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Commodity system assessment on postharvest handling, storage and marketing of maize (*Zea mays*) in Nigeria, Rwanda and Punjab, India

Munir Abba Dandago[1*], Lisa Kitinoja[2] and Nura Abdullahi[1]

1, *Department of Food Science and Technology, Kano University of Science and Technology, Wudil PMB 3244 Kano, Kano State. Nigeria*

2, *The Postharvest Education Foundation, P.O. Box: 38 La Pine, Oregon 97739, USA*

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***Corresponding author:**
Department of Food Science and Technology, Kano University of Science and Technology, Wudil PMB 3244 Kano, Kano State. Nigeria.
Email: hodfst@kustwudil.edu.ng, dandago223@gmail.com

ABSTRACT

Purpose: Maize output is decreasing in developing countries due to poor postharvest management despite the huge investments. The study is aimed at identifying and quantifying sources and causes of postharvest losses from farm to retail and suggest appropriate interventions for reducing these losses. **Research Method:** Commodity system assessment on postharvest handling, storage and marketing of maize was conducted between July and August, 2017 in Nigeria, Rwanda and Punjab (India) using surveys, interviews, observations, measurements and quantification of losses along the value chain. Postharvest quality and economic loss assessments along the chain were based on physical damage, decay and weight loss. **Findings:** Causes of postharvest losses at farm level are similar in all the countries studied, with sorting losses from 2 to 50% and drying losses from 10 to 40%. Damage and defects were extremely high in Rwanda at the farm level. Maize is stored for 5 to 10 months with 2 to 3.5% damage in Nigeria and 6% in Rwanda. Maize is stacked in sacks during wholesale and cleaning rejects obtained is 2 to 11% in Nigeria and India, little or no sorting in Rwanda at wholesale. Postharvest losses are 15%, 60% and 20% of total produce for Nigeria, Rwanda and Punjab, which account for economic losses of $720 million, $131.2 million and $8.2 million respectively. **Limitations:** The research is limited to major production areas in the three countries because of funding. **Originality/Value:** The study identified problems, sources and causes of post-harvest losses and suggests appropriate interventions, training needs and advocacy issues to reduce these losses.

INTRODUCTION

Globally, maize (*Zea mays* L.) is an important food and fodder crop in many countries (Cadoni & Angelucci, 2013) and ranks 3rd in production after rice and wheat. Maize is the most important food crop in Sub-Saharan Africa and Latin America, and is one of the important crops in Asia. In Sub-Saharan Africa, maize is consumed by 50 percent of the population and is the preferred food for 900 million poor people worldwide. As the world's population increases and more people begin to include higher amounts of meat, poultry and dairy into their diets, demand for maize as animal feed is expected to rise. By 2025, maize will be the developing world's largest crop and between now and 2050 the demand for maize in the developing world is expected to double (CGIAR, 2016).

Nigeria is the second leading producer of maize in Africa but despite the high production, Nigeria's average maize yield potential at 5MT per hectare is 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 producing more than 70% of the nation maize. The national requirement for maize is estimated at about 16 million tons, with the production of 12.8 million MT in 2018 (NAERLS, 2018), supply deficit is about a shortfall of 3.2 million MT.

In Rwanda the government has been promoting maize development, working with international donor agencies (UK Department for International Development, United States Agency for International Development) and private sector companies since 2008 (Rwibasira, 2016). Rwandan maize plots are small, at 0.6 ha on average. Cooperatives pool farmers' produce; these constitute 40% of the total maize bought by the National Strategic Grain Reserve. According to Daly et al. (2017), "Minimex, Rwanda's largest maize processor, is exceptional, with storage facilities and links with Bralirwa brewery to buy maize grits." However, despite the harmonization of maize standards in east Africa, country-level adherence is still low.

The failure to comply with these guidelines is the result of: 1) Consumers' unawareness of the benefits of food safety; 2) consumers' sensitivity to higher prices; or 3) inability of national governments to publicize, test, or enforce the standards at all stages of value chain.

According to the Punjab Government Department of Agriculture website (http://agripb.gov.in/index.php), maize can play important role in crop diversification policy of the state. It is used in poultry and animal feed, as fodder and for the manufacture of starch, glucose, corn flakes. It is also used as a human food Makki di roti (a flat cake made of maize flour) in winter season. Traditionally, maize was grown as a kharif season crop (sown at the end of monsoon rainy season), and now sowing during the rabi season (spring or winter crop) has been started in some districts with the release of new varieties. It is now possible to raise a spring maize crop in Hoshiarpur, Shaheed Bhagat Singh Nagar, Jalandhar and Kapurthala areas in Punjab.

