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FOOD LOSS IN THE SWEET POTATO VALUE CHAIN: A FOOD AND NUTRITION SECURITY THREAT IN SOUTH AFRICA

Motsa NM[1]*, Laurie SM[1], Finiza TN[2], Makhuvha MC[1] and MF Mashitoa[1]

Dr. Nozipho Motsa

*Corresponding author email: MotsaN@arc.agric.za
ORCID ID: https://orcid.org/0000-0002-5993-8947

[1]Agricultural Research Council: Vegetable, Industrial and Medicinal Plants; Roots, Tubers and Bulbous Crops Section. Private Bag X293. Pretoria, 0001. South Africa

[2]Southern Africa Network for Biosciences (SANBio), Council for Scientific and Industrial Research (CSIR): Meiring Naude Road, PO Box 395, Pretoria, 0001, South Africa

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ABSTRACT

South Africa is food secure at national level, but not at household level. Some communities experience food shortages for a certain period during the month or for a period during the year. This is a food security threat to the community, as long as food loss and waste is not given the attention it deserves. Food loss mostly takes place at post-harvest and throughout the value chain until it reaches the consumer. Sweet potatoes are not spared from such losses. These losses tend to undermine the impact of sweet potato as a food security crop. This study was conducted to determine sweet potato food loss experienced at different stages of the value chain. A semi-structured questionnaire was used to collect data from a number of entities that are involved in the sweet potato food value chain and have purchased sweet potato material from the Agricultural Research Council. These entities were located in four provinces of the country where sweet potato is mostly produced and processed. Moreover, these entities were involved in at least one post-harvest (value chain) activity. The results indicated that small-scale sweet potato producers sold sweet potato to the local informal market while commercial producers with washing facilities, pack-houses and distributor licenses were supplying established formal markets. Sweet potato processing was done by commercial entities only, not small-scale entities. Sweet potato food loss was experienced throughout the food value chain beginning from crop growth where poor weed management and pest attack was observed. Sweet potato breakages and skinning were predominantly experienced during the post-harvest stage. “Out of specification” losses were experienced at packing and distribution stage while at processing stage, losses were through peeling and removal of insect bites/lesions. No losses were reported at the storage of processed sweet potato stage because entities had well established infrastructure to prevent losses. Processing of sweet potato and other crops reduces food loss and further strengthens the agrifood system and extends shelf-life of food crops to provide food and nutrition security.

Key words: Agri-food, post-harvest, food waste, commercial processing, small-scale, informal markets

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INTRODUCTION

Food waste and loss, and all related environmental, social and economic implications, have become a topic of increasing global concern and it is recognized as a serious threat to food security [1, 2]. According to the Food and Agriculture Organization (FAO) [3], food loss and waste (FLW) reflects the inefficiency and unsustainability of agrifood systems, with negative impacts on the economy, food security and nutrition, and the environment. Losing food in the value chain, especially at post-harvest handling, translates to losses in the embedded nutrition, energy, water, capital and other resources. This loss further exacerbates food insecurity and increases emissions of greenhouse gases experienced across the world [4, 5]. Approximately 1.3 billion tons of edible food is lost and wasted across the entire supply chain every year [1, 6] of which 45% is roots and tubers [4]. The authors further indicated that food loss is influenced by the level of income, urbanization and economic growth. In developing countries, food loss is experienced mainly at harvesting, post-harvest and processing stage thus decreasing the availability of food for human consumption [6]. This situation poses a large delay in achieving goal number two of the United Nation's Sustainable Development Goals [3].

In the agri-food system, losses can occur throughout the food crop value chain. The value chain includes harvesting; during washing and grading; at handling; during transportation and distribution; at storage due to pest attack, spillage, spoilage, and contaminations; during processing due to inefficient technologies; and finally, during commercialization [7]. Sweet potatoes are not spared from such losses. A study on post-harvest handling practices of sweet potato in Ethiopia indicated that most losses occur at marketing and distribution stages of the value chain due to root spoilage from lack of proper packaging, and mechanical damage [8]. Losses at post-harvest stage undermines the significance of the crop as a food security crop. This crop plays an important role in human diet and is considered the second staple food in developing and under-developed countries [9, 10]. It is one of the key crops for nutrition and income generation for approximately 300 million people in the humid tropics of sub-Saharan Africa [8, 11]. It is one of the major staple crops of the world, with global production of approximately 100 million tons in 2019 [12]. In South Africa, sweet potato is mostly produced by smallholder farmers in rural areas as a staple in many households [8, 13]. A total of 93 000 tons of sweet potato was produced in 2019/2020 [14]. The versatility of the crop and its multiple end-uses as food and feed is attracting attention of researchers and policymakers in particular, since it is showing potential to address Sustainable Development Goals and promote a sustainable society [15]. The crop has high nutritional value and sensory versatility in terms of taste, texture and flesh color [16]. It is easy to produce; hence it is

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preferred by smallholder farmers; however, the incessant losses at post-harvest is threatening food security of the 50% population of South Africa who are in danger of being food insecure in the country [17].

