was derived and to evaluate the quality of the estimate.



Regional PHL by cereal [% of total annual production]											
Cereal	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Wheat	5.6	5.5	13	9.9	12.8	12.6	15.1	14	13.1	12.9	15.2
Maize	16.8	17.3	17.1	17.9	18.9	20	17.7	18.8	17.8	18	17.6
Rice	11.8	11.8	11.6	11.8	11.8	12.1	12	12.6	12.1	13.6	12.2
Sorghum	12.3	11.8	12	12.3	12.3	13	12.5	12.6	12.4	12.4	12.3
Barley	9.8	4.5	9.4	9.4	9.4	9.5	10.9	10.1	9.7	9.7	10.5
Rye	-	-	-	-	-	-	-	-	-	-	-
Oats	-	-	2.1	2.1	2	2.1	2.1	2.1	2.1	2.1	2.1
Millets	9.5	9.9	9.8	10	10.2	10.7	10.1	9.9	10.4	10.1	10.4
Fonio	11.7	11.7	11.7	11.7	11.7	12	12.4	12.2	11.7	11.8	11.7
Teff	11.7	11.7	12.5	12.5	12.1	12.5	12.5	12.5	12.5	12.4	12.5

Figure 1. Example of APHLIS weight loss maps (2012) and tables (2003-2013) for nine cereal crops across sub-Saharan Africa (Source: www.aphlis.net)

Work has now begun on APHLIS+, which in response to demand is working to expand APHLIS to also include loss estimates for key root and tuber, and legume staple food crops such as cassava, cowpeas, common bean, and if resources suffice groundnuts, sweetpotato, plantain and banana. Creating the PHL profiles for these new crops involves screening the published and grey scientific literature to extract measured or estimated PHL figures from high quality studies. Details of the factors which influence the magnitude of PHLs at each stage in the value chains or sub-chains of each of the crops are being compiled to assist in identifying the additional information required for creating more location-specific estimates. These might include: proportion of crop being consumed in fresh form versus dried or processed forms, distance from production site to markets for fresh products, climatic conditions during harvest and drying, postharvest methods used, storage duration etc.

This new phase of APHLIS is also developing methods for extending the loss estimates from beyond just weight losses to also consider the financial and nutritional value of postharvest losses in quantity and quality. The financial PHL activities involve deepening understanding of the relationship between % weight loss and visual damage in the different crops, and between damage and price-discounting which typically varies by location and during the season depending on food availability and quality. The nutritional PHL work is initially using food composition data to calculate the potential nutritional impact of postharvest weight losses, and will then aim to adjust these estimates based on the findings from linked laboratory studies measuring the impact of key insect pests on nutrient loss in stored grains, and deepening understanding of the selective feeding behaviour of these pests on grains.

Postharvest risk warning systems linked to high loss projections and food safety problems, including aflatoxin and insect pest attack risks are also being developed. Significant attention is also being focused on improving the user interface to enable APHLIS to be more easily accessed, used and valued by a wider user group. Seasonal data is also being collected by the network of African experts across the continent to enable the cereal postharvest loss estimates to be kept up-to-date.

Conclusion and Recommendation

APHLIS already provides evidence-based information on the level of postharvest weight losses occurring for nine different cereal crops across the different provinces of 37 sub-Saharan African countries each year. Attention is now being focused on: expanding APHLIS to provide evidence-based postharvest loss estimates for key root and tuber, and pulse staple food crops; developing systems for additionally estimating the financial and nutritional value of postharvest losses; creating postharvest risk warning systems; and increasing the utility of APHLIS.

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40013 Experiences With Business Models and Dissemination Techniques for Sustainable Postharvest Management Among Smallholder Farmers

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Abstract

A reduction of postharvest losses (PHL) of cereals provides a cost-effective means of promoting food and nutrition security in Africa. In achieving wide access to information and technologies for effective postharvest management (PHM), the project "Postharvest Management in Sub-Saharan Africa" applies a multi-stakeholder approach in Benin and Mozambique. The objectives include evaluating, documenting and disseminating the best PHM options tested, and using field evidence to advocate for appropriate PHM policies and regulations. Business models are elaborated and promoted among the market actors using the cost-benefit and technical effectiveness analyses of the PHM technologies and practices. Furthermore, the project fosters innovative communication channels and tools for broad dissemination of information on good PHM options through extension services and media, including didactic videos, interactive radio programmes, theatre performances and online platforms. The success of PHM business models and adoption of PHM technologies largely depends on the access of farmers and agro-entrepreneurs to finance. Cost-benefit and technical effectiveness analysis show that the economic benefit of good PHM technologies depends on 1) additional benefits from selling safely stored grain later in the season (price fluctuations); and 2) the rate of PHL of particular foods in a given context. Hermetic systems such as metal silos and triple (PICS) bags show most promising results. Farmers are willing to pay for PHM technologies when a reasonable economic benefit is demonstrated. The experience collected shows that innovative extension and dissemination tools are decisive for the adoption of PHM technologies and practices.

Key words:
Benin, food security, Mozambique, postharvest loss, postharvest management

Introduction

The value of postharvest losses for cereals in Africa is estimated at more than four billion US$ annually or almost 15% of the total production value. Therefore reduction of postharvest losses (PHL) can provide a cost-effective means of promoting food and nutrition security. This is particularly true in the context of Sub-Saharan Africa (SSA) where it is estimated that up to 40% of food losses occur at postharvest and processing stage (FAO, 2011). The scoping studies in Benin and Mozambique identified the following constraints that impede effective postharvest management (PHM):

a. lack of awareness on PHM;
b. limited accessibility to financial services;
c. limited entrepreneurial skills;
d. unavailability of inputs, PHM tools and innovations;
e. limited demand and adaptability of PHM innovations; and
f. missing food quality standards and PHM not being sufficiently anchored in the farmers traditions, among others.

In order to deal with these constraints, a concerted effort of public, private and civil society actors is a precondition (Springfield Centre, 2015), as this reflects a multi stakeholder problem that requires a multipronged solution. This would guarantee a wide access to and use of information and technologies in postharvest management by all stakeholders including smallholder farmers. The project "Postharvest Management in Sub-Saharan Africa" (PHM-SSA) is being implemented since 2013. Its aim is to increase food security of smallholder farmers through reduced postharvest losses of grains and pulses at farm and community level. The objectives of the project are; a) Pre-storage handling and storage technologies within the grains and pulses value chains benefitting smallholder farmers in the pilot countries; b) Good and tested practices for reducing postharvest losses are compiled, documented, disseminated and scaled up and c) Appropriate regulatory frameworks on reducing postharvest losses in food supply chains are introduced and implemented at national and regional levels. This article describes the results of various studies carried out by the project and the experience collected during implementation.

Methodology

The project is piloted in Benin and Mozambique by a consortium including HELVETAS Swiss Intercooperation (HSI), Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN), African Forum for Agricultural Advisory Services (AFAAS) and AGRIDEA (Swiss Centre for Agricultural Advisory and Extension Services). The project follows the theory of change that with increased awareness on PHM issues; promotion of effective PHM practices and technologies; capacity building and facilitation of access to markets; leads to smallholders adopting improved PHM solutions and reducing postharvest losses and therefore to improved food security. The project uses the "Making Markets Work for the Poor" (M4P) approaches to development. This concept is premised on the idea that efficient delivery and exchange of goods and services has to be supported by rules and functions formulated and performed by different players in a market system (DFID, SDC 2008). The project applies the approach at two levels; i) supply and demand of PHM solutions constitutes the main function, and ii) pluralistic Rural Advisory Services (RAS) seen as supporting function. The players in this market system are public and private, formal and informal.

To elaborate business models for PHM options, consultative processes were used. Business models are promoted among public and private market players including; farmer cooperatives, financing entities, local artisans and local agro-dealers. The project facilitates exchange and collaboration between players of the market system through formal agreements. It promotes the PHM business models through informing the market players on business opportunities in PHM and assisting the entrepreneurs to discover and establish a business case from PHM. The agro-dealers procure input materials, contract artisans for silo production, sell or lease PHM technologies to farmers and market them through their client networks. The success of PHM business models and adoption of PHM technologies largely depends on the access of farmers and agro-entrepreneurs to finance (Schaltegger, 2016). The project thus validates different financing modalities including saving groups, warrantage and cooperation with local banks. On farm validations, cost-benefit and socio acceptability analyses of the different PHM solutions have been carried out among the farmers. Results are being analysed. Among the project's activities, RAS materials and tools including posters, leaflets, factsheets and manuals on good PHM practices were elaborated. They are widely used by RAS providers from farmer cooperatives, government agencies and the agro-dealers. A cascaded training model, elaborated, adopted and used by the project offered a basis for training of trainers. Extension officers from organizations in the business model are equipped with the necessary knowledge to train farmers on PHM and provide them with didactical materials. The project identifies and trains artisans and master trainers in different villages in the production of the metal silos and quality control, respectively. In broadly disseminating and raising awareness on good PHM solutions, the project fosters innovative communication channels through extension services and media, including didactic videos, interactive radio programmes and online platforms. Additionally, weeks of action are held during which activities that combine live radio and television broadcasts, mobile fares, PHM video shows, live discussions, theatre performances and distribution of videos on PHM options. Similarly, local working groups (WG) were established, in which stakeholders gather to share experiences and propose strategies to better intervening in PHM. These activities have created an enabling environment for the acceptance of the PHM technologies and practices. Awareness is created within national, regional (SSA) and global audiences to attain scale and sustainability.

Results

The project brings together local entrepreneurs, suppliers of raw materials, local microfinance institutions (MFIs) and local artisans, facilitating the joint developing of business ideas for the markets of triple bags, super bags and metal silos. The goal is to enhance the availability of storage facilities by closing the gaps in the value chain of PHM options. Contractual arrangements between the actors were negotiated and the first memoranda of understanding (MoUs) between input providers and sellers were signed in Benin and Mozambique, hence the actors perform their functions in the model. The role of the project in the business is steadily reducing while the private sector is taking up leadership in the marketing and promoting of the PHM options among smallholder farmers.

Cost-benefit and technical effectiveness analyses show that there is a reasonable economic benefit of well used PHM technologies, therefore willingness to pay for these is assumed. The economic benefit largely depends on; i) additional benefits from selling safely stored grain later in the season (price fluctuations), and ii) the rate of postharvest loss (PHL) of particular foods in a given context. For example in Mozambique, our studies found that good storage prevents losses by at least 15%, and prices of grains increase by up to 67% at off-season. Hermetic storage systems such as metal silos and triple (PICS) bags are the most promising in terms of reducing PHL. At minimum, profits obtained from selling maize stored in a 500 kg hermetic metal silo may be sufficient to pay back the cost of the technology after two to three cropping seasons. However, initial investment costs of this technology compromise its demand. Other non-hermetic storage systems that include the Gorongoza in Mozambique and the improved clay granary in Benin are less effective in storage. To inform stakeholders on the opportunities of PHM, the project has developed seven (7) factsheets covering aspects of harvesting, drying, solar disinfection and storage of maize and cow peas. Comprehensive manuals on PHM of maize and cow peas have been produced in respective national languages. These materials are used for imbedding the PHM topic into pluralistic RAS. PHM media content has been developed and packaged into didactic videos, radio programs, and theatre performances. Training of trainers on the use of didactical materials in training farmers on PHM has been carried out. The trained artisans and master trainers in the different villages now produce quality metal silos. The provision of the promotional and educational materials is a shared task between the actors in the model. To achieve scale, the project disseminates PHM knowledge and experiences in regional audiences through regional events, in the community of practice (CoP) and online platforms.

Conclusion

From the PHM-SSA project and in comparison with other similar projects, it can be concluded that provided the support system functions well, considerable gains can be made from good PHM. A well-functioning support system means availability of: financial services, professional information and advisory services, and entrepreneurial skills to the agripreneurs including farmers. The role of the agro-dealers should be to sell the PHM technologies while the public services facilitate the development of the market system. The project proves that farmers are willing to pay for PHM technologies when a reasonable economic benefit is demonstrated. The experience collected shows that innovative extension and dissemination tools are decisive for the adoption of PHM technologies and practices.

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40014 A More Sustainable Path Toward "Zero Hunger"

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Abstract
One-third of the food that we already produce is lost between the time that it is harvested and consumed. This is enough food to feed two billion hungry people. If we are to feed the world's starving population, we must develop strategies to substantially reduce postharvest food losses. We have invested a disproportionate small amount of our agricultural resources in the preservation of food (5%) compared to food production (95%). To meet these challenges, the World Food Preservation Center® LLC has launched a "Food Preservation Revolution™." Increasing food production has negative impacts on the environment, besides the anticipated crop yields will barely be 1% per year as opposed to the green Revolution" in the 1960's and 70's where we were able to increase crop yields 3-5%. This is going to leave us far short of the food that we will need by 2050 to feed the world's ballooning population. Many questions have been raised as to whether launching a "Second Green Revolution" is a sustainable approach toward meeting the present world food shortage crisis. Since we are not going to meet this world food shortage by just producing more food, a major paradigm shift in our agricultural investments is needed where we need to focus more on saving the food that is already produced.

Keywords:
Postharvest loss, world hunger, food preservation, agricultural investments

Introduction/background
The world's food supply is shrinking, one side we have a rapidly exploding population and on the other side we have a rapidly deteriorating agricultural environment. Climate change has now come on the scene and portends to severely restrict crop yields. Also, increased use of food for fuel and a greater consumption of animal protein over plant protein in our diets is further diminishing our food supply. In the past were able to meet food shortage crises by producing more food as we did during the "Green Revolution." But, presently we are not going to be able to produce enough food to keep up with the world's increasing population.

Although individuals in developing countries living on the margins of food security will be impacted most severely by the world's pending food shortage crisis, the developed world will be affected profoundly as well. As food become scarce, food prices soar, resulting in more people in developing countries being denied access to food. Food shortage crises in developing countries lead to political unrest and even terrorism. Uprisings during the Arab Spring that occurred in Egypt and Tunisia were thought to have been triggered by soaring food prices. Most of the world's hungry people live in developing countries. According to the latest Food and Agriculture Organization (FAO) report, there are 795 million hungry people in the world with 98 percent being in developing countries. A disproportionate number of these individuals are children.

Agribusiness and government organizations are launching a "Second Green Revolution" in order to produce more food to meet the "Zero Hunger Challenge." Agribusiness sets the agricultural research and education agenda and it makes its profits through the sale of seeds, fertilizers, and pesticides (production technologies). Agribusiness sees little profit in the preservation of food once it is produced. Agribusiness profits from food loss in that this reduces the food supply thus creating a demand to produce more food.

Many questions have been raised as to whether launching a "Second Green Revolution" is a sustainable approach toward meeting the present world food shortage crisis. The "First Green Revolution" while helping to meet the world's increased demand for food left in its wake an agricultural system that was unsustainable. It involved significant environmental costs such as unsustainable groundwater extraction, fertilizer run-off, pesticide residues, and salinization. The "First Green Revolution" required expensive inputs of fertilizers, pesticides, and irrigation water which were not available to small holder farmers that produce most of the food in developing countries. Since the "First Green Revolution" one-third of our agricultural land has had to be abandoned because of soil contamination, erosion, and lack of fertility. Over seventy percent of our ground water is used for agriculture globally. Heavy dependence on irrigation to increase crop yields during the "First Green Revolution" in some countries has resulted in the mining of this water at a much greater rate than it is being replenished.

Addressing the world hunger
The "Zero Hunger Challenge" was launched by the United Nations' Secretary-General Ban Kimoon in 2012. His ambitious goal envisioned a world free of hunger by 2030. A multifaceted program was proposed to reduce world hunger based on the Sustainable Development Goals (SDG) of the United Nations. Subsequent to this the African Union Commission (AUC) and other international and national organizations have set their own goals toward reducing postharvest food losses and world hunger. There are mixed reports on whether global hunger is increasing or decreasing in spite of all the new initiatives. Agreement does exist that world hunger is set to increase dramatically if we remain on the present path toward meeting this crisis. By remaining on the present path toward reducing world hunger we are going to fall far short of the food required to feed the world's exploding population. Not only is our present course to reduce world hunger unsustainable, our food supply is also being further diminished by global warming.

We have two fundamental approaches in increasing the world's food supply. We can produce more food or save more of the food that we already produce. The question becomes, "Which of these approaches are the best investment of our agricultural dollars to meet this pending world food shortage crisis?" Presently, we are investing 95% of our agriculture dollars in the production of food while investing only 5% in food preservation. Even with our present investments of hundreds of millions of dollars in research and development to produce more food we are barely able to increase our crop yields a little over 1% per year. Since we are not going to meet this world food shortage by just producing more food we clearly need another strategy of saving food that we have already produced.

One-third of the food that the world produces already is lost between the time that it is harvested and consumed. This is enough food to feed over two billion hungry people annually. Since we are not going to be able to feed the worlds exploding population by just mounting another "Green Revolution" it is important that we look at alternative strategies. Saving more of the food that we already produce is a compelling approach. Investments in postharvest infrastructure and research also make good economic sense.

Harvested commodities have baked into them substantial investments in the cultivation, harvest, and processing of the crop. Therefore, a tremendous gain can be return on investments in postharvest infrastructure and technologies. Such investments allow you to protect and realize a full return on investments in the production of food. A good example of this is the "Grain Cocoon" technology commercialized by GrainPro, Inc. Investments in this postharvest technology allows farmers to realize maximum return on their investment grain production. Without investments in the "Cocoon" technology a 100% loss would have been realized in the investment in the production of this grain. This is contrasted to the slightly over 1% increase in crop yields that are received from investments in new technologies to enhance grain production.

Recommendations

Meeting the challenge of "Zero Hunger" and feeding the world's rapidly expanding population sustainably requires a major paradigm shift in our agricultural investments. Since agribusiness at this point sees little profit in postharvest technologies to increase our food supply an added burden is placed on the rest of agriculture, particularly its agricultural higher education systems to accept this challenge. It is not only IMPORTANT that we do this. It is IMPERATIVE!

With investments in the postharvest preservation of food toward reducing world hunger being advantageous over investments in food production, we need to examine where the best place is to make these postharvest investments.

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40015 Rationale for Establishing the World Food Preservation Center® Llc

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Abstract
Substantial (over 30%) food produced in the world is lost at postharvest level thus compromising the ability to feed the ever increasing population and exacerbating the food insecurity situation especially in developing countries. To address this challenge, the world food preservation centre was established to address these postharvest gaps by increasing capacity through promoting post graduate training on post harvest issues, supporting research and post-harvest workshops and access to postharvest knowledge and technologies. The World Food Preservation Center comprises 25 major agricultural research universities and three major agricultural research institutes from six continents. For effective management of postharvest losses, there is need to increase the level of investment in research, validation and up-scaling of post-harvest innovations. Low investment of agricultural resources in food preservation has resulted in postharvest "skill gaps" and "technology gaps" in our agricultural institutions of higher learning particularly in developing countries.

Keywords:
Postharvest loss, developing countries, postharvest education, postharvest research.

Introduction
One third of the food that we already produce globally is lost annually between the time that it is harvested and consumed. This is enough food to feed two billion hungry people and to feed the world's expanding population. Therefore, it is apparent that we must save more of the food that we already produce if we are to avoid escalating world hunger. It is clear that we are not going to be able to meet this global food shortage crisis by simply producing more food as we did during the "Green Revolution." Even with our most advanced food production technologies, we are going to fall far short of enough food to feed the worlds expanding population. The world's food supply is being shrunk by a rapidly exploding world population and a rapidly deteriorating agricultural environment. Now global warming has come on the scene and portends to further restrict our crop yields.

Approach
The World Food Preservation Center® LLC was established in response to a pending global food shortage that is destined to increase world hunger if not sustainably addressed. The World Food Preservation Center® LLC was formed to address intellectual postharvest gaps in developing countries by: (1) promoting the education (M.S. and Ph.D.) of young student/scientists in developing countries; (2) having young student/scientists in developing countries conduct research on much needed new postharvest technologies adaptable to their native countries; (3) organize continent-wide postharvest congress and exhibitions; (4) publish much needed new texts/reference books on postharvest technologies/methods for developing countries; and (5) develop a comprehensive database on all postharvest knowledge relative to developing countries with access portals for researchers, students, administrators, industry, businesses, and farmers.