Commodity Systems Assessment Methodology (CSAM) is a step-by-step assessment developed by the Inter-American Institute for Cooperation on Agriculture (IICA) in the late 1990s for describing and evaluating the planning, production, postharvest handling and marketing of agricultural commodities. The World Food Logistics Organization (WFLO) and The Postharvest Education Foundation (PEF) have utilized this assessment methodology for studying postharvest losses in fruits, vegetable crops and staple food crops in many countries during 2007 through 2017, and PEF was involved in the recent revision of the methodology and manual (LaGra et al., 2016). The original CSAM used many lengthy written surveys, face to face interviews and observation checklists (LaGra, 1990).

The modified CSAM includes a summary list of key questions to guide interviews of stakeholders, observations of handling practices, worksheets for making direct measurements of quality and quantity losses on farm, packinghouse, storage and at the wholesale and retail market levels, and cost/benefit worksheets. The report includes description of the CSAM food loss assessment process, findings related to 26 components of the commodity system and summary information for the maize (*Zea mays* L.) value chain in each of the three target countries including:

- The average % and range of postharvest losses on farm at harvest, during storage, wholesale marketing and retail marketing
- Losses segregated by category (physical injury/damage, pathological disease/decay, quality losses/defects, and weight loss/water loss) at each stage in the postharvest value chain
- The estimated economic losses due to changes in market value for the crop
- Recommendations for reducing postharvest losses
- Costs and benefits of alternate postharvest practices or technologies
- Identification of specific research needs, extension/training needs and key advocacy issues for reducing losses of the crop in each country.

The objectives of these CSAM studies were to identify and quantify the main causes and sources of food loss in the postharvest chain from the harvest to the retail market. 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

Site selection

The team identified Nigeria, Rwanda and Punjab in India and worked simultaneously in these countries in July – August, 2017. In Nigeria Kano and Ogun States were selected because they are leading producers of maize. Kano state also host Dawanau grains market (largest grain market in Sub Saharan Africa). Nyagatare and Kamonyi Districts in Rwanda and Punjab State in India were selected due to their being high maize production areas and having local harvests during July-August.

Tools for assessment

The tools used during the CSAM studies included 5 kg capacity digital scale, 30 kg capacity hanging scale, digital temperature probe, digital camera, digital hygrometer and a set of data collection worksheets with protocols. Data collection measurements were designed to be simple and non-destructive whenever possible. For example, quality characteristics were determined via sorting a random sample of 20 grains into categories (defects, appearance, damage, decay, etc.). The undamaged maize can then be returned to the farmer or vendor.

Data collection

CSAM is a systematic process of using survey questions, interviews and observations to collect data on the key aspects of the value chain, including pre-production, production, postharvest handling and marketing. The study began with a literature review of published articles and unpublished documents, review articles and government reports. This was followed by field work which includes interviews, administering questionnaires, field measurements and personal observations.

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 (Table 1) were conducted with 25 to 40 persons in each country, 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 a minimum of 10 farms, 10 storage facilities, 10 wholesale markets and 10 retail marketing sites via direct measurements, questions and observations.

Data analysis

Data entry was via a simple spreadsheet that matches the data collection worksheets, and calculations of sums, ranges, averages and standard deviations.

RESULTS AND DISCUSSION

Results are presented for on-farm, wholesale, storage and retail postharvest losses. A discussion of quantitative, qualitative, economic and food safety losses is followed by examples of the costs and benefits of making changes in postharvest practices and technologies for reducing losses.

On farm postharvest losses

In Nigeria, the cultural practices for maize production vary from one region to another and this affect the quality and quantity of the commodity produced. 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, 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 contribute to postharvest losses and subsequently affect farm gate prices.

Postharvest losses (PHLs) measured in Nigeria (Table 2) on the farm ranged from 7 to 23% (average 13%) lost 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%. On the 10 farms in Nigeria, 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 per ha. Lost or discarded maize was typically used for animal feed. Earlier studies have reported on high postharvest losses in maize, and a host of factors that lead to losses (Kitinoja et al., 2019; Olaniyan, 2015; GIZ, 2013; Meridian Institute, no date). Postharvest losses at the farm level are similar for all three countries, with a wide range of sorting losses from 2 to 50% and a reported range of estimated drying losses from 10 to 40%.

Table 1. Interviews with stakeholders and maize value chain actors during CSAM assessment and field visits during July-August 2017

Country	Chiefs, community leaders	Agro-dealers	Crop Experts	Extension	Farmers	Wholesalers and storage operators	Retailers
India	-	1	-	-	16	10	-
Nigeria	1	-	1	4	13	13	11
Rwanda	-	4	1	2	10	20	10
Total	1	5	2	6	39	43	21

Table 2. Postharvest % losses measured for maize in Nigeria, Rwanda and Punjab India

	Relative perish-ability	N	Avg. Time from harvest	Defects (%)	Decay (%)	Mechanical damage (%)	Sorted out/discarded before sale (%)	Lost or discarded during the harvest
Nigeria								
Farm	1	10	0 hour	17	4	4	Only 2 farms sorted; estimated 2% discards	Average 13% SD = 5 Range 7 to 23%
Whole-sale market	1	10	24 hours	8	1	3.5	No sorting	
Storage	1	10	Unknown	2	0	2	Only 1 operator sorted; estimated 2% discards	
Retail market	1	10	Unknown	12.5	1.5	9	No sorting	
Rwanda								
Farm	1	10	0 hours	60	67.5	83	Little or no sorting reported on farm	Farm
Collection centers	1		Within 24 hours				Unknown % but assumed to be very high. Rejected produce is used for home consumption or as animal feed	Collection centers
Wholesale market	1	10	unknown	35.5	1	6	Only accept "good quality" maize	Wholesale market
Storage	1	10	unknown	35	0.5	6.5	Only accept "good quality" maize	Storage
India								
Farm	1	10	0 hours				8.9% Range: 2 to 25% SD = 6	8.9% Range: 2 to 25% SD = 6
Wholesale market	1	10	unknown				11% Range: 1 to 40% SD = 12	11% Range: 1 to 40% SD = 12

Postharvest losses (PHLs) observed and measured in Rwanda (Table 2) on farm were very high (67.7% decay, 83% damage) but little or no maize was sorted out and discarded at the farm level. Damage and defects were extremely high in Rwanda at the farm level, and the worst quality, rotten, inedible produce was removed before it reached the markets. These sorting operations (taking place either on the farm or at a nearby collection centre) are required since the storage operators and wholesalers "only purchase good quality maize". Sorted out maize is most likely used for home consumption. The most badly damaged, decayed, discarded maize was used for animal feed.

Maize harvesting in Punjab is sometimes done manually (10% in the assessed area) but is more typically done using a combine harvester. The maize is dried as soon as possible after harvesting to safe levels of moisture (ideally 14-15%) for storage. The drying can be on the cobs in a crib before shelling and on tarpaulins or in the open after it has been shelled. PHLs measured in Punjab, India on farm ranged from 2 to 25% (average of 9%). Any sorted out or discarded maize (due to unfilled cobs/heat damage, stalk borer or damage by stray animals) was used for animal feed.

Wholesale postharvest losses

Wholesale assessment in Nigeria was done in the Kano area in Northern Nigeria, as this is the major maize wholesale, storage and retailing area (Table 2). Containers were not of standard sizes, mostly reuse old fertilizer bags or rice sacks for packaging maize, but they are all sold as "100 kg sacks" (Fig. 1A). A few small-scale wholesalers do shelling and/or cleaning as a value addition practice using manual methods (Fig. 1B). Marketers complain about being at the mercy of middlemen regarding market prices. Sorting discards at the storage and wholesale levels were low to none, and mechanical damage in the assessed samples was 2 to 3.5%.

Maize intended for marketing in Rwanda is packed into standard sized "50 kg sacks". The produce is sorted on the farm or at the nearby collection centre to remove damaged or decayed maize. Wholesalers in Rwanda reported that they "only purchased good quality maize". Little or no sorting was done at the wholesale level. The maize produce is packed in woven plastic sacks of 50 and 100 kg sizes, but they are not weighed.

Packages are not appropriate for the product as compared to sisal woven bags that accumulate less moisture content compared to woven plastic sacks. Kernels are often spilled during filling of the sacks. There was also little or no sorting at the wholesale level but mechanical damage in the assessed samples was 6%. The drop in measurable % of decay and damage later in the value chain indicates a great deal of the maize was sorted out at the farm and/or collection centre level.