Reducing post-harvest losses is another positive contribution towards food and nutrition security in sub-Saharan Africa [7]. However, reducing post-harvest losses will not necessarily reduce food waste because there is a subtle difference between food loss and food waste. 'Food loss' and 'spoilage' occur at agricultural-field production, harvesting, post-harvest storage and handling, processing, packaging or distribution, retail and ultimate consumption stages of the food supply chain [18]. 'Food waste' on the other hand occurs at the later stages of the food supply chain and it generally applies to food lost due to behavioral issues (for example, food being discarded, whether after it is left to spoil or kept beyond its expiry date) [1, 18]. In as much as food loss contributes to food insecurity, it is food waste that keeps communities in danger of being food insecure as they tend to waste food that has survived earlier food loss stages.

The above clarification between the two terms is an indication that food loss stems from the agricultural process. If these losses are not controlled during the on-farm production up to and including all stages until the retail stage, food loss will continue to threaten food security and may even be the main cause of food insecurity. The losses when converted to profit, may also threaten the economy and employment since post-harvest activities tend to employ more people than primary agriculture, as modelled by the International Labor Organization (ILO) [19]. Most of the post-harvest employment (post-harvest storage, handling, transportation, processing, packaging and distribution) posts are located in urban areas where food production is limited, hence the higher percentage of food insecurity in the large metropolitans in South Africa [20]. It is important that post-harvest systems and processes thereafter, be very mindful of the impact caused by food losses because the current situation indicates that food loss at harvesting, post-harvest storage, transportation, processing, packaging and distribution is not given the attention it deserves. Instead, municipalities are more concerned about food waste which takes place at food preparation and consumption. Even so, the organic or food waste interventions that were identified from literature focused on 'end-of-pipe' solutions, such as composting [5] and landfill. Currently, there are limited published examples of food loss/waste reduction strategies at a national, provincial or municipal level identified in South Africa. The government, however, is still consulting on a draft strategy for reducing food loss and waste [21]. The slow pace in adopting food loss strategies and interventions is delaying the United Nation's Sustainable Development Goal number 12, specifically target 12.3 which sets a target to reduce food waste by 50% by 2030 [22].

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According to earlier reports by Gustavsson *et al.* [6] and Salami *et al.* [23], most of the food loss occurs after leaving the farm gate and it was particularly high during the processing and packaging stage (25%). Similar sentiments were reported by Oelofse *et al*. [24] that in South Africa, most losses and waste (49%) occur at the post-harvest handling, storage, processing and packaging stage in the value chain. Reports indicate that data to measure the possible causes of these losses were limited [5, 6, 24, 25]. A survey conducted in 2017 [5] with companies involved in formal post-harvest activities provided little information on the actual stage of possible high post-harvest losses in the value chain due to lack of transparency with actual figures and absence of response from others. Moreover, most responses indicated a lack of clarity on where exactly, in the food value chain does food loss and waste occur. Earlier publications [18, 22) had defined post-harvest loss as a measurable quantitative and qualitative loss of a given food product at any moment along the post-harvest chain and it includes the change in the availability, edibility, wholesomeness or quality of the food that prevents it from being consumed. It was on this definition that this study was born. The objective of this study was to determine sweet potato food loss experienced at different stages of the value chain in order to come up with recommendations and capacity building interventions.

MATERIALS AND METHODS

Study area

The study was conducted in four provinces of South Africa namely: Limpopo, Mpumalanga, Gauteng and Western Cape. The major production areas for this crop are Limpopo, Mpumalanga, Brits area in North-West, and parts of KwaZulu-Natal and Western Cape. The Western Cape and Gauteng provinces are mostly involved in packing and distribution of raw sweet potato sourced from other provinces, such as Limpopo and Mpumalanga. The two sweet potato processing companies are located in Mpumalanga and Limpopo. They also export processed sweet potato products.

Study population

The survey specifically targeted sweet potato farmers and processors who have a working relationship with ARC to get an insight into their experience on pre- and post-harvest losses of the sweet potato across various provinces in South Africa. A total of forty persons representing their specific entities were contacted and requested to participate in the survey. Only 38% of the persons contacted responded to the survey. A similar response was recorded by WWF [5], where they also received 30% responses from the specific companies' survey on food loss/waste study in South Africa.

Data collection

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A semi structured questionnaire was developed since it allows more exploratory data collection. It was then distributed to sweet potato entities (farmers and processors). The farmers/processors were called to seek consent and explain the questions before the questionnaire forms were distributed to them through emails. Convenience sampling was used by contacting persons and companies with which the ARC had interacted with before. These interactions were mostly through enquiries made by these entities to the ARC, for example, when requesting planting material, production/processing advice, interest in newly developed sweet potato cultivars and involvement in ARC sweet potato outreach projects.

The rapid assessment tool captured respondents' demographic information, information on the type of sweet potato and market, pre and post-harvest losses and lastly it captured processing and potential of the orange-fleshed sweet potato varieties.

Data analysis

The study utilized *a priori* themes and emerging codes especially where open-ended questions were used [26]. Categorizing production from small-scale to commercial scale, processing and potential of sweet potatoes in terms of various cultivars planted across South Africa and quantifying food loss into percentages constituted the *a priori* or pre-determined themes. The themes were then used for reporting findings from this study. Quantitative data were analyzed using descriptive statistics, including pie charts, bar graphs, and percentages to summarize sweet potato farmers' and processors' demographics, cropland yields, market participation, and pre- and post-harