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Postharvest loss assessment of maize (*Zea mays*) along its value chain in Nigeria

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Maize is the third most important cereal and staple globally. Poor agricultural policies and funding are the major problems of agriculture in Nigeria. This work was aimed at studying maize postharvest losses through identification of causes and sources. Data were gathered via Commodity Systems Assessment Methodology which includes 26 components, structured interviews and protocols for measuring quantity, quality and economic losses. Information on marketing, storage, handling, production and pre-production was obtained through interviews, observations, measurements and literature. Results of the study showed that cultural practices for maize vary from region to region and this affects the quality and quantity of maize. Poor quality seeds and fertilization have effects on the quality of the harvested crop. Maize is sundried on farm prior to sale. Quality and cob size affect farm gate prices. Farmers were unaware of postharvest losses because the harvested crop was not sorted before sale. Factors identified to affect maize losses at farm are; production constraints, improper drying, lack of grades and lack of storage. On farm postharvest losses were measured to be 13%. Mechanical damages during handling and transportation account for 2 to 3.5%. An average loss of 15% was recorded across the value chain.

Key words: Postharvest, maize, commodity, crop, quality, storage.

INTRODUCTION

Maize is an important food and fodder crop in many countries (Cadoni and Angelucci, 2013). It ranks third globally in terms of production after rice and wheat. Nigeria is the second leading producer of maize in Africa but despite its high production, Nigeria's average maize yield is still among the lowest in the world.

Experts have reported that Nigeria could become the largest maize producer in Africa and one of the largest producers in the world without increasing the area under cultivation (SAHEL, 2017).

The majority of maize producers in Nigeria are smallholder farmers (male and female) producing more than 70% of the nation's maize. There are only a few large-scale producers (GIZ, 2013). Cultivation is highest in the northern part of the country especially in the states of Kano, Kaduna, Bauchi, Gombe, Adamawa, Taraba and Jigawa (BRIU, 2015).

In 2013, Kano and Kaduna states produced 12.1% of national maize supply (GIZ, 2013). Among the South western states, Ogun, Ondo and Oyo are the leading

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producers of maize (SAHEL, 2017). The national requirement for maize is estimated at about 16 million tons, with the production of 10.3 million MT in 2013, supply deficit is about a shortfall of 5.7 million MT (NAERLS, 2014).

Since the report on Global Food Losses and Food Waste (FAO, 2011) reported that 1/3rd of all foods were being lost, and the World Bank (2011) "Missing Foods" report on storage losses of grains in Africa, many new reports have been published on the topic (APHLIS, 2014).

The many postharvest loss studies and crop loss assessments that have been published in recent years often use ad hoc measurements, survey questionnaires or interviews, and focus on measuring overall quantitative (physical, volume or weight) losses (APHLIS, 2014). Each researcher has developed their own data collection instruments for different crops and target populations, and has reported on recall of % losses or weight losses for the crop, generally reported as estimates or ranges. PHL data is rarely available on the quantitative losses being experienced at the different levels of the value chain, standard deviations for reported loss levels, characteristics of qualitative losses, value of economic losses or other parameters related to food security such as nutritional losses.

Affognon et al. (2015) reviewed postharvest loss reports generated in some African countries and found out most had to be eliminated because they provided unreliable data. Affognon et al (2015) further found out that most of the available historical data was focused on storage weight losses for maize and therefore recommended expanding future postharvest loss assessment studies. APHLIS (2015) reported the estimated postharvest losses of maize in Nigeria according to states.

The objectives of the CSAM study were to identify and quantify the main causes and sources of food loss in the postharvest chain from the harvest to the retail market in major maize production states of Kano and Ogun. The analysis identifies where farmers and traders are losing the most quantity, quality and economic value, and identifies appropriate interventions for reducing these losses.

MATERIALS AND METHODS

The field work for this study was conducted between July and August, 2017 in Kano and Ogun states using Commodity Systems Assessment Methodology (CSAM), recently updated by postharvest trainers at IICA and PEF (LaGra et al., 2016). The study was done as part of an Agribusiness Associates Inc. project funded by the World Bank Group.