In Punjab generally, the kernels are packed in jute bags with the capacity of 50 kg. The bags of maize are stacked and left in the open in the wholesale markets during the brief period of time between delivery and resale. The major portion of maize harvested in Punjab goes to the agro processing industry.

Sorting at the wholesale level resulted in 11% discards (range of 1 to 40% removed prior to resale), with the result of little to no defects, decay or mechanical damage observed in the assessed samples. Discarded maize (due to deformed, small sized or broken kernels) was used for animal feed.

Storage postharvest losses

Most of the storage observed during the CSAM studies in all three countries were for maize kernels in woven polypropylene sacks (50 or 100 kg). Home based storage was not assessed, but the field teams were informed of the availability of smaller scale storage options including PICS bags in Nigeria and sealed metal containers in Punjab.

The assessment was done in Kano, 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). Sorting discards at the storage were low to none, and mechanical damage in the assessed samples was 2 to 3.5%.

Storage operators in Rwanda reported that they "only purchased good quality maize". Little or no sorting was done at the storage level but mechanical damage in the assessed samples was 6.5%. The drop in measurable % of decay and damage later in the value chain indicates a great deal of the maize was sorted out at the farm and/or collection centre level. In India**,** there is no storage facilities for produce in any of the markets. Maize sacks were stacked outdoors temporarily in wholesale markets while awaiting resale.

Retail postharvest losses

In Nigeria, 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.

There was also little or no sorting at the retail level and therefore no discards but mechanical damage in the assessed samples was 8.5%. Retailers in Rwanda reported that they "only purchased good quality maize". Little or no sorting was done at the retail level.

In Punjab, India this is not assessed, since dried maize kernels are bagged and sent directly to wholesale or processing markets and is not typically sold in bulk at the retail level in Punjab.

Postharvest losses measured quantitatively

If the maize crop in Nigeria is experiencing a very 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 NGN160 per kg, 15% PHLs equate to a loss in potential market value of US$720 million per year (Table 3).

The damage and decay observed on the farm during maize harvest by the CSAM team was enormous (83% of maize with damage and 67.5% with decay). By the time the maize reached storage or markets, decay was measured to range from 0.5 to 1%.

The market value of the maize crop decreased as the quality decreased, providing an economic opportunity in Rwanda for use of improved postharvest handling and investment in improved containers. Excellent quality maize could be sold for 500 Rwf per kg. One example (from July 2017) of the market value for lower quality maize at the storage level: Grades by size and appearance Grade 1: 300 Rwf per kg, Grade 2: 270 Rwf per kg, Grade 3: 250 Rwf per kg. If the maize crop in at the national level in Rwanda is experiencing a similar loss in quantity during the farm to market period, this equates to a cumulative loss in market value of at least 60%. If the annual production of maize is 583,000 MT, at a market value of Rwf 300 per kg this equates to a loss in potential market value of US$131.2 million per year (Table 3).

If the maize crop in India is experiencing a conservative loss of 20% in quantity during the farm to market period, this equates to an estimated loss in market value of 20%. If the annual production of maize in 2016 in Punjab was 445,000 MT at a mid-range market value of INR 6 per kg ($0.10 per kg), 20% losses is US$8.2 million per year. Punjab produces less than 2% of India's annual production of maize (Government of Punjab, 2017).

Fig.1. A) Wholesale marketing in Kano, Nigeria, showing maize in heaps and maize in sacks. B) Maize cleaning is via manual screening.