Beside promoting the postharvest graduate education of young students in developing countries the World Food Preservation Center® LLC has organized the "1st All Africa Postharvest Congress & Exhibition in 2017; the "1st All Latin America Postharvest Congress & Exhibition" in 2019; and "First All Asian Postharvest Congress & Exhibition" that will be conducted in 2019. The World Food Preservation Center® LLC has also partnered with CRC Press (Taylor & Francis) to publish the World Food Preservation Center® Book Series.

Results/Outcomes
The World Food Preservation Center® LLC addresses two major deficiencies in our present attempts at reducing postharvest food losses in developing countries. It promotes a world-class education to young postharvest scientists in developing countries in advanced postharvest technologies for the preservation of food and conducts research on much needed new postharvest technologies. When young scientists return to their native countries after attending "Sister" Universities of the World Food Preservation Center® LLC they are able to establish independent research, educational, and extension postharvest programs tailored for the needs in their specific country. Also, they are able to introduce innovative new technologies for the postharvest preservation of food, developed at the World Food Preservation Center® LLC such as solar refrigeration, transportation, and storage, as well as, biological controls for postharvest diseases and insects, and active and intelligent packaging. With its specific focus on postharvest losses, the World Food Preservation Center® LLC acts as an informational hub and coordinator of other efforts worldwide to reduce the postharvest losses of food such as its "Global Mycotoxin Alliance." The World Food Preservation Center® LLC is presently comprised of 25 major agricultural research universities and three major agricultural research institutes on six continents.

Recommendations
There is need to increase the level of investment in food preservation from the current level of 5%. Currently only 5% of our agricultural resources are invested in the postharvest preservation of food as opposed to food production where 95% of agricultural resources are invested.

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http://www.worldfoodpreservationcenter.com/index.html

Sub Theme 5

Gender, Youth, Policy and Governance Issues Affecting Postharvest Management

5001 Inclusiveness and Efficiency in Post-Harvest Loss Reduction – A Glance at the FAO-Thiaroye Fish Processing Technology

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Abstract
In 1967, to address the inefficiencies in fish smoking in the tropics, the UN Food and Agriculture Organization (FAO) developed the Chorkor kiln. This latter has been strongly promoted worldwide, but new subsequent scientific knowledge of the food engineering made it essential to improve it. This is due to the polycyclic aromatic hydrocarbons (PAHs) which are significant hazards linked to this process, with harmful food to be removed from the supply chain and impacts on the smallholders' incomes. Compliance problems with the European Union (EU) requirements have prompted the development of the FAO-THIAROYE fish processing technique, now known as the FTT or FTT-Thiaroye, which meets the regulatory requirements of these lucrative markets. The FTT is more efficient than the Chorkor kiln. It generates safer products as proven by reference laboratories and the resumption of exports by initially banned processing units. In Cote d'Ivoire, a country to have first experienced the FTT, the 1.6 million economic losses between 2006 and 2010 due to the self-ban from export have been reduced; the ratio of wood fuel dramatically decreased - from 5 to 0.8 kg wood/kg fish. A 2016 FAO-commissioned study concluded that the initial investment (1,600$ for a full equipment) may be a challenge for these small-scale fishers, but FTT kilns are financially and economically profitable, technically, socially and environmentally sound. This supports the trends of its expansion from 2 countries before 2014 now to more than 10 countries in Africa, with a foreseen dissemination in 2017 to Asia.

Keywords:
Fish safety, FTT, kilns, market, smoking, women

Introduction
Smoking and drying are very popular techniques in the fisheries sector, especially at small scale, in Africa (FAO, 2007). These two techniques represent the main and, at times, only ways to supply populations, particularly those far from fishing sites, with fish, which is known to be perishable. They are however not without several drawbacks, the most prominent being the potential for generating products with high levels of polycyclic aromatic hydrocarbons (PAHs). PAHs may have a detrimental effect on human health at certain levels. For most of the PAHs it is the carcinogenic potential that constitutes the critical effect for hazard and risk characterizations. Also, some of them have shown clear evidence of mutagenicity/genotoxicity in somatic cells (EFSA, 2008). This has been the reason for major markets, especially the EU to regulate them. Indeed the 5 µg/kg limits of benzo(a)pyrene/B[a]P set up in 2006 (EU, 2005) has been gradually strengthened to 2 µg/kg and 12 µg/kg respectively of benzo(a)pyrene and the 4 compounds (Benzo[a]pyrene, benzo[a]anthracene, benzo[b]fluoranthene and chrysene) since 1st September 2014 (EU, 2011). Those provisions in an important outlet established a significant compliance challenge to the export oriented producers of smoked-dried products from most developing fishing nations. Under the 2006 provisions, some medium-scale smoked fish production units from the Africa region were flagged in the EU rapid alert system for food and feeds, with subsequent suspension or ban from export. This was the case for exporting countries such as Cote d'Ivoire, Ghana and Senegal (Diei-Ouadi, 2005; National competent authorities reports, not published). As illustrations, Cote d'Ivoire lost US $ 1.6 million between 2006 and 2011 for a self-ban from export following the critical alerts; PAHs were the main causes of rapid alerts of fishery products exported from Ghana (46% of the total of Ghana alerts) between 2004 and 2014.

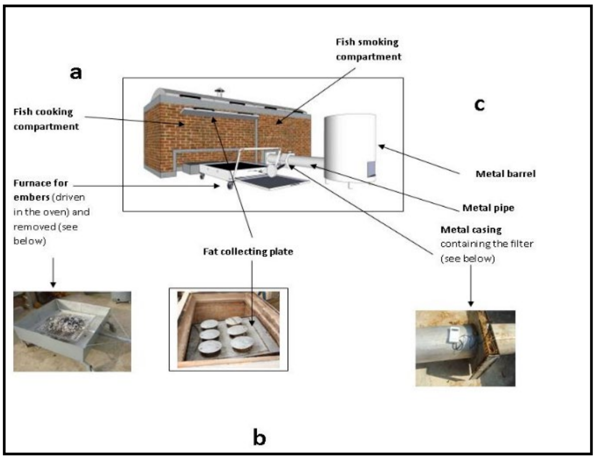
That inefficiency involved medium scale export units, but it mirrored a worse scenario for small-scale fisheries, known for their comparative structural limitations. Yet these fisheries make up the largest share in terms of contribution to food security and livelihoods of communities, with women representing more than 50% of the workforce in the post-harvest domain.

In 2009 the Codex Alimentarius Commission issued codes of practice (Code of practice for the reduction of contamination of food with polycyclic aromatic hydrocarbons (PAH) from smoking and direct drying processes (Codex Alimentarius, 2009). These guidelines highlighted that the formation of PAH during smoking and direct drying is dependent on a number of variables, including:
a) Fuel (woods and other plant materials, diesel, gases, liquid/solid waste and other fuels);
b) Smoking or drying method;
c) Smoke generation process in relation to the temperature of pyrolysis and to airflow in the case of a smoke generator or in relation with other methods such as direct smoking or regenerated smoke by atomizing smoke condensate;
d) The distance between the food and the heat source;
e) Position of the food in relation to the heat source;
f) Fat content of the food and what happens to the fat during processing;
g) Duration of smoking and direct drying;
h) Temperature during smoking and direct drying;
i) Cleanliness and maintenance of equipment;
j) Design of the smoking chamber and the equipment used for smoke/air mixture.

It is against this backdrop that within the framework of the African Network in Fish Technology Safety and Quality, FAO took the lead in a collaborative investigation with fisheries institutions. The primary objective of development and promotion of the FAO-Thiaroye Technique was to enable Africa to pursue its own food safety objectives and reduce post-harvest losses due to inefficient processing techniques, while caring for the food safety elsewhere.

Methodology

The collaborative investigation started in 2005 with the Institut de Recherche Technologique in Gabon, the Food Research Institute in Ghana, and the Centre National de Formation des Techniciens en Pêche et Aquaculture in Senegal) following the Expert meeting in fish technology and Safety in Bagamoyo, Tanzania (FAO 2007). The FTT-Thiaroye is the fruit of five years of design improvements, trials, sensory evaluation, laboratory tests, networking and target users' assessments, concluded with CNFTP. While the frame is similar, the FTT has important features that differentiate it from existing systems such as the Chorkor, the Banda and Altona kilns (Ndiaye, 2009, 2011).



The additional components are:

- A square container for embers, corn or millet cob or any other energy source for heating the fish placed in the smoking or drying trays.
- A fat collecting tray: a metal sheet with raised cones placed between the fish on the racks and the heat source, in order to prevent the dripping fat from the fish falling onto the fire which could generate tar deposits.
- An external smoke generator, which contributes to cooling the smoke and retaining harmful materials through a humid phase or humidified sponge;

Figure 1: The components of a FTT-Thiaroye kiln

The key operational principle of the FTT-Thiaroye is based on the separation of the cooking phase from the smoking phase.

Results and Discussion

FTT enables the delivery of safer products, which means less loss. In 2010, with the adoption of the first prototype piloted (SFP Info, 2010), previously banned medium-scale processing units were back on the national competent authority list of EU approved establishments, a clear sign of restored confidence. Its comparative strengths make the FTT-Thiaroye appreciated both by medium and small-scale fishers.

Improved fish quality and safety:

Below some findings of an ongoing risk assessment work involving FAO, the Ghana-Legon and Belgium-Ghent universities.

