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Reducing Food Loss and Waste through Innovative Food Preservation Technologies Applied by Women in Rural Areas in Kenya

Julius M. Huho
Garissa University, Kenya

Introduction

Agriculture, Forestry and Other Land Use (AFOLU) accounts for 24% of global GHG emissions. Continentally, Africa is the third-largest emitter at 15% after Asia (44%) and Latin America & the Caribbean (17%). Of the 15% of the GHG emissions in Africa, 5.9% is produced in Eastern Africa, 3.5% in Western Africa, 3.1% in northern Africa, 2.0% in Middle Africa and 1.0% in Southern Africa (FAO, 2016). According to FAO (2015), Food Loss and Waste (FLW) accounts for about 8% of global anthropogenic GHG emissions or 4.4 Gt CO_2 eq per year (Figure 1) thus contributing to climate change. The SDG no 12 of the United Nations on "Ensuring sustainable consumption and production patterns" targets a reduction of 50% of the 2011 FLW in all regions of the world. It proposes to halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses by 2030. This implies that a reduction in FLW at all levels will have a substantial positive effect on climate change. Gromko&Abdurasolova (2019) observes that about one-third of food produced globally is either lost or wasted accounting for economic losses amounting to US$ 940 billion per year. Food loss occurs when food is damaged before it is consumed while food waste occurs when the food is ready for consumption but it is not consumed (Bhandari, 2018). FLW occur in both the "upstream" and the "downstream" sections of the food value chain. Food losses are common in the "upstream" which includes food production, post-harvest handling and storage while food wastage is common in the "downstream" which includes processing, distribution and consumption stages (Parameshwari, 2017). Food processing, distribution and consumption stages account for 46% the global FLW (Parameshwari, 2017). It is interesting to note that although Sub-Saharan Africa faces severe food shortages, on one hand, it experiences high rates of postharvest loss on the other. It is estimated that about 50% of fruits and vegetables, 20% of cereals, pulses and legumes and 40% of roots and tubers are lost before they reach the consumer (Njagi and Wainaina, 2018). Acknowledging that reduction of FLW through preservation of food does not only safeguard households against food insecurity but also plays a major role in mitigating climate change, this study aimed at establishing the innovative food processing and preservation technologies applied by women in rural areas in Garissa and Machakos Counties in Kenya that aimed at reducing FLW at post-harvest handling and storage stages.

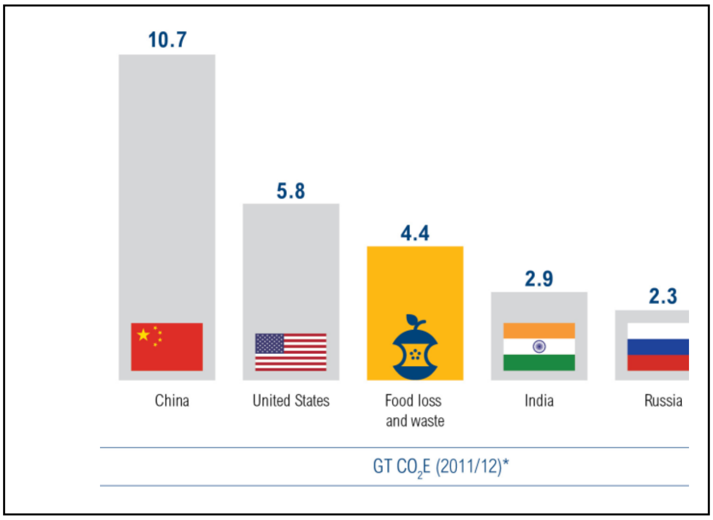

Fig 1: FLW would be the third largest GHG emitter, if it was a country (Hanson, et al., 2015)

Objectives of the Study

The goal of the study was to establish the innovative food processing and preservation technologies designed to reduce FLW that were applied by women in rural areas of Garissa and Machakos Counties in Kenya. Specifically, the study aimed at:

1. Identifying the various ways in which food is lost and wasted inKamuthe (Garissa County) and Kangundo villages (Machakos County)
2. Establishing food processing and preservation technologies applied by women in Kamuthe and Kangundo villagesin reducing FLW.
3. Identifying the challenges hindering the application of innovative technologies to curb FLW.

Study Area and Methodology

Data was collected in the rural Kamuthe village in Garissa and Kangundo village in Machakos Counties. Garissa County is located in arid Northern Kenya, an area characterized by hot and dry climate suitable for nomadic pastoralism. The County has an annual average of 280 mm of rainfall which is marked by high variability making it unreliable for rain-fed crop production. Temperatures are high throughout the year ranging from 22°C to 38°C with an annual average of 28.6^0C. Milk and meat was the principal food for rural households in the County. Except for a few people under employment by the governments (National and County), the rural population is predominantly Somali speaking people and hence has a uniform culture. Machakos County is located in lower Eastern Kenya with a semi-arid climate suitable for irrigated to marginal rain-fed agriculture. The County has an annual average of 500 mm of rainfall with temperatures ranging from 18 to 29 °C. Residents of Kangundo village practiced mixed farming(keeping livestock and growing crops). The village is largely occupied by the Akamba speaking people. Overall, about 54% of the population in Machakos County is food poor (CIAT, 2018). Figure 2 shows the location and size of Garissa and Machakos Counties in Kenya.

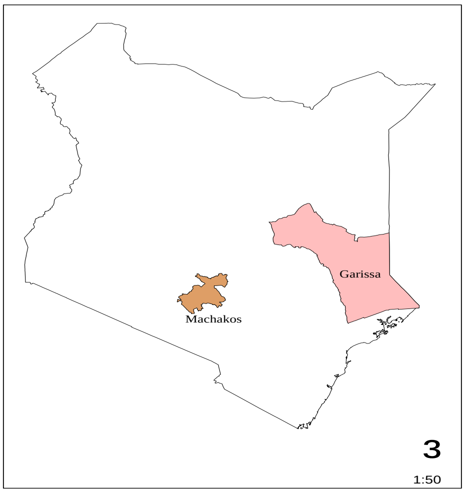

Fig 2: Size and Location of Garissa and Machakos Counties

Purposive sampling was used in the selection of the respondents. A total of 100 women (50 women from each village) aged between 30 and 50 years from Kamuthe and Kangundo villages were sampled. The two villages were selected due to the insignificant urban influence owing to the vast distance between the villages and the nearest urban centres. Respondents sampled had knowledge of food processing and preservation. In-depth interviews were used in data collection.

Food Loss and Waste in Kamuthe and Kangundo Villages

Three ways in which FLW occurred in the study areas were identified as spillage, spoilage and attacks by rodents and insect pests.

Spillage

Spillage was common for milk and cereals in both villages. Milk spillage occurred during milking, distribution and marketing. Poor transportation and lack of proper milk handling equipment were reported as the main causes of milk spillage by 70% and 31% of the respondents respectively. Spillage during milking was minimal accounting for 13%. Spillage of maize and beans during threshing was one of the main causes of quantitative food loss.

Spoilage

Food spoilage involves any sensory change (tactile, visual, olfactory or flavour) which makes food undesirable for human consumption. There are many causes of food spoilage which include: physical damage due to bruising, drying, freezing etc., damage by insects, microorganisms activity, particularly bacteria, yeasts and moulds, activities of indigenous enzymes in animal and plant tissues and chemical changes not brought about by microbial or naturally occurring enzymes (Forsyth & Hayes, 1998). Food spoilage in the study areas occurred during harvesting, processing, storage and transportation. In Kangundo for example, the study found out that about 24% of mangoes (*Mangiferaindica*) were bruised during harvesting and transportation. Besides, the prolonged period before consumption of the fruits resulted in a 17% loss due to over-ripening and growth of maggots inside the fruit. About 8% loss in cassava (*Manihotesculenta*) and pumpkin (Cucurbita) harvests were lost due to physical damages. Rotting and discolouration of maize (*Zeamais*) at farm levels lowered the grain quality. The extended wet season during harvesting time, poor drying and open cob tips while in the farm were cited as the main cause of rotting and discolouration. To minimize the loss, the rotten grains were stored for use as poultry feed. Spoilage of milk in Kamuthe and Kangundo was reported to be more frequent than spillage. This was attributed to the unhygienic handling process (48%) and storage facilities (70%) and also changing environmental conditions (63%). Without any form of refrigeration, for instance, 51% of the women indicated that increase temperature was one of the causes of quick spoilage of milk. Rawat (2015) argues that if milk is not cooled sufficiently, the Lactic Acid Bacteria (LAB) which is the predominant microbes in raw milk multiply. And, when its population reaches about 106 cfu/ml, lactic acid and other compounds are produced resulting in off-flavours. Other causes of milk spoilage mentioned by women were livestock diseases such as mastitis (35%) and adulteration of milk by adding water (21%) in the attempt to increase the quantity. Adulteration was done where milk was to be sold. Vegetables are perishable and once exposed to air, high humidity and higher temperature during storage they get spoilt quickly. Lack of suitable storage facilities during periods of bumper harvest led to a massive loss of vegetables in Kangundo. The loss was accelerated by the low demand for the produce.

Rodent and Insect Pest Attacks

About 80% of food loss is caused by poor on-farm storage. The losses, which usually occur within 6 months after harvesting are caused mainly by insect pests, rodents and pathogens. In Kangundo, the type of storage was on-farm, a storage type characterized by traditional or simple storage structures prone insect pests and rodents' invasion. The maize weevils (*Sitophilus zeamais*) were the most common form of insect attacks and largely affected stored grain with physical damage (cracked or broken) as a result of "hand and stick" threshing of maize and beans. The weevils also attached dried cassava. Another insect pest mentioned was the red-rust flour beetle (*Triboliumcastaneum*) which affected the stored flour. Flour infested with red-rust flour was discarded. Rodents, particularly the black rat (*Rattus Rattus*) and the house mouse (*Mus musculus*) were reported to be responsible for most of the postharvest crop damage. Rats destroyed any type of food stored including stored dry meat strips in Kamuthe.

Innovative Food Preservation Technologies

Preservation of food aims at prolonging the shelf life by delaying spoilage either by chemical or biological processes or inhibiting or reducing pests attacks (Jans et al., 2016). In Kamuthe and Kangundo, inadequate knowledge ofmodern technologies coupled with strong cultural practices and low income necessitated adoption and enhancement of traditional food processing and preservation practices. In this study, therefore, innovation was defined as the creative ways in which traditional methods were used in food preservation in the attempt to reduce FLW. Women reported that traditional methods had environmental concerns integrated into them and therefore were not only suitable but also sustainable. Hence, food preservation techniques adopted by women dependent on five main factors (i) traditions and culture; (ii) climate; (iii) food availability; (iv) foodborne diseases present in the area; and (v) available preservation technologies. The study was carried out in dry areas characterized by high daytime temperatures and erratic rainfall which falls in the form of storms. This factor led to the adoption of drying as the most preferred mode of preservation which in essence prevented most of the common foodborne diseases in the study areas. For instance, in Kamuthe houseflies were kept off from contaminating meat through sun drying of the meat strips. Whereas modern methods of food preservation exist, traditional methods predominated. The adoption of modern technologies was curtailed by three factors: low uptake due to strong traditions and cultures, near non-existence of such technologies in rural areas and low income. It was established that more preservation measures were applied during periods of surplus food than scarcity. During scarcity food available was immediately consumed. Four main methods of innovative techniques of food preservation were identified. These were: drying, boiling, fermentation and use of ash, chillies and neem leaves.

Drying

Drying was the main food preservation methods both in Kamuthe and Kangundo. Except for milk, all other foods were sundried in the process of preservation. Ibeanu, et al, (2010) assert that the objective of drying is to remove as much water as possible from the food items. Bacteria need a moist environment to grow in, a requirement that is usually expressed as water activity (aw) (Murphy, 2010). Thus as a method of food preservation, the drying process lowers the available water by removing it. The role of water activity (a_w) in food spoilage has been observed by Jans et al, (2016) who assert that the growth of microorganism and chemical or enzymatic reactions depends on aw. They observe that while a_w values of 0.61 - 0.95 are tolerated by foodborne pathogens, halophilic bacteria, xerophilicmoulds and osmophilic yeasts, no microbial growth occur at a_w values of < 0.61. Hence, reduction of aw through drying plays an important role in preventing spoilage. Foods dried ranged from meat, vegetables, fruits and cereals.

Preservation of Meat through Drying

Preserving meat through dying was very common and still in practice in Kamuthe. In essence, it was the only means of meat preservation. Three methods which involved drying were identified. In the first method, the process involved slicing the meat (steak) into very narrow strips and then sun drying the strips in the open air for 4 – 5 days until they became hard (devoid of moisture and blood). The hardening was an indicator that the a_w was eliminated, that is, moisture is completely removed. The sun-dried meat strips were then stored in *karbat* or *karirat* (dry containers made up of camel or cowhides) or sacks. To prepare a meal out of the dried meat strips, the strips are cut into small pieces up to the required quantity and then soaked in water for about 5 minutes to moisten the pieces ready for cooking. The meat preserved in this manner could last over one year if not exposed to water and rodents. The second method and the most embraced involved cutting meat into narrow thin strips; sun-drying to remove moisture until the strips hardens; cutting the dried strips into very small pieces (about 5mm in diameter); deep frying in cooking oil until cooked (Plate 1) and finally cooling the cooked meat in a container filled with cooking oil.

Plate 1: Processing and preservation of meat (*nyirinyiri)* through sun drying and deep-frying

The purpose of preserving meat under the cooking oil was to keep off flies, which respondents indicated that they were main meat contaminators. The meat preserved this way was referred to as *nyirinyiri* and lasted for 2-3 months. The third method involved cutting of meat into big chunks, boiling, sun drying and salting. This method was used when the meat was to be consumed after a short time. Although sun drying and salting was aimed at eliminating a_w, it was not possible to completely eliminate the moisture from the big chunks of meat hence quick spoilage. Meat preserved in this manner lasted for about 4 - 6 days.

Preservation of crop harvests through sun drying

Crops grown in Kangundo ranged from vegetables, roots and tubers to fruits. Cassava, pumpkins, fruits, maize and common beans (*Phaseolus vulgaris*) were preserved through sun drying. While processing of cassava for preservation included peeling off, slicing into small pieces and sun drying, the processing of pumpkins and fruits (mangoes in particular) involved washing, slicing into small pieces and sun drying (Plate

2). When dried, the mango skin become hard thus resistant to pest attacks while at the same time preserving the juicy part of the fruit. This would last for 2-3 weeks. The dried cassava would last for up to 4 months while dried pumpkins would last between 2-3 months if stored in dry containers. In rural areas where inhabitants were connected to electricity, the dried cassava and pumpkins were groundinto flour and would last for 6 months. Cassava and pumpkin flourswere used in making porridge. In some few cases, women deep fried the cassava slices to produce cassava crisps as the end product. Other crops that were sundried included maize and beans. Sundried maize and beans would last for years if well stored, free from moisture, pest and rodents.

The demand for and the cost of African Indigenous Vegetable (AIVs) in Kangundo, had been on an increase due to the much publicity given to them concerning their nutritional and medicinal values. The most commonly grown AIVs were the African nightshade (*Solanum scabrum*), leafy amaranthus (*Amaranthaceae*) and green grams (*Vignaradiata*). Once introduced in the farms, these AIVs grow with minimal efforts and inputs from farmers. The AIVs increase tremendously during rainy season followed by periods of scarcity during dry periods. The bumper harvests of the AIVs coupled with inadequate storage facilities and low demand resulted in yield losses. To cushion against the losses, about 3% of the women indicated that they sundried and stored the harvested AIVs for future use. If adequately dried and well stored, the AIVs would last for one month. Other women pointed out that they fed their livestock with the produce.

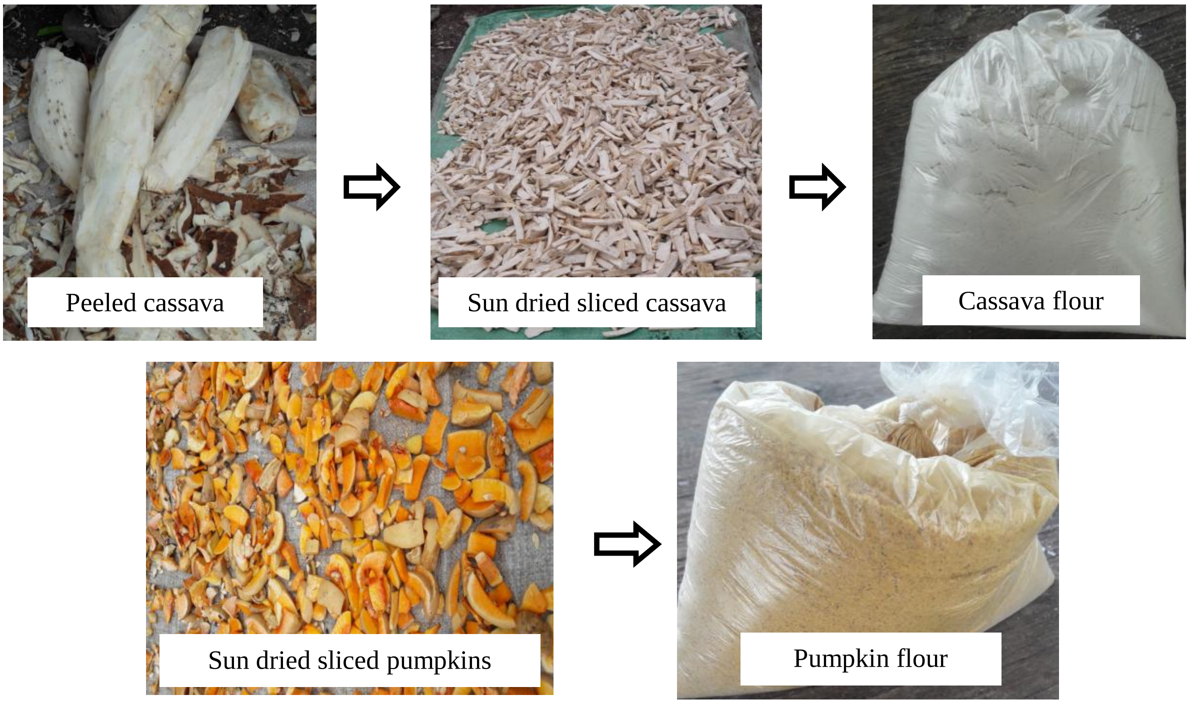

Plate 2: Processing and preservation of cassava and pumpkins through sun drying

Use of Ash, Red Chillies and Neem Leaves as a Preservative

Grain storage plays an important role in preventing losses which are caused mainly by insect pests, pathogens and rodents. In rural areas, rodents and pests were the main cause of postharvest grain and pulse losses. Harvested grains were often attacked by rats and weevils owing to poor storage facilities in Kangundo. As a preservation measure, mixing wood ash with sundried maize or common beans was common among 61% of women with low income in Kangundo due to its abundance and accessibility. Studies have shown that the silica in ash interferes with pests' feeding habits; the ash keeps grains dry by reducing the relative humidity of the storage condition; and also hampers pests' egg-laying and larval development. Similarly, powdered red chilli was mixed with sundried grains and pulses. The pungent nature of chilli has a repellent effect on pests. Women also preserved stored grains and pulses by mixing with dry neem leaves. Like the ash, the neem leaves interfere with pests' feeding habits, are good insecticidal, inhibits storage pests' growth and have a repellent effect on pests. However, the use of neem leaves and chillies was not common and was practiced by 38% and 20% of the women respectively. This was attributed to the inadequacy of these two resources in the area. Grains and pulses preserved under these methods would last for more than six months.

Boiling

Boiling was used in the preservation of milk and meat. In Kamuthe, milk was obtained from camels, cows and goats while in Kangundo milk was predominantly from cows with some few farmers obtaining from goats. Milk was a highly valued commodity that prompted special handling measures to minimize losses. It formed an important part of the daily meal in Kamuthe and was the key ingredient for making tea in Kangundo. Thus, there was no surplus milk in the study areas and when it occurred; it was counteracted by high demand. Cases of milk loss before getting to the consumer were rare and where it occurred it was reported to have originated either from sick animals or poorly cleaned milk containers. Nevertheless, its spoilage was rapid in both villages due to high temperatures.

Preservation of Milk through Boiling

One key determinant of longevity of milk during processing both in Kamuthe and Kangundo was clean milk equipment. Coupled with high temperatures, milk got spoilt in 2-3 hours in poorly cleaned milk equipment. While milk for immediate consumption was consumed raw without boiling or warming in Kamuthe, it was boiled in Kangundo. However, when milk was not for immediate use, it was boiled to prolong its shelf life even in Kamuthe. The purpose of boiling milk was to kill any form of food pathogens that may cause spoilage. In Kamuthe, where temperatures were relatively higher than Kangundo, unboiled milk from camel lasted between 4 and 6 hours after which it started getting sour and unsuitable for making tea. To prolong the shelf life, camel milk was warmed immediately after milking (not boiling). Warming the camel milk prolonged the shelf life by additional 3-4 hours. To further extend the shelf life by additional 2-3 hours, the milk was rewarmed again before it started getting sour (*susa* as referred to in Somali language). Owing to differences in day-to-day temperatures between the villages, unboiled milk from cows and goats lasted for about 8 hours in Kamuthe and between 10-12 hours in Kangundo. Boiling prolonged the shelf life to about 14 and 24 hours in Kamuthe and Kangundo respectively. Just like for camel milk, further extension of shelf life by 2-3 hours in Kamuthe and up to 5 more hours in Kangundo was achieved through warming the already boiled milk.

The meat was also preserved through boiling. In Kamuthe meat was cut into big chunks, boiled, sundried and salted. This process helped to preserve meat for up to about 6 days. However, this preservation method was rarely used. In Kangundo meat was cut into sizeable pieces, boiled and salted. Meat preserved in this manner lasted for about 4 days.

Fermentation

Fermentation as a preservation method was done using cattle milk and was mostly used when milk was in surplus. Fermentation is achemical process in which a substance is broken down by microorganisms like yeast and bacteria into a simpler substanceanaerobically.Milk was kept in special containers which maintained the required temperature suitable for fermentation. Two fermentation processes in use were identified: simple fermentation for the production of yoghurt and the complex fermentation that resulted in semisolid milk products. In simple fermentation, surplus milk was put in a container and allowed some 2-3 days to ferment. When milk was in excess surplus women hastened the fermentation process by backslopping, a process in which previously fermented milk was mixed with the fresh milk. This was practiced either by (i) adding small amount fermented to the fresh milk or (ii) reusing the containers used in fermentation more than once before washing to quicken the fermentation process. The fermented milk was referred to as *kalba*among the Somali and *iriyaikaatu* among the Akamba people. The fermented milk lasted for about 4-5 days after which it got too sour for consumption. In complex fermentation, surplus milk was put in a container and allowed some 2-3 days to ferment after which the liquid part of the milk was decanted. The decantation process continued for 3-4 times until no more liquid was produced. The end product was semisolid fermented milk that could last for a period of up to one month. Although camel and goat milk was also used in this process, cow milk gave the best results and thus mostly adopted. Complex fermentation was practiced in Kamuthe.

The other method of preserving milk identified in Kangundo was putting milk in an aluminium container (sufuria) and placing it on cold surfaces such as cemented floors. This method prolonged the raw milk shelf life by 5-7 hours and was most effective at night. It was commonly used when the preserved milk was to be sold without boiling.

Challenges Hindering Application of Innovative Technologies to Curb FLW

Although efforts to curb FLW had largely borne fruits, women in rural areas continued to face socio-cultural and environmental challenges that hindered full control of FLW. The challenges identified included:

The weakening of Cultural Practices

The existing food processing and preservation technologies in rural areas were rooted in cultural practices and thus the skills were transferred from one generation to the other. Young and educated people were continuously getting modernized thus relegating some of the traditional practices that reduced FLW. Two challenges associated with weakening of cultural practices were: (i) the disregarding of traditionally processed and preserved food owing to the perceived "unpleasant taste" and "poor hygiene" during processing by some educated young people, and (ii) the weakening channels of transfer of traditional knowledge between generations due to formal education, generation conflicts and incoming of easy-to-use modern facilities like refrigerators. All elderly women with no formal education had mastered the technologies compared to 33% of the younger and educated women. FLW were common in households with younger parents. As a challenge, the effects of the weakening of cultural practices on FLW were high in poorly developed rural areas where modern facilities were inadequate and also where the younger generations were getting modernized.

Increasing Extreme Climatic Events

Extremely high temperatures, out of season rainfall and prolonged rainfall seasons contributed to increased FLW. In Kamuthe for instance, the duration for milk to get spoiled was reported to have been decreasing with increasing temperatures. Women indicated that in the 1980s and 1990s fresh camel milk would last for up to 8 hours compared to the current 4 - 6 hours due to warmer days and nights. It was reported in Kangundo that occasional exceptionally high yields resulting from extremely high rainfall overstretched the storage facilities increasing FLW. Also, the extended periods of wet seasons hindered the appropriate process of sun-drying of various food items leading to postharvest loss.

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