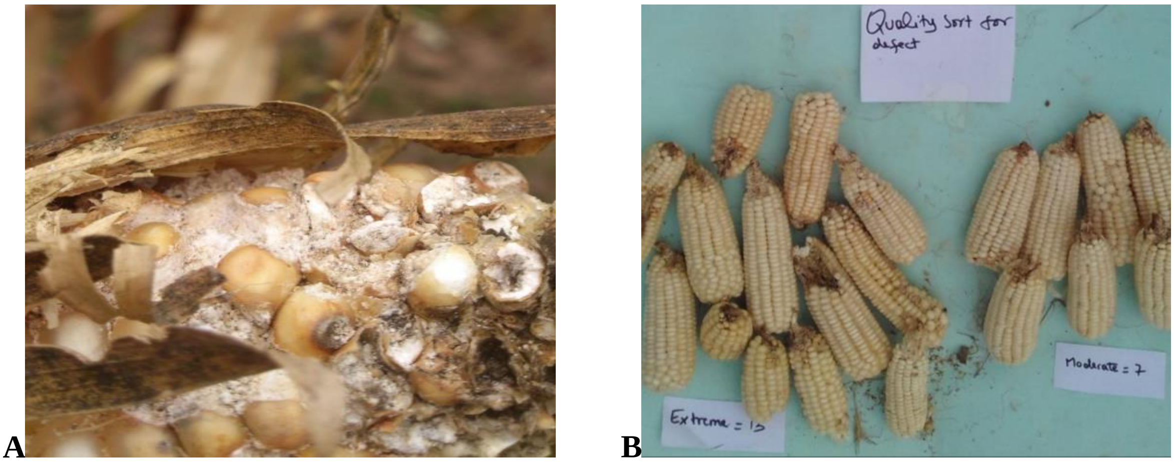

Fig. 2. A)100% of the cobs were damaged; B) Maize fungal damage on the farm in Rwanda

Since the annual production of maize in 2014 for all of India was 23,670,000 MT at a mid-range market value of INR 6 per kg, 20% losses equate to national economic losses of US$ 436 million per year. PHLs are likely to be higher in states other than Punjab, as Punjab is considered a progressive state using modern harvesting and postharvest handling practices.

Postharvest loss measured qualitatively

In addition to earnings losses, these same maize losses can be equated to a loss in calories and nutrition; amino acids such as methionine, valine and proline, and fatty acids contents can be affected (Mutungi et al., 2018). Per kg in the traditionally used units of measure, maize contains 3650 kilocalories, 90 g of protein, 27 mg of iron and 6 mg of Vitamin B6. Per metric ton, maize contain 3.65 million kilocalories, 90 kg protein, 27 g of iron and 6 g of Vitamin B_6 (USDA, 2017).

Calorie daily requirements range from 2000 to 2500 kilocalories per person (an average of about 821,250 kcal per year), so the food losses due to postharvest losses of maize in

Nigeria alone could satisfy the nutritional needs of 7 million people for one year (https://ndb.nal.usda.gov/ndb/).

Estimated economic losses in quantity and quality

Overall, for these three countries, depending upon their total maize production and conservatively estimated % PHLs (15% in Nigeria, 60% in Rwanda and 20% in India), the annual economic losses for maize amounts to $720 million in Nigeria, $131.2 million in Rwanda and $8.2 million in the state of Punjab, India (Table 4). These food losses result in lost earnings for farmers and vendors, as well as lost GDP for the nations assessed in these CSAM studies.

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 in all three countries included:

- Defects: unfilled cobs, darkening, shrivel, misshapen kernels, small kernels
- Decay: fungi/mould
- Damage: mechanical injury, cracks, pest damage (army worms, weevils, stray animals)

During harvesting, maize in Nigeria and Rwanda were 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 in storage 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 (Fig. 2A and Fig. 2B).

The sacks used for maize transport in Nigeria and Rwanda are large and heavy. The farmers and traders do not weigh the full woven sacks, but generally estimate the sack as equal to holding 100 kg in Nigeria and either 50 or 100 kg in Rwanda. After weighing different filled sacks in Rwanda, the CSAM team determined that the "50 kg sack" holds about 40 of maize on cobs and 50 to 60 kg of dried maize kernels.

Table 3. Estimated range of the value of postharvest losses of maize in Nigeria, Rwanda and Punjab India

Annual production (2014)	Market value range (high quality)	Market value range (low quality)	Market value per kg (average)	Annual economic loss in local currency	Annual economic loss in USD
Nigeria					
10.8 million MT	N170.kg^{-1}	N 150.kg^{-1}	N160.kg^{-1}	15% PHLs	
10.8 billion kg			N 1,728 billion	N259 billion	USD 720 million
Rwanda					
583,000 MT	Rwf 500.kg^{-1}	Rwf 250.kg^{-1}	Rwf 300.kg^{-1}	60% PHLs	
583,000,000 kg			Rwf 174.9 billion	Rwf 105 billion	USD 131.2 million
India					
445,000 MT	MSP gov't fixed price Rs 1365.q^{-1}	Rs 1200.q^{-1}	Rs 6.kg^{-1}	20% PHLs	
445,000,000 kg			Rs 2,670,000,000	Rs 534,000,000	USD 8.2 million

360 Naira = USD 1, 800 Rwf = USD 1 and Rs 65 = USD 1.

Table 4. Calculations of calorie, protein and vitamin nutritional losses due to PHLs for maize

Country	Postharvest losses (%)	Weight losses (MT)	Kilocalorie losses	Protein losses (g)	Iron losses (mg)	Vitamin B6 losses (mg)
Nigeria	15%	1.6 million	6,000 billion	144 billion	43.2 billion	9.6 billion
Rwanda	60%	350,000	1,300 billion	31.5 billion	9.45 billion	2.1 billion
Punjab, India	20%	89,000	325 billion	8 billion	2.4 billion	534 million

(Author calculations based on nutritional information for maize via USDA website https://ndb.nal.usda.gov/ndb/accessed October 2017).