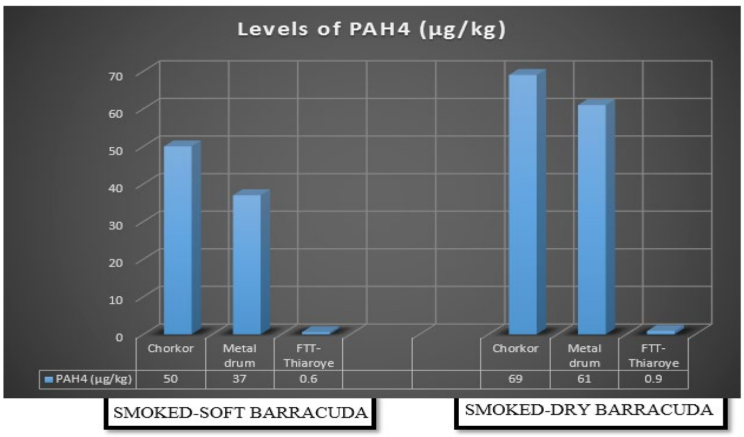


Figure 2: Comparison of the PAH4 levels on traditional kilns and the FTT-Thiaroye with smoked-soft and dry barracuda species

Analyses made at SGS Laboratory in Antwerp, Belgium, using gas-chromatography mass spectrometry (GC-MS) show that fish smoked with traditional kilns had PAHs levels 13 to 33 times the EU regulatory limits. FTT-Thiaroye products had the lowest PAH levels, which were all lower than these limits. However, replacing charcoal with wood as fuel in the cooking stage of FTT results in high PAH levels, suggesting that the use of charcoal is essential in the cooking stage; in the flavouring stage, wood could be used to generate the smoke. The complete or incomplete combustion and use or non-use of fat collection tray in FTT has the greatest impacts on PAH levels.
Improved yield: Because of reduction in the smoking time, more smoking sessions are enabled, hence a higher volume of marketable product. Significant reduction of post-harvest losses is an asset of the FTT, considering a country like Côte d'Ivoire where they can go up to 16.64 tons (about 4.000 USD) annually per smallholder. As a mechanical drier, the FTT-Thiaroye enables drying irrespective of cli-

matic vagaries, and helps increase fish processors' resilience in the face of eventual changing species distribution. The use of the FTT during bad weather, when compared to common sun-drying racks reduces the drying time from more than two days to two hours.

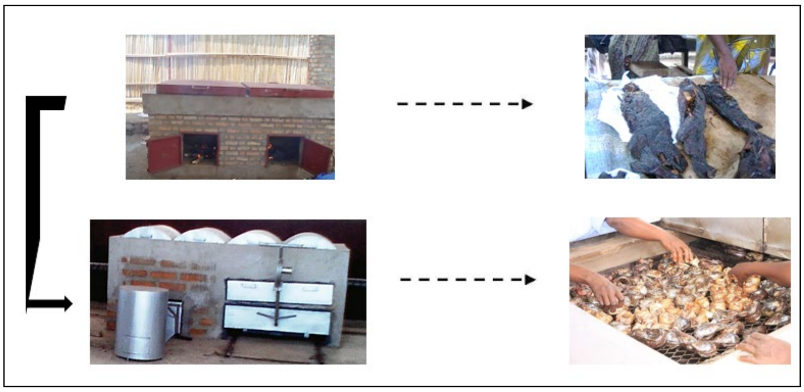


Image: A Banda kiln transformed into a FTT-Thiaroye kiln with finished products of much better quality

Environmental benefits:

Less fuel used would mean less environmental pollution and deforestation, including the depletion of mangrove trees. Indeed the FTT results in a dramatic decrease- from 5 to 0,8 kg- in wood required for 1 kg of smoked fish.

Improved occupational safety and health/OSH: Comparative studies conducted in 2015 & 2016 by the Cocody University and the National Laboratory for Agricultural Development (LANADA) of Cote d'Ivoire portrayed serious occupational health hazards (respiratory, skin and eyes diseases due to hot smoke exposure) of the fish smokers with the traditional kilns. OSH is actually a key driver of the FTT adoption by smallholders.

Cost-benefit analysis of the FTT: A feasibility study held within the 1st small-scale fishing community to have adopted (in 2013) the FTT-Thiaroye, concluded that FTT kilns are financially and economically profitable with an investment of less than 0.86 or less than 2.85 million CFAF with either one kiln prototype or various prototypes. Their net present value (NPV) amounts to close to 7.64 and 10.35 million CFAF, respectively. This corresponds to an internal rate of return (IRR) of 31.7% and 34.9% based on a discounting rate of 10% over a period of 10 years (Mindjimba K. to be published). However this study underscored the critical role of the consumer in fuelling the dissemination of the FTT, by paying a premium price for safe and better quality products. As of today the FTT is formally established in Angola, Cameroon, Cote d'Ivoire, DR Congo, Gambia, Ghana, Guinea-Bissau, Senegal, Tanzania, and Togo.

Conclusion and Recommendations

The experience and lessons learned so far are that stringent regulations coupled with consistent enforcement measures (e.g. rejections, bans) by the EU has been the driving force towards adoption of the FTT by processors. But the benefits of the FTT go beyond taking care of safe fish for export. Though within reach of medium-scale and export-oriented small-scale processing units (because of the high unit value paid for the product), for most individual small-scale processors supplying domestic markets, the costs are higher. Financial support and technical assistance will be needed for them to benefit from the FTT's assets.

While communicating to fishers the advantages of using the FTT, an effective consumer information and education programme by the competent authorities would be instrumental in the process of wide dissemination of the FTT, to champion food safety as well as protect the business of small processors.
The medium term perspective for the FTT optimization is to promote the use of the oil from the fat collection tray, transform the liquid from the external smoke generator into a liquid smoke and to promote products such as fish pastries developed in this system.

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5002 Post-harvest Losses in Banana Production Value Chain in Meru and Kisii Counties of Kenya: The Role of Socio-Cultural Diversity

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Abstract
Banana is considered as one of major fruit crop in Kenya and is produced in large numbers in Kisii and Meru counties. Regardless of high production the farmers incur a lot of losses due to various social and cultural factors in the two regions. Post-harvest losses are the main causes of reduced productivity in two regions. Such wastes and losses are associated with the failures of the agricultural sectors and other stakeholders to come up with better approaches to manage the losses. Due to this problem, the focus of this paper was based at evaluating the extent of losses and the contribution of social cultural factors. The findings were obtained through the use of literature searches relevant in banana production in the region. The results revealed various factors such as immature harvesting, poor handling and storage, lack of infrastructure for transportation. Social aspects such as lack of secondary school education among the farmers as well as having many women in the farm than men contribute to the problem. Culturally, some of the homes are also used to serving buffet while other areas such as Kisii prepare their local brews. Therefore, there is an indication of high chances of reducing the current food insecurities through employing of effective management strategies to minimize food losses and wastes.

Keywords:
Cultural values, eating habits, food diversity, food security, post-harvest waste

Introduction
Banana (Musa spp) is an important economic resource in the rural population of Meru and Kisii counties of Kenya. In the two countries, it is a dominant crop and is used as a source of dietary supplements. Regardless of being a crop of importance in the two counties, most of the produce is prone to qualitative and quantitative losses during and/or after harvesting; which are referred to as Post-harvest Food Loss (PHL) (IITA, 2010). The current global hunger statistics indicate that 12 % of the world population is unable to meet the dietary requirements. Most of this hunger has been associated with food wastes, especially losses that occur after harvesting.

Banana is documented to supply the consumers with major nutrients such as potassium, magnesium, folate, vitamin C and vitamin-B. In addition, it also contains special substances that prevent development of diseases such as stomach upset and heartburn Food and Agriculture Organization of the United Nations (U.N.) predicts that around 1.3 billion tons of food is globally wasted or lost per year ((Ndaka et al., 2012). Importantly, most of the developing countries have been affected by the malnourished problems due to lack of knowledge. Specifically, in Kenya there are a greater percentage of losses that has been recorded on wastes in production of banana production zones (IITA, 2010). This relates to failure in agriculture sectors and other stakeholders in the value chain to develop approaches to help farmers increase the quality of the foods they present unto their tables.

Food losses are not only associated with reduction of available food for population consumption but also have a negative implication to the society. Importantly they lead to increased cost of wastes management and also production of greenhouse gases that impact the global warming which is a current environmental issue ((Kinyua 2008). This is due to poor means of disposal of the spoiled food at various garbage outlets. Besides, there is a major issue in the determination of the magnitude of the losses caused after harvesting. Reduction in these losses would increase the amount of food available for human consumption and enhance global food security; a growing concern with rising food prices due to increasing consumer demand, increasing demand for biofuel and other industrial uses, and increased weather variability. Moreover, reduction of PHL has positive impacts to the environment such that it reduces the cost of production for the farmers and also pollution.

The focus of this review paper was to analyze the extent and magnitude of the post-harvest losses in bananas that exists in the major producing counties in Kenya for both the large scale and smallholder farmers. Also, there was need to evaluate the socio-cultural factors underlying the magnitude of loss since the two counties have extreme cultural values and practices. Besides, some of the efforts made by the growers to minimize the losses were also identified.

Materials and Methods
This research was undertaken through use of desktop reviews of the existing literature in regard to banana production in Kenya with a focus to the main regions in Kenya, i.e. Kisii and Meru counties. Specifically, reports from the ministry of agriculture that has summarized data in terms of practices, production and the size of the land under production were very useful. The review summarized published articles, unpublished work, student's theses, surveys and case studies that covered the scope of the study - Kisii and Meru counties.

Results and Discussion
The banana supplied from Kisii and Meru to the Kenya market is complex and inefficient and it is estimated that 95% of the bananas sold are grade two bananas. This implies that the quality is very poor and can only be handled by the street vendors and retailers. Only 5% of the produce can be presented to the supermarkets and other commercial institutions (Kinyua 2008). Therefore, there was indication that the entire supply chain of the banana is associated with losses and hence could to malnutrition in the country. The reason for great losses of banana is due to several factors surrounding the crops during and after harvesting.

In Meru county 15-30 % losses was associated with improper handling of the bananas while in Kisii 20% waste was estimated from mechanical due transportation caused by motor bikes such as de-handing and piercing of the bunch fingers. Importantly, such extent of damage is caused by increased shaking of the banana in the rough roads to the market and major urban centers. Such damage was estimated to reduce the value of the produce by 30% due to poor appearance hence resulting to rejection by the traders in the market (Ndaka et al., 2012). Besides, damaged banana fruits are low in the nutrients thus implying that the consumers experience deficiency of vital elements in the diet.

Losses due to poor storage were approximated to be 30% in both regions due to poor means and lack of storage or effective storage facilities. High losses are also experienced in the society due to the lack of basic knowledge in the production practices of banana. According to the reports from the ministry of agriculture ("Fortunes change with tissue culture banana", 2013) 60% of the farmers in the rural areas have not attained secondary education hence creating awareness of PHL becomes very difficult. Immature harvesting of banana is also another potential loss of the bananas in the two counties.

Approximately 10% of the bananas taken to the market have not attained maturity contributing to 33% loss of value. These aspects are attributed to financial needs of the farmers and also at times of low banana supply like December and January. Additionally, 80% of the farmers are women and thus need for satisfying urgent and other family issues forces them to get engaged in activities such as premature harvesting due to lack of food, lack of techniques of harvesting at greater heights among others and these contribute to waste of this commodity (Okoko et al., 2013).

It is apparent that there are difficulties in the harvesting of the bananas by women since most of them have a bulk bunch hence leading to increase in wastes. For, instance in Meru, most of the fingers that get plucked off are directly fed to the cattle whereas a few are selected for cooking though this is less nutritive. In addition, the diversity of consumption is also another factor that contribute to losses in banana production having in consideration that these societies serve their families with buffet and thus contributing to more food waste. In Kisii, over-ripe bananas can be used for alcohol production, while in Meru such fruits go into wastes.

Conclusions and Recommendations

There is high potential to reduce food insecurities in the country through reduction of post harvest losses. Specifically banana production can form a backbone of the economy of the regions producing it. This is due to high demand of the quality bananas in the market. Therefore, there is need to carry out more research to develop better strategies to mitigate the problem of banana wastes among the farmers. More training and extension services should be encouraged to sensitize farmers on the need for effective handling of the banana during and after harvesting. Appropriate storage and transportation facilities need to be installed to minimize the magnitude of loss.

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5003 Enhancing Global Harmonization of Regulations for Reducing Food Losses and Waste in Sub-Saharan Africa

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Abstract
Food losses all over the world are estimated to account for over a third of all the food produced, a staggering 1.3 billion tonnes lost. Several reasons are responsible for this magnitude of global food losses with general consensus being that the post-harvest losses (PHLs) is the major cause of food loss in the developing countries while food waste is a major food loss contributor for the developed world. For sub-Saharan Africa, curbing food loss due to PHL is most critical. Losses at this level does not just mean loss of food but also the loss of time, energy, water and labour hours spent in producing the products, a situation that leaves households more vulnerable and exhausted. One of the sources of food losses and safety across different regions within Africa is the loss of food based on different standards or their application and or interpretation across sub-Saharan Africa. Global harmonization of food standards and especially across Africa has the potential for reduction in the food losses all across this region. This paper is the result of thorough review of published data, government documents, disseminated information and several websites of important stakeholders and evaluates the application of global harmonization across various countries within sub-Saharan Africa. The aim is to evaluate any benefits accruing from the implementation of harmonization of standards across different regional blocks within sub-Saharan Africa.

Key words:
Food standards, global harmonization, postharvest losses, sub-Saharan Africa

Introduction
Food losses all over the world have received renewed focus over the last few decades. This is due to the increasing food insecurity situation in most parts of the world especially in the developing economies. It is estimated that food losses account for over a third of all the food produced, a staggering 1.3 billion tonnes lost (World Bank, 2011). Post-harvest losses (PHLs) are the major culprit of food loss in the developing countries while food waste is a major food loss contributor for the developed world (World Bank, 2011). For this reason, curbing food loss due to PHL is most critical for the sub-Sahara Africa. Losses at this level do not just mean loss of food but also the loss of time, energy, water and, labour hours spent in producing the products, a situation that leaves households more vulnerable and exhausted.

One of the sources of food losses and safety across different regions within Africa is the loss of food based on different standards or their application and or interpretation across sub-Saharan Africa. Global harmonization of food standards and especially across Africa has the potential for reduction in the food losses all across this region FAO/WHO Regional Coordinating Committee for Africa (CCAFRIKA, 2017). The information on the progress with harmonization of standards within Africa is scanty, sometimes disjointed or simply regionally localized. This paper through rigorous reviews available published data, government documents, disseminated information and several websites of important stakeholder's reviews and evaluates the application of global harmonization across various countries within the sub-Saharan Africa region with the aim of quantifying any benefits accruing from the implementation of harmonization of standards across different regional blocks within sub-Saharan Africa. Depending on the level of harmonization, some of the benefits may not be fully experienced at this stage but will surely be realized in future. Thus, reduction of post-harvest food losses even through global harmonization initiative is a critical component of ensuring future global food security (Aulakh and Regmi, 2015).

The overall objective was to review the status of harmonization of standards within sub-Saharan region and establish its contribution to post harvest losses accruing from the process. The specific objectives of this review were: i) to review the nature of global harmonization of standards adopted within the sub-Saharan region; ii) to review the situational analysis of the current harmonization of standards within the sub-Saharan region; and iii) to review the real or perceived benefits of the standards' harmonization initiatives within sub-Saharan Africa and their contribution to reduction of post-harvest food losses.

Methodology
This paper was developed through a rigorous desk-top review of available online data, published data, and relevant government documents. Data was also collated from websites of important stakeholders with regard to standards development and harmonization. Situational analysis of global harmonization initiatives of standards and its impact across various countries within the sub-Saharan Africa was reviewed. Further information was also gathered by authors' participation at the 22nd session of CCAFRIKA, 2017 held in Nairobi, as delegates. Various representatives of the different regions of Africa were engaged through focused group discussions and one on one key informant's interviews.

Results and Discussion
Harmonization of standards allows capacity of countries to export and makes it possible for small scale farms to be involved in commercial supply chains. This exercise by itself can significantly reduce post-harvest losses especially during glut when the supply is more than the demand and yet the supply's quality is too low to be accepted by the commercial market supply chains (Keyser, 2012). World Trade Organization (WTO) has been the starting point for regional Sanitary and Phytosanitary Standards (SPS) policy. The SPS policy acts as basis for countries' creation of opportunities to protect their citizens from unsafe foods, increase their inter-country trades, and set food laws. It offers several alternatives for example, harmonization, equivalence agreements, and mutual recognition agreements.

The choice of which method to adopt between trade partners determines the benefits nations derive from trade as well as opportunities to expand market and trade on staple foods and by so doing, decrease post-harvest losses which may accrue from inadequate compliance to too many standards competing for compliance. Harmonization has an advantage because it eliminates the need for tedious and expensive risk analyses by most countries. Different regions are at different stages of harmonization with East Africa community (EAC) having a great deal of experience. It is also for this reason that The Common Market for Eastern and Southern Africa (COMESA), is considering adoption of some of these standards (BMZ, 2015). The adoption of or actual harmonization of standards within COMESA region which is a free trade block of over 22 countries and stretching all the way from Libya to Swaziland, demonstrates the role standard's harmonization could play to facilitate trade.

Codex Alimentarius regional committees are the linking hubs through which most of the standards harmonization is taking place within the sub-Saharan region. The equivalence agreements apply within countries which negotiate on the basis that a set of standards, however, different aim to achieve the same or equivalent level of food safety. This is a more pliable way by which countries may achieve SPS protection. Within the East Africa Community (EAC) the differences in maize standards across the different countries was noted to be devastating to small scale farmers who may only come to know of the differences at the boarder thus causing delays that may result in post-harvest losses (RATES, 2003). This confusion triggered the beginning of standards harmonization initiatives for staple commodities within EAC. EAC commodity has developed and harmonized standards covering 42 staple foods. These standards begun from the need for enhanced trading in grains within the region, and have now evolved into more areas.

Codex Alimentarius Commission (CAC) has targeted questionnaire with set of questions through Codex contact officers within the regions to collect information on emerging issues as well as for priority areas for action. There is an ongoing process of establishing a model food law to help close food safety gap in the region (CCAFRICA, 2017). As a result, work is already at advanced state to establish e-Working groups to develop project document on a harmonized food law within the region. Kenya is tasked with the mandate to draft a working/discussion paper that will be considered in the next meeting of Codex Africa committee meeting. Apparently there is still need for roll out tools for measuring performance of national and regional food safety and their correlation to adoption or harmonization of laws within the region. At the same time the effects of these harmonization initiatives on reduction of food losses are still unraveling.

Key areas of relevant regional standards are:

i. Numerical standard (MRLs of pesticides in food and feed) based on total diet studies.
ii. General subject standards (general standards for food additives, for contaminants and toxins in food and feed and for labelling of pre-packaged foods).
iii. General principles of food hygiene.
iv. Fresh fruits and vegetable standards and fish and fishery products
v. Mycotoxins and antimicrobial resistance

Currently at the draft stages are: proposed draft standard for dried meat, fermented cooked cassava, Shea butter and Gnetum spp. leaves. These are just some of the areas in which the regional harmonization of standards within sub-Saharan Africa is focusing. Some studies have raised concerns about harmonization of standards relating to negative impact such as costs of compliance and new inspections and certifications which have to be borne by the various actors of the value chains. Different countries have different certifying capacities and hence the operationalization of these harmonized standards within the countries or regions may still be hard to implement. Standards could be too high for small scale farmers or could be such that consumers do not really require them or they cannot afford them. A good example of these problems is the case of the recently harmonized EAC standards for dairy which is reported to have increased the cost of milk beyond the regular customers' ability to afford (World Bank, 2013).

Conclusion and Recommendations

Efforts to harmonize standards within the sub-Saharan region are highly laudable and in high gear. From development of Prevention and Control of Non-Typhodal Salmonella, microbial criteria guidelines, processed cheese, and ready to-use therapeutic foods harmonization of regional standards is happening vigorously. However, across the board, challenges to implementation and enforcement of harmonized standards are rampant. This therefore, negates the essence of harmonization of standards which in the long run will not be enforced. To benefit fully from the process of harmonization, capacity of the region to enforce harmonized standards is paramount. It is envisaged that increased capacity will address the challenges and reduce post-harvest losses reported due to different standards being imposed by different countries.

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5004 Improvement of Women's Livelihoods Through Provision of Bio-Fertilizer for Vegetable Gardens in Two Villages at West Kordofan, Sudan

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Abstract
Consequence sand encroachment in the area adversely affected soil fertility leading to crops failure in women gardens. The objective of the research was to improve the productivity of home gardensowned and managed by poor women in rural rain-fed semi-arid areas of Sudan adversely affected by climate change. 20 gardens were randomly selected from 46 gardens. Different concentrations of the bio-fertilizer (control, 0.5m3, lm3, and 1.5m3 for each m2) were applied in 12 plots (2x6m) and 3 subplots within each plot as replicate. Two types of vegetables were randomly planted in each plot; one representing fruit vegetable (Okra) "Abelmoschusesculentus L. Moench" and the other leafy vegetable (Jews mallow) "CorchorusolitoriusL.". The experiment was conducted for two successive seasons. Parameters measured were mainly fresh pod weights, number of pods per plant, plant height, leaf area etc. MSTATC and STATISTIX8 program were used for data analysis. Results showed signifiant increase in yields for both vegetables, except Jews mallow in the first season. Okra yield increased from 0.93 ton/ha fresh green pods to 1.4 ton/ha with 1.5 m3 fertilizer in season one. In season two, okra increased from 0.92 ton/ha to 1.38 ton/h with 1.5 m3 fertilizer application. In season two, Jews mallow yield increased from 13.15 ton/ha to 21.06 ton/ha with 1.5 m3 fertilizer application. Combined analysis of variance indicated that there were significant differences among treatments for all studied traits in Okra and Jews mallow. It could be concluded that bio-fertilizer adoption could contribute to women empowerment through using high dose from bio-fertilizer to insure optimum yield of Okra and Jews mallow during offseason and using dry vegetables losses (pods and leafs) for home consumptions and hence improve family socioeconomic life style.