A CSAM study begins with a literature review of published articles and unpublished documents, review articles and government reports. CSAM is a systematic process of using survey questions, interviews, observations and field measurements to collect data on the key aspects of the value chain, including preproduction, production, postharvest handling and marketing. It considers the entire commodity system, from planning and production to processing and marketing, but focuses heavily on the postharvest and marketing aspects in order to determine the relative costs and benefits of any potential or observed changes in handling practices, containers, value addition or marketing practices.

For this study, data on the maize value chain was collected via literature review, interviews following a simplified set of written questions targeted to the crop, observations of the harvest and postharvest handling practices, and direct measurements in the field. Questions related to production were asked mainly to farmers; traders and marketers were asked about postharvest handling and marketing and researchers, project staff and/or extension workers were questioned about the entire commodity system. CSAM interviews were conducted with 10 to 15 persons via a stratified sample of known crop experts, extension workers, farmers, traders, storage operators, processors and marketers.

Additionally, the field teams utilized standardized worksheets for on farm, storage, wholesale and retail market data collection on postharvest losses, quality characteristics, market value changes, and a worksheet on the costs/benefits of potential changes in practices. The general process of the field-based assessment was to sample postharvest losses for a random selection of 10 farms, 10 storage facilities, 10 wholesale markets and 10 retail marketing sites via direct measurements, questions and observations.

Tools used during the CSAM studies included: Digital scale (5 kg capacity); hanging scale (30 kg capacity); digital temperature probe; digital camera; digital hygrometer and set of data collection worksheets with protocols.

Data collection measurements are designed to be simple and non-destructive whenever possible. For example, quality characteristics are determined via sorting a random sample of 20 cobs or kernels into pertinent categories (defects, appearance, damage, decay, etc.). The undamaged maize can then be returned to the farmer or vendor.

Data analyses are likewise kept as simple as possible when conducting a CSAM study. Data entry is via a simple spreadsheet that matches the data collection worksheets, and requires calculations of sums, ranges, averages and standard deviations.

RESULTS AND DISCUSSION

The following is a summary of the key findings on maize postharvest losses and overall results of the CSAM studies (Tables 1 and 2).

Cultural practices

The cultural practices for maize production vary from one region to another in Nigeria and this affect the quality and quantity of the commodity produced. During field visits in Ogun state, the team observed that the majority of farmers do little or no fertilization at all, unlike in Northern part of Nigeria where maize is believed not to do well without fertilizer. The harvested crops were mostly unsorted and so farmers were largely unaware of any postharvest losses. Harvest losses can be due to missing produce on the plant, dropping cobs in the field, and discards due to obvious pest damage.

Maize is dried in the sun on the farm prior to sale. Quality at harvest (defects, decay and/or damage), size of cobs and moisture content all affect farm gate prices.

Table 1. Summary of general information for the maize commodity system assessments in Nigeria.

Country	Farms	Storage	Wholesale	Retail
	N=10	**N=10**	**N=10**	**N=10**
Nigeria	Ogun State (southern) Harvest in July-Aug Nigeria average yield = 1.84 MT/ha Farm size: 1 to 5 ha CSAM average measured yield: 5 MT/ha Produce both white and yellow maize	Kano State Storage in 100kg woven sacks. Sites included one 20 MT Metal silo Storage period: Range of 5 to 10 months (kernels) or 4 to 9 months (cobs)	Ogun State markets operate for a few weeks after harvest Kano area grain markets (northern) Operate year round Some cleaning, but no drying, sorting or grading Maize sold as cobs and kernels Average temperature of air = 31.3°C	Ogun and Kano States No grading or retail pricing by quality grade. Price range N15,000 to 17,000/100 kg 100 kg is an estimated weight of one sack (sold by volume)

Table 2. Summary of the CSAM finding summarizing the causes and sources of losses for Maize in Nigeria.

CSAM Components	Interviews	Observation	Comparison to Best Practices
Planning/ Preproduction	Farmers report Saving their seed for the next season	Nil	Use of good quality seeds provides higher yields
Production	Few farmers use appropriate levels of fertilizers	Pesticides use was spotty or improperly done	Use of recommended inputs can improve yields and quality, reduce loss of kernels during harvesting
		Harvest not based on moisture content	Protection from pests
		Maize fell off cobs, was dropped into the field, lost during harvesting	Proper drying to M. C. of 14% for best quality and longest storage life
		Drying was done in open field or in heaps (exposed to rain, dust, and pests).	
		Only high-quality maize was accepted for storage	
Marketing	Resale was often done without inspection of contents of the bags	Little or no sorting or grading during marketing	Markets can better protect maize by providing shade and some type of cover (tarp or roof) to protect the crop from rain
		Sacks were said to be 100 kg, but there was little or no weighing done before resale	

The yield of maize for the farms in Ogun State visited during this study was higher than the national average. The farm gate price is determined by the number of cobs or by the volume sold, and the moisture content, but maize is not sold by weight.

Table 3. Postharvest system characteristics for maize in Nigeria.

Farm	N	RH%	Air Temp (ºC)	Grain Temp (ºC)	Package Protection* (sacks)	Sold as cobs or kernels	White or yellow maize
	10	**70.7**	**28.9**	**28.5**	**2**	**Cobs**	**both**
Wholesale market	10	57.9	31.3	29.7	2	3 as cobs/ 7 as kernels	Both
Storage	10	64.5	28.0	26.0	2	2 as cobs/ 8 as kernels	Both
Retail market	10	44.9	34.6	32.1	2	Kernels	Both

*1 = low, 3 = moderate, 5 = excellent protection.

Maize losses at wholesale markets

The assessment was done in the Kano area in Northern Nigeria, as this is the major maize wholesale, storage and retailing area while assessment of fresh cobs wholesale was done in Ogun state. Containers are standard 100 kg sacks for maize kernels while reuse old fertilizer or rice sacks for packaging maize cobs. A few small-scale wholesalers do shelling and/or cleaning as a value addition practice, using manual methods. Marketers complain about being at the mercy of middlemen regarding market prices.

Maize losses in storage

The assessment was done in the Kano area in Northern Nigeria, as this is the major maize wholesale, storage and retailing area. One of the ten storage facilities assessed offered storage in a well-ventilated metal silo. The standard sized sack was 100 kg of kernels. The storage period had a range of 5 to 10 months (for kernels) or 4 to 9 months (for the few who stored maize as cobs).

Maize losses at retail markets

The assessment was done in the Kano area in Northern Nigeria, as this is the major maize wholesale, storage and retailing area. There was no grading or pricing by quality grade at the retail level, but sometimes cleaning was done to remove debris. Damage or defects (especially small sizes) was related to reduce prices, but there were little or no reports of discards.

Percent postharvest losses and discarded maize

Postharvest losses (PHLs) measured in Nigeria on farm ranged from 7 to 23% (average 13%) loss or discarded during the harvest. Sorting discards at the storage and wholesale levels were low to none, and mechanical damage in the assessed samples was 2 to 3.5% quality loss. At the retail level, there was no sorting. PHLs cannot simply be added across these value chain stages, due to the very wide range of losses measured in each sample. If the minimum levels of the range of measured PHLs are added up for the farm, storage, wholesale and retail sites, the total is 15%, which is the most conservative estimation of overall losses (Table 4).

On the 10 farms, the field team was able to collect and weigh the total amount of maize harvested, and collect and weigh the maize left in the field after the harvest. Based upon the average weight collected from 3 sample plots on each farm, 646 kg/ha was either left on the plants or discarded on the ground in the field. Therefore, the PHLs during the harvest was 13% of the total estimated harvest of 5 MT/ha. Lost or discarded maize was typically used for animal feed.

Postharvest quality and food safety

Maize quality characteristics were assessed during the CSAM studies, and found to be closely related to market value. Typical quality issues on the farm included: 1) Defects: unfilled cobs, darkening, shrivel, misshapen kernels, small kernels; 2) decay: fungi/mould and damage: mechanical injury, cracks, pest damage (army worms, weevils, stray animals).

During harvesting, maize was left in the open field under direct sunlight and during humid weather until harvesting is completed, thereby heating up the produce. Temperature is the most important environmental factor that influences the rate of deterioration of harvested produce. High temperatures recorded in Table 3 during harvest, storage and retailing will therefore reduce potential storage life. Most of the decayed maize was sorted out at the farm level and so does not reach the markets. The sacks used for maize transport are large and heavy. The farmers and traders do not weigh the full woven sacks, but generally estimate the sack as equal to hold 100 kg.

There is no local, regional or national standard for quality inspection carried out on farms and markets in the

Table 4. Summary of quality postharvest losses assessed for maize (% PHL, standard deviation).

Country	**Farm** N=10	**Storage** N=10	**Wholesale** N=10	**Retail** N=10
Nigeria	13.3% (SD 1.8%) PHLs at harvest. Measured in 30 random plots. Average yield of 5 MT/Ha and losses of 646 kg/ha Drying is estimated to reduce the weight of the crop by 10% (typically sun dried on farm before delivery to storage or the market).	Low or no report losses One storage operator (metal silo) reported 2% sorting losses prior storage	Low or no reported losses, little or no sorting done at wholesale One wholesaler reported 5% sorting losses.	0% reported losses No sorting done at retail

Table 5. Postharvest losses (% percent defects, decay, mechanical damage and discards) measured for maize in Nigeria.

Farm	N	Avg time from harvest	% defects	% Decay	% mechanical damage	% sorted out/discarded before sale	Lost or discarded during the harvest
	10	0 h	17	4	4	Only 2 farms Sorted; estimated 2% discards	Average 13% SD = 5 Range 7 to 23%
Wholesale market	10	24 h	8	1	3.5	No sorting	
Storage	10	Unknown	2	0	2	Only 1 operator sorted; estimated	
Retail market	10	Unknown	12.5	1.5	9	No sorting	

study area. Farmers farming practices had tremendous effects on the quality of the produce. The quality of maize seeds used for planting by farmers in the study area was generally poor. They made use of seeds saved from their previous harvest, and replant each year without using improved seeds. These seeds have lost vigour and good quality characteristics with time.

Estimated value of postharvest losses of maize in Nigeria

If the maize crop in Nigeria is experiencing a conservative 15% loss in terms of quantity during the farm to market period, this equates to a loss in market value of at least 15%. If the annual production of maize is 10.8 million MT, at an average market value of N160/kg, 15% PHLs equate to a loss in potential market value of $720 million per year (Tables 5 and 6).

Factors affecting maize losses

Earlier studies have reported on high postharvest losses in maize, and a host of factors that lead to losses. The Meridian Institute published a summary of the key production, postharvest and marketing impediments for maize smallholder farmers for a project funded by the Gates Foundation for a study undertaken in East Africa (Meridian, no date). According to the CSAM study findings, these factors hold true for Nigerian maize farmers and traders as well. These factors include:

Production constraints

1) Few farmers use fertilizer or purchase improved seeds.
2) Uncertainty about rainfall (which affects returns)
3) Lack of access to credit

Lack of storage

1) Sharp seasonal fluctuations in maize prices particularly in remote areas suggest insufficient storage by farmers and traders.
2) Storage is limited by liquidity constraints, capacity, and high storage losses (storage losses are higher for maize than for other crops).

Fragmented sales by small numbers of farmers

1) Farmers are predominantly selling small amounts of

Table 6. Estimated value of postharvest losses of maize in Nigeria.

Annual production 2014	Market value Range (high quality)	Market value range (low) quality	Market value (average)	Annual economic loss in Naira (15% PHLs)	Annual Economic Loss in $US
10.8 Million MT	N170/kg	N150/kg	N160/kg		
10.8 billion kg			N1,728 Billion	N259 billion	US$720 million

360 Naira = $US 1.

maize in the village to traders.
2) Aggregation is time consuming and costly, contributing to low farm prices.
3) Farmers lack information about prices in nearby markets and also lack cost-effective means of transporting maize individually.
4) Low levels of trust between farmers may limit collective sales or transportation.

Improper drying and lack of grades

1) Maize is often not fully dried at the farm nor is it fumigated, resulting in the need for further drying and sometimes fumigation by traders.
2) The amount of sorted out maize is higher if the harvest occurs during a rainy time (USAID 2012).
3) The absence of standardized grades requires the quality of produce to be manually checked. As a result of both of these factors, maize is repeatedly packed and unpacked during marketing, creating inefficiencies in the market chain.
4) Poor drying at initial stages in the marketing chain can result in high levels of aflatoxins (which cannot be visually observed).