Table 5. Use of maturity indices for maize harvesting in Rwanda

Start with 1000kg	Current Practice	New Practice
	Harvest whenever the market price is right	Harvest at 22 to 30% moisture content
Cost		
Salt test for training on maturity indices		8000 Rwf (US$10)
Benefits		
% Loss	30%	10%
Amount to sell	700 kg	900kg
Value per kg (excellent quality)	300 Rwf ($0.38)	500 Rwf ($0.63)
Total market value	Rwf 210,000	Rwf 450,000
Market value – costs		Rwf 442,000
Relative profits		Rwf 232,000 (US$290)
ROI		Generates an immediate increased profit of $290 for each 1000 kg load.

Rwf 800 = US$1.

Table 6. 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 Packing 100 kg in a bag	Storage in improved PICS bags (hermetic storage) Packing 100 kg
Costs	150 NGN per bag	500 NGN per bag
Need 10 bags		
Relative cost	1500 $NGN.1000\ kg^{-1}$	5000 $NGN.1000\ kg^{-1}$
Expected benefits		
% losses	2-5%	<1%
Amount for sale	950 to 980kg	990 kg
Value/kg	90-170 $NGN.kg^{-1}$	95-175 $NGN.kg^{-1}$
Total market value range	85,500 – 166,600 NGN	94,050 – 173,250 NGN
Highest market value minus relative costs	165,100	168,250
Relative profit		3,150 NGN (US$8.75)
ROI		Immediate profits by using PICS bags for storage. Bags can be used again, for a subsequent profit of 8,150 NGN per MT (US$22.64)
Lowest market value minus relative costs	84,000	89,050
Relative profit		5,0505NGN (US$14.03)
ROI		Immediate profits by using PICS bags for storage. Bags can be used again, for a subsequent profit of 10,050 NGN per MT (US$27.92)

NGN 360 = US$1.

Costs and benefits of improved practices and technologies for maize

The costs and benefits of recommended changes in postharvest handling practices and/or adoption of improved postharvest technologies are provided in this section of the CSAM report, with tables with comparative information, calculations of relative cost and expected benefits, and expected times required to achieve 100% return on investment (ROI). A few recommended postharvest technologies for reducing losses in maize to highlight the cost benefit of using the improved practices are given below:

i) Use of maturity indices during harvesting.

In Nigeria and Rwanda, 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 farmgate prices will be lower than the potential market value of higher quality maize (Table 5).

ii) Use of improved storage bags.

In Nigeria, PICS bags, used for hermetic storage of maize and dry beans, are much more expensive than traditional woven polypropylene storage bags. The Purdue Improved Crop Storage (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 (Table 6). If taken care of between uses, they 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.

CONCLUSIONS

The postharvest losses and quality problems for the maize crop were found via the CSAM studies to be similar in the two Sub-Saharan African countries due to rudimentary postharvest handling practices, while postharvest losses in India were mainly due to farm level pest or weather problems.

In Nigeria and Rwanda, the CSAM studies determined that there is an inadequate electricity supply, high cost of fuel, lack of access to good quality water supply, and expensive packaging materials. Most of these issues must be dealt with by governmental policy and regulation changes or via direct investments, ensuring that an enabling environment is created for supporting future crop production, market development and agri-business investments.

Overall, the maize commodity system in Punjab, India is a positive example of how losses can be reduced via improved harvesting and postharvest handling on the farms and during marketing. The success story of the use of improved varieties, improved harvesting, drying and postharvest handling practices, and technology adoption for maize drying and processing in Punjab provides a model that should be replicated whenever possible in other states of India, as well as in Nigeria, Rwanda and many other countries in Sub Saharan Africa.

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Conflict of interest

All the authors declare that there is no conflict of interest in publishing this manuscript.

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