Keywords:
Bio-fertilizer, food security, Sudan, vegetables garden

Introduction
Sudan is one of developing country vulnerable to climate change because natural resources represent the backbone of its economies, and its low adaptive capacity, these events become a major threat to world food security, as it has a strong impact on food production, access and distribution. Women represent most vulnerable groups to climate variability among rural communities in developing countries this attribute to poorer, less educated, lower health status and have limited direct access to ownership of natural resources(Chindarkar, 2012). Majority of rural women in the study area are engaged to varying degrees in crop production (cereal and vegetables) due to it's proximately to home or village. The average size of the homestead (locally known as Jubraka) area varies from less than 0.5 feddan to one feddan. This proximity to home or village enables women to spend their spare time in out of home activities to produce vegetables for family consumption (Moore-gough et al., 2007).

The yields of crops grown in the Jubraka are low because rainfall is both low and erratic in addition to the adoption of poor cultural practices (such as the use of seeds of low quality, poor soil fertility, lack of appropriate soil and water conservation). Okra (Abelmoschus esculentus L. Moench) and Jews mallow (Corchorus olitorius L.) represent most preferable vegetables in western Sudan due to special consumption for rural household either fresh or dried. Successful productions of vegetables rely on the local climate and season, varieties cultivated and supply of satisfactory seeds. Vegetables are essential elements to supplement their diets and income and produce lush, continuous growth throughout the season, they need a uniform supply of nutrients (Anon, 2014). Okra; the crop is originated in Asia and Africa, established by sowing seeds directly into the garden and harvest in 60 to 70 days after planting, fresh pods consume as boiled vegetable, its dried form is used as soup thickener or in stew. The green fruits are rich sources of vitamins, calcium, potassium and other minerals. The origin of Jew's mallow is unknown, but it has reportedly been cultivated for centuries, both in Asia and Africa, is planted either by direct seeding or transplanting and popular leafy vegetable in Kordofan, Leaves are alternate, simple, 5 to 15 cm long and very nutritious, rich in beta-carotene, iron, protein, calcium, thiamin, riboflavin, niacin, vitamin C and E and dietary fiber(Ahmad et al., 2007). Due to wide preference of some vegetables crops such as Okra and Jews mallow the study is seek to investigate the effect of the application of biogas bi-product fertilizer on women gardens and produce advices regarding using biogas effluent in home garden to improve women resilience to bridge the gap of seasonal variability.

Methodology

Description of Study area
West Kordofan State is located in the western part of Sudan, and falls in transition belt between war-effected in the south and the drought affected in the north(UN, 2003) located within latitudes 12° 0' N, and longitudes 28° 9' E. The state borders North Kordofan, South Kordofan, East Darfur, North Darfur and South Darfur(Awad et al., 2010) figure (1). The total area covered is estimate to be 111,373 square km2 (UN, 2003), extending from low rainfall savanna to high rainfall and hill catena and its vegetation varies greatly.

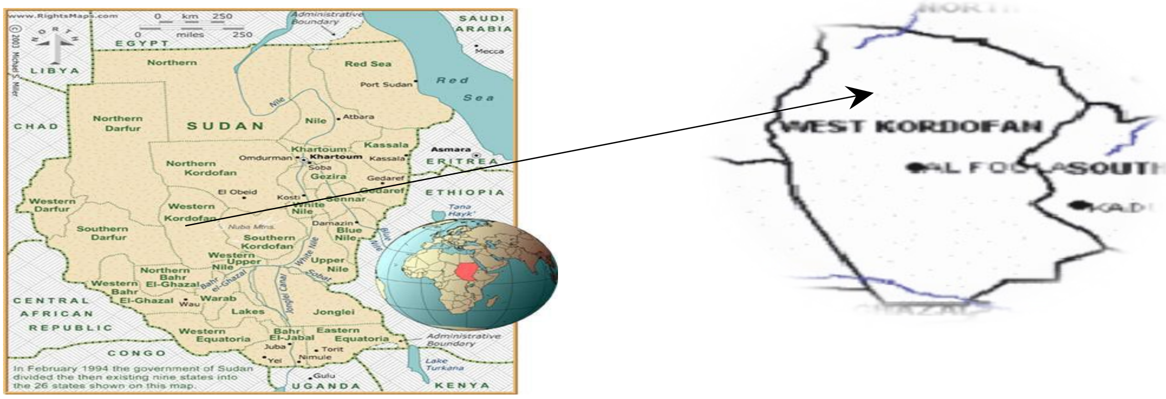

Figure 1: Location of the study area

The field experiment was conducted for two successive seasons 2014/2015 and 2015/2016 Using Randomized Complete Block Design (RCBD), experimentation with women gardens included application of biogas fertilizer with different concentrations and their effects on plant performance and vegetables' yield. The piece of land allocated for vegetables plantation was divided into 12 plots (2x6m) and 3 subplots within each plot as replicate. Different concentrations of the biogas fertilizer high, medium, low and zero were applied (control, 0.5m3, lm3, and 1.5m3 for each m2). Two types of vegetables were randomly planted in each plot; one representing fruit vegetable Okra "Abelmoschus esculentus L. Moench" and the other leafy vegetable Jews mallow " Corchorus olitorius L.". Women gardens involved in this experiment were 46 gardens. The obtained data for two successful seasons were analyzed using Statistix8 program and MSTATC for comparison between seasons.

Results

Application of biogas liquid effluent to women gardens showed increased Okra yield in successive seasons. The yield ton/hectare for the fresh green pods increased with the increase of the concentrations. The results obtained showed that the yields were 0.93 ton/ha, 0.98 ton/ha, 1.31 t/ha, 140 ton/ha for the control (0 m3), 0.5m3, lm3, and 1.5m3 respectively for the first season. In the second season the yields obtained were: 0.92 ton/ha, 0.95 ton/ha, 1.26 ton/ha, and 1.38 ton/h for 0 m3, 0.5m3, lm3, and 1.5m3 respectively. For the fresh weight significant differences were obtained for both first ($P \leq 0.05$) and second ($P \leq 0.04$) season. For number of pods per plant significant differences were observed for first ($P \leq 0.05$) season only (Table 1)

The fresh weight for Jews mallow although decreased with the first concentration compared with the control, but increased significantly with increase in biogas effluent concentration for the first ($P \leq 0.064$) and second season ($P \leq 0.024$). Significant increases were also observed for plant height for the first ($P \leq 0.025$) and second season ($P \leq 0.038$). However, for number of leaves per plant was significant only in the second season ($P \leq 0.058$), leaves surface area was significant for first ($P \leq 0.003$) of and second season ($P \leq 0.019$) (Table 2).

Table (1) Results of okra production for two seasons (2014/2015 add 2015/2016)

Treatment	Fruit fresh weight (ton/ha)		Fruit length (cm)		Plant Height (cm)		No. of Fruits per plant	
	Season 1	Season2	Season1	Season2	Season1	Season2	Season 1	Season2
0 m^3	0.93	0.92	5.33	5.33	66.67	64.3	1.02	1.02
0.5m^3	0.98	0.95	6.33	5.67	66.33	68.00	1.25	1.25
1m^3	1.31	1.26	9.00	8.00	74.33	71.00	1.88	1.48
1.5m^3	1.40	1.38	7.67	8.33	83.33	80.33	2.06	1.95
Mean	1.16	1.13	7.08	6.83	72.67	70.92	1.55	1.43
P-value	0.05	0.04	0.07	0.11	0.28	0.34	0.05	0.21
±SE	0.11	0.09	0.79	0.88	5.47	5.84	0.23	0.28
LSD 5%	0.37	0.34	2.7458	3.0336	18.945	20.213	0.79	0.9574
CV%	15.84	15.27	19.40	22.22	13.05	14.27	25.47	33.61

$P \leq 0.05$ Significant,indicating by Statistix8, source; field research (2016)

Table (2) Results of Jews mallow for two seasons (2014/2015 add 2015/2016)

Treatment	Fruit fresh weight (ton/ha)		Plant height (cm)		Number of leafs pe plant		Leaf surface area (cm)	
	Season1	Season2	Season1	Season2	Season1	Season2	Season1	Season2
0 m^3	14.11	13.15	53.00	51.00	18.67	20.00	3.567	3.267
0.5m^3	13.89	12.85	51.33	47.67	18.33	18.67	3.967	3.567
1m^3	17.37	15.57	57.00	57.67	20.00	22.33	4.767	3.733
1.5m^3	21.62	21.06	62.67	62.67	25.33	23.67	4.067	4.300
Mean	16.75	15.66	56.00	54.75	20.58	21.17	4.092	3.717
P-value	0.064	0.024*	0.025*	0.038*	0.058*	0.229	0.003**	0.019*
+SE	1.766	1.472	1.969	2.872	1.552	1.630	0.121	0.159
LSD 5%	6.1116	5.095	6.816	9.939	5.3692	5.6411	0.419	0.552
CV%	18.27	16.29	6.09	9.09	13.06	13.34	5.14	7.44

$P \leq 0.05$ Significant,indicating by Statistix8, source; field research (2016)

Discussion

Women gardens known locally as Jubraka is a wide spread activity among women in the area, according to deforestation and soil degradation, the vegetables yield was drastically affected. The use of biogas effluent as fertilizer was applied to improve vegetables' yield. Experimentation with women garden showed that increase in biogas effluent concentrations as fertilizer significantly improved yield of this was particularly true for the fresh pod weights for Okra for the first season. For Jews mallow, all parameters were significantly improved for the two seasons. Most of the women admitted that their vegetables' yield had improved.