Costs and benefits of improved practices and technologies for maize

A few recommended postharvest technologies for reducing losses in maize include:

1) Use of maturity indices during harvesting. In Nigeria, maize is harvested at various stages of moisture, which can lead to losses due to kernels dropping off (too dry) or to mouldiness (too wet). The offered farm gate prices will be lower than the potential market value of higher quality maize.

2) Use of improved storage bags. In Nigeria, Purdue Improved Crop Storage (PICS) bags, used for hermetic storage of maize and dry beans, are much more expensive than traditional woven polypropylene storage bags. “Imitation PICS” are available at a lower price, but their effectiveness is unknown. The PICS bags are triple layered, made with a layer of solid plastic to seal out air in order to asphyxiate any insect pests that may be inside the bag of grain. Their use for maize storage in Kano can result in a small but immediate profit, regardless of the market price. If taken care of between uses, PICS bags can be reused for grain storage at least one more time, and they can keep maize safe from pests during a storage period of up to one year. Table 7 provides details on cost and benefits of using PICS bags for maize storage in Kano State, Nigeria.
Deterioration of maize is mainly affected by moisture content, temperature (grain and air), relative humidity, storage conditions, fungal growth, and insect pests (Suleiman et al., 2013). Exposure to higher RH after harvest can increase moisture content and this will negatively influence the physical and sanitary quality of maize (José et al., 2017). Presented in Table 3 are postharvest system characteristics for maize in Nigeria. Grain moisture content is among the most important factors that influence time needed for preservation as well as the whole health status of maize grain (Andrade et al., 2017; Bhandari et al., 2017; Mirna et al., 2007). High moisture level during harvest, storage and retailing is unfavourable and can minimize preservation ability of the grain.
Intensive respiration process prior to drying enables activities of microorganisms, and produce favourable medium (temperature raise, moisture raise and heat release) for storage pests (Volenik et al., 2007).
Polypropylene bags used for maize packaging in Nigeria provide poor protection during storage and this contributes to huge postharvest losses. Proper drying and use of hermetic packaging system were reported to provide good keeping quality after year storage under ambient storage conditions (Gopal et al., 2017).

Conclusion

There are no local, regional or national standard for quality inspection along the maize value chain. Defects found to affect postharvest quality and safety of both fresh cobs and dried kernels were; decay (mostly caused by fungi), mechanical injury, cracks, pest damage (army worms, weevils, stray animals), unfilled cobs, darkening, shrivel, misshapen kernels and small kernels (Table 5).

Table 7. Storage of maize in hermetic bags in Kano State, Nigeria.

Assume harvest 1000 kg	Current practice	New practice
Describe	Storage in ordinary 100 kg PP bag	Storage in improved PICS bags (hermetic storage)
	PACKING 100 kg in a bag	Packing 100 kg
COSTS	150 NGN per bag	500 NGN per bag
Need 10 bags		
Relative cost	1500 NGN/1000 kg	5000 NGN/100 kg
Expected benefits		
% losses	2 to5%	<1%
Amount for sale	950 to 980 kg	990 kg
Value/kg	90 to170 NGN/kg	95 to175 NGN/kg
Total market value range	85,500 to166,600 NGN	94,050 to173,250 NGN
Highest Market value minus relative costs	165,100	168,250
Relative profit		3,150 NGN (US$8.75)
ROI		Immediate profit by using PICS bags for storage. Bags can be used again, for a subsequent profit of 8,150 NGN per MT (US$22.64)

The defects can be influenced by combination of high temperature and relative humidity, and poor transportation and storage system

Maize postharvest losses on Nigerian farms were found to be 13% (average). Mechanical damages during handling, transportation and transportation account for 2 to 3.5% quality loss in dried maize. An average of 15% loss was recorded across the value chain. If the annual production of maize is 10.8 million MT, at an average market value of N160/kg, 15% PHLs equate to a loss in potential market value of $US 720 million per year.

Training farmers on the importance of using improved varieties, modern farming practices, understanding and applying the knowledge of maturity indices, good postharvest management, and use of improved containers and modern storage systems will minimise losses at all levels along the value chain.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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