Conclusion and Recommendation

Adoption of bio-fertilizer contribute to women empowerment through using high dose from bio-fertilizer to ensure optimum yield of Okra and Jews mallow during off-season and using dry vegetables (pods and leafs) for home consumptions and hence improve family socioeconomic life style. This benefit is directly linked to the Millennium Development Goals of reducing income poverty, promoting gender equity. Application of high dose from bi-fertilizer is highly recommended.

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5005 Gender Roles, Relationships, and Social Equity in Post-harvest Management

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Abstract
Research has shown that women and children play a major role in farming as they provide labour for all agricultural activities. Apart from on-the-farm activities, women are also heavily engaged in postharvest activities and preservation of food to ensure that it is available for the whole family in and out of season. Addressing gender issues within the postharvest management (PHM) field is therefore imperative. In efforts to understand the challenges faced by women in PHM, the Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN) under the Postharvest Management in Sub-Sahara Africa project, conducted a study to look at how gender roles, relationships, and social equity issues affect PHM in Benin and Mozambique. Two focus group discussions and literature review were done. In Mozambique, a review of national, regional, and global literature on PHM, gender and social equity and interviews with policy key informants were conducted. The studies were also validated by national stakeholders in the focus countries through validation workshops. The studies highlighted that despite the women empowerment awareness campaigns conducted, there is still a gap existing in policies, programmes and projects delaying the realization of gender and social equity in PHM. Gender and PHM strategy and policy documents must align to local and regional policy documents so that PHM gender mainstreaming becomes a national and regional responsibility. Increased involvement of smallholder farmers in PHM research trials and measurement of postharvest losses in the countries will also improve PHM interventions acceptability. Tools and innovations developed to aid post-harvest handling must meet requirements according to gender needs, age, and socio-cultural relevance.

Key Words:
Agriculture, gender, innovations, postharvest management and loss, technologies.

Introduction
At the centre of household farming are women and children. Apart from on-the-farm activities, women are also heavily engaged in postharvest activities and preservation of food to ensure that it is available for the whole family in and out of season (Tomo, 2015). Addressing gender issues within the postharvest management (PHM) field is therefore imperative (Igue, 2015).

Post-harvest food losses are one of the largest contributing factors to food insecurity and under-nutrition in Sub-Saharan Africa (Capone et al., 2014). Post-harvest losses (PHL) significantly lower the quality and volume of food available for consumption and sale, thus aggravating hunger, malnutrition, and reducing household income. In Sub-Saharan Africa only, annual food losses exceed 30 per cent of total crop production and representing more than USD$4 billion in value per year (World Bank, 2011). African Post-Harvest Losses Information System (APHLIS) reported physical grain losses in Africa as ranging from 10 to 20 per cent (APHLIS, 2013). Common causes of PHL are inadequate handling and storage practices at the household level, causing crops to be susceptible to insects, pests, mould, and moisture. Post-harvest management (PHM) at farm level is therefore, a critical starting point in the supply chain.

Post-harvest activities influence farm productivity and efficiency; which in turn affects optimal efficiency of agriculture as a whole. When postharvest activities are done manually, they tend to be time and energy consuming and can affect the physical well-being of farmers (Tomo, 2015). When technology is introduced to replace manual activities, roles held by household members may be replaced, with positive impacts, especially if the technology improves efficiency and food security (Igue, 2015). It is important that any intervention in PHM positively influences food security by addressing the pillars of food security, which are availability, accessibility, stability, and utilisation. Research has shown that women and children play a major role in PHM. Therefore, it is important to understand, through gender analysis, how efforts to reduce PHL can affect women's welfare (Tomo, 2015). Gender encompasses social roles and identities associated with what is expected, allowed, and valued in a woman or man as established in different socio-cultural contexts. Gender roles are shaped by ideology, religion, ethnicity, education, culture, and tradition. They are therefore, key determinants of the distribution of responsibilities and resources between women and men as well as social groups. In PHM, fairly and clearly defined gender roles will determine the effectiveness of combating PHL at household level. Gender equality and social equity are the key factors in sustainable development in rural communities. In a rural household setting, women, men, and children are assigned different tasks, and responsibilities in PHM. Women are key actors in the agricultural and economic system, both through their remunerative work on farms and activities they render at home and in the community. However, in many societies women are systematically excluded from accessing resources, essential services, and decision-making processes. Gender analysis targeted at improving PHM ensures that women and men participate in the development of strategies and that proposed programs target their resources most effectively, taking into account the different roles, needs, and perceptions of women and men. Furthermore, it makes it easier to identify obstacles and solutions to achieving gender equality and women's empowerment. In efforts to understand the challenges faced by women in PHM, the Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN) under the Postharvest Management in Sub-Sahara Africa project, conducted a study to look at how gender roles, relationships, and social equity issues affect PHM in Benin and Mozambique. The study was guided by three objectives : (i) To identify gaps, challenges and opportunities with regard to how dimensions of gender and social equity of PHM are addressed in the existing policy frameworks; (ii) To identify PHM innovations, tools or mechanisms that enhance gender balance and social equity which can be scaled up and; (iii) To draw general lessons on the participation of women smallholder farmers and marginalized social groups in PHM.

Methodology

In Benin two field surveys, one with farmers and another with policy and agricultural key informants, two focus group discussions, and literature review were carried out. The literature reviewed was from documents on dry cereals in Benin, agricultural policies, post-harvest management, gender promotion policy in the agricultural sector and documents covering the evolution of the consideration of gender in post-harvest management of dry grains. In Mozambique, a review of national, regional, and global literature on PHM, gender and social equity was undertaken. Interviews were conducted with policy key informants. The studies were also validated by national stakeholders in the focus countries through validation workshops that were attended by more than 40 participants per country.

Results and Discussion

The studies highlighted that despite the women empowerment awareness campaigns being conducted, there is still a gap existing in policies, programmes and projects delaying the realization of gender and social equity in PHM. Two types of documents are available in Benin, the agricultural sector strategy that highlights gender considerations, and the gender policy. There is no specific document, policy, or strategy on PHM. Moreover, there is no specific chapter on PHM in these gender related documents. Mozambique advocates for the promotion of research and innovation, food security, equal rights and opportunities by all social groups. However, its legislative documents do not mention the importance of conducting targeted actions to reduce post-harvest losses with the intent of promoting food security, gender equality, and social equity.
As much as both countries have gender and social equity policies, they do not mainstream PHM, thereby neglecting the existing gap of the practical and strategic gender needs of rural communities. The quality of life in the rural community in Benin and Mozambique will not improve, gender and social equity will not be realized and existing gender roles, and stereotypes will not change if these gaps are not closed.
Women are key actors in the agricultural and economic system, both through their remunerative work on farms and activities they render at home and in the community. Lack of PHM policies affect women more than men. Women will continue to have limited access to PHM interventions, extension services, and PHM education. Decision-making power and control over resources will continue to be skewed towards men. Consequently, women will be the most affected by grain losses. Integration of post-harvest management and gender policies facilitates synergistic positive influence on PHM. It determines all major decisions and actions, and all activities concerning post-harvest handling of grains at rural community level. Gender and PHM strategy and policy documents must align to local and regional policy documents so that PHM gender mainstreaming becomes a national and regional responsibility
In Benin, there are many different technologies and equipment for the improvement of maize and rice PHM, either for tasks performed by men and women or for tasks performed only by women. However, some of this equipment continues to aggravate gender inequalities because women cannot access and utilize them. Since PHM activities at household level are responsibilities of the women, it is ideal to develop equipment that can be used by women without seeking help from men, as most of this equipment requires physical strength.
The uptake of PHM innovations among women has been slow in Mozambique. Reports have shown that adoption of the mud-brick silos has been constrained due to poor financial conditions of the rural farmers, especially female farmers. FAO has also been promoting construction of metal silos unsuccessfully due to poor skills and capital by local artisans; and scarcity of appropriate metal sheets on the local market for construction of metal silos. There is need to strategize on how to quicken the dissemination of PHM technologies in Mozambique.

Conclusions and Recommendations

Gender is a socially constructed definition of roles, behaviours, and power relations between women and men. Understanding how to bridge the gender gap that exists in PHM and provide appropriate interventions can help to effectively reduce PHL and improve rural community well-being. Currently, reports from study countries reveal that high volumes of grain are lost after harvest resulting in food losses and loss of expensive inputs such as fertilizer, irrigation water, and human labour. There is need to create grains PHM policies specific to rural farming.
Mainstreaming gender and social equity policies with PHM policy will ensure that PHM policies are improved in terms of relevance to gender and social equity dimensions; and effectiveness. This also allows development of strategies and innovations that increase the probability of equalising opportunities, and bridging gaps among men, women, and youth farmers. Men and women have different needs. Women's empowerment and the adoption of gender-sensitive policies and PHM innovation are crucial because of the contribution both can make to shifts in gender roles.

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5006 Ten-Years of FAO Support to Assessment Methodology and Informed Fish Loss Reduction Policies and Strategies

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Abstract
With more than 60% of Africa's fisheries production and ten million actors, small-scale fisheries is the backbone of the sector, a key contributor to food and nutritional security, income generation and economic welfare. However, its actual potential is not fully utilized owing to several shortcomings, one of the salient being the high level of post-harvest losses. In 2006, in order to have a better understanding of the patterns of losses, the UN Food and Agriculture Organization (FAO) engaged in a collaborative undertaking with 12-Sub-Saharan African countries to establish a methodology for post-harvest losses assessment in small-scale fisheries. The methodology has framed a systematic approach to reduction of losses amongst smallholders. It consists of three methods, the exploratory qualitative method (IFLAM-Informal Fish Loss Assessment Method), Load Tracking (LT) and Questionnaire Loss Assessment Method (QLAM). It has been proven to be valuable in overcoming the challenges in data and information collection in small-scale fisheries and can be tailored to the geographical context and value chain needs. Further improved to mainstream the multifaceted aspects of losses, it then evolved into a methodology to understand the losses in the use of important tropical fishing gears in Africa, Asia and Latin America. The work has generated data, case studies with baseline indicators and milestones, and has facilitated strategy development, documenting best practices and promoting technology innovations. Lessons from the process reveal its contribution to countries' efforts towards the realization of the Malabo Declaration of halving the current levels of post-harvest losses by 2025.

Keywords:
Fish loss, interventions, methodology, policy, post-harvest, strategy, technology

Introduction
A recent continent-wide study estimated that 12.3 million people are employed as full-time fishers or full-time and part-time processors (Garibaldi. 2014). This represents 2.1 percent of Africa's population of 15-64 year olds. Fish and fish products are excellent sources of protein and exceptional sources of other valuable macro- and micro-nutrients. This underscores the role of "food" from the oceans, seas, lakes, rivers, reservoirs and wetlands, as a significant economic activity to feed and provide livelihoods to the population. This performance however, is seriously challenged owing to several shortcomings, some of the salient ones being illegal, unreported and unregulated fishing (IUU), over-utilized stocks, degraded environment and ecosystems, and fish losses. The latter, particularly post-harvest losses occur against a backdrop of stagnant capture fisheries production, in a region where aquaculture is still developing (Akande, 2010). These losses mostly involve small-scale fisheries which make up 60 % of Africa's fisheries production, and incur greater losses compared to large-scale fisheries because of their structural shortcomings (Sofia, 2014).

Wide ranges of losses had been estimated in the past, between 15 and 75% (FAO. 2009) and in many cases the key factors behind these figures have not been clarified. These makes planning and implementation of effective loss reduction strategies difficult, and risks wasting scarce development resources. Yet setting and implementing informed loss reduction interventions is reflected in Article 11.1 (Responsible fish utilization) of the Code of Conduct for Responsible Fisheries (FAO. 1995). A better understanding of these losses is therefore fundamental to prevent disjointed interventions. This calls for a simple, practical and cost-effective method, which does not generalize the root causes from one context to another. The situation is further complicated by the fact that, as in any tropical region, many fisheries are multispecies and catches lack uniformity in terms of composition, weight and shape. In addition, spoilage rates vary under different conditions for different fish, and value chains can have fragmented distribution systems involving many stakeholders. Moreover, landing sites and markets often use non-standardized units of measurement for trading and pricing purposes (FAO, 2014).

This has prompted the Fisheries and Aquaculture Department of the UN Food and Agriculture Organization (FAO) to engage, since the mid-1990s, in collaborative work with several institutions and with 12 Sub-Saharan African countries that led to the establishment in 2006 of a methodology to assess post-harvest losses in small-scale fisheries (Akande, 2010) and to help in tackling losses effectively. The objectives of developing systematic and practical post-harvest loss assessment tools are to inform the design, planning, implementation and monitoring of loss reduction measures, through the identification of the significance of losses, whether they can be reduced, and what sustainable benefits are likely to accrue, leading to good practices being introduced and scaled up.

Methodology
The challenges posed by the lack of practical tools to address the complexities described above have been tackled through the collaborative work of FAO, the Department for International Development of the United Kingdom of Great Britain and Northern Ireland, and a project funded by the European Union in West Africa in the mid-1990s. This was capitalized by the regional post-harvest loss assessment programme (RPHLA) implemented by FAO. In acknowledging the indispensable role of adequately trained practitioners for the data and information collection and analysis, the RPHLA, which ran from 2006 to 2008, developed a core of regional expertise in fish loss assessment for a common understanding on the types and magnitude of losses, the root causes and a prioritization process towards the identification of feasible solutions; Reviewed the methodology in Ward and Jeffries (2000), made up of 3 methods: the exploratory qualitative method (-Exploratory or Informal Fish Loss Assessment Method - EFLAM/IFLAM), Load Tracking (LT) and Questionnaire Loss Assessment Method (QLAM). These methods can be used in combination or in isolation. EFLAM relies heavily on the active involvement and par-

ticipation of fisheries operators, taking advantage of their abundant local knowledge to generate a good understanding of the loss problem (Mgawe and Diei-Ouadi. 2011). Its application requires a knowledgeable enumerator in participatory rural appraisal principles. LT is used to measure specific losses and relies on evaluating the quality and weight as fish moves through stages in the chain. QLAM is used to quantify and validate key loss data including extrapolation over a wider geographical area and fill data gaps that were not well captured in EFLAM. It relies on the administration of questionnaires; Piloted in the field and then validated.

Results and Discussion

Following from the 2007-2008 validation in socio-economically important fisheries in 5 sub-Saharan African countries (Ghana, Kenya, Mali, Tanzania and Uganda), (Akande. 2010, FAO. 2009), the methodology was documented into practical guides for extension officers and fishery operators (Mgawe and Diei-Ouadi. 2011). The established methods are as shown in Figures 1 and 2 below:

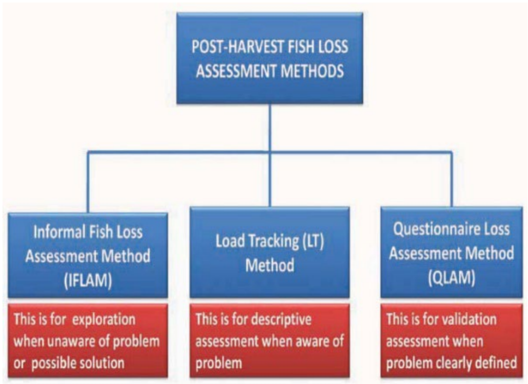

Figure 1: Different post-harvest fish loss assessment methods (source Mgawe and Diei-Ouadi, 2011, p.26)

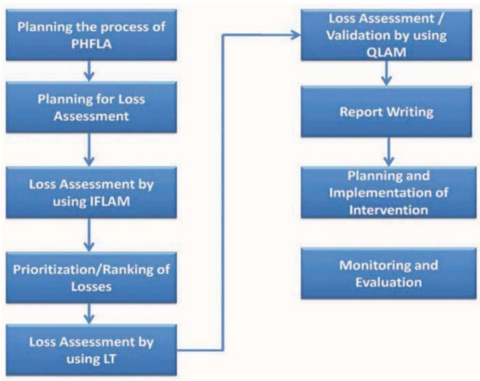

Figure 2: Key steps in a typical fish loss assessment (source Mgawe and Diei-Ouadi, 2011, p.27)

This work has formed the basis for the development of the methodology for food loss case studies in the small-scale agriculture and fisheries subsectors by the Global Initiative on food loss and waste reduction (FAO 2014). Its simplicity, user friendliness, flexibility (its ability to be tailored to the geographical context and value chain needs) and cost effectiveness have allowed the methodology to effectively respond to the multifaceted dimensions in addressing fish losses. The NEPAD-FAO Fish Programme (NFFP) was an illustration of this comprehensive approach to loss reduction. In the Volta Basin riparian countries, Lake Victoria region and others such as Angola, Cameroon, DR Congo, Liberia, the approach paved the way for holistic loss reduction interventions. Most of the studies (Akande, 2010; FAO Save Food 2014, FAO 2015) have found:

- High levels of post-harvest losses - well beyond the one-third which is the average global level for the whole fisheries sector as per FAO's 2011 estimates (Gustavsson, 2011)
- A relatively low quantity of fish found to be lost from the chain (to the extreme, 10% of physical or quantity loss), supporting thus the overriding importance of the quality loss, which accounts for up to 70 percent of total losses.
- That the "market force loss" or price reduction, irrespective of the quality of the fishery product, is another type of loss, leading to lost opportunities for income earning. In most systems assessed so far market force losses ranked second in volume and value terms, and at times, first in value terms. It illustrates some facets of post-harvest losses that are yet to be understood within the poverty eradication sphere.
- That coping strategies such as the "loss transfer" phenomenon and the interwoven factors have paved the way for a vicious cycle of the poverty trap.
- That multiple factors, stemming from technical, technological and/or infrastructure deficiencies, weaknesses in knowledge and skills, account for 65% of the bulk of factors that undermine the availability of food. However the share of 35% of the drivers of losses identified to lead to significant losses. They are indeed linked to the actors and consumers' social and cultural dimensions of vulnerability, the lack of responsible governance, regulations and their enforcement.
- That there are gender specific questions: Even if they have the will or the financial means, women have little opportunity to be able to always access the fish of the highest quality in the first hours of auction/sale, given that they are responsible for household chores.

Figure 3: Main gender issues in fisheries processing and sale (source FAO, 2014)

Since processing does not improve the quality of an already poor quality raw material, the loss process is embedded right from the purchase and exacerbated over the subsequent stages, depending on the handling practices. The same applies during processing, particularly in terms of incomplete or excessive smoking or calcination of the product during this process. Managing this disadvantage to to reduce the level of losses is therefore a priority in the context of lightening chores and capacity development.

There are many examples of the promotion of good practices to address critical losses in small-scale fisheries, such as the dual processing technique known as the FAO-Thiaroye Technique (FAO, 2015), the strengthening of the cold chain using solar energy, and enforcing policy measure to address the losses linked to "artificial glut" resulting from poor public safety (armed robberies on highways, trade corridors). The loss elements mapped out and priority areas for interventions partially informed the African Fisheries and Aquaculture Policy Framework and Reform Strategy (AFPF & RS). The implementation of the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication" is being largely informed by that work as far as the approach and lessons learned are concerned. The Volta Basin strategy developed in 2016 (FAO 2016) is in line with the AFPF & RS, which is the implementation mechanism within the fisheries context towards achieving the Malabo Declaration.

Conclusion and Recommendations

In order to address the multifaceted problems of post-harvest losses and to prioritize interventions, a systematic appraisal within any given context is required. This appraisal needs to focus on the efficiency of the entire post-harvest system, which can then provide reliable information to make cases for evidence-based policies, strategies and programmes. The RPHLA methodology has demonstrated its utility.

The outputs from the 10 year old methodology have raised a more thorough understanding of issues that were not captured before, and have contributed to promotion of good practices, development of other methodologies, such as used in the Save Food initiative, and in the ongoing process of establishing a methodology to assess wasted resources in gillnet fisheries.

The approach and connected methodology highlight that reducing PHLs efficiently and sustainably requires thinking outside the technology and infrastructure box and to consider addressing important factors that undermine resource sustainability, efficient and competitive post-harvest systems and trade. But it also shows that the multifaceted dimensions of losses remain yet to be understood fully. As one of the objectives of the RPHLA, the development of normative guidance on losses is timely, hence the significance for Africa of the upcoming work on the development of practical guidance to inform policy in addressing common loss scenarios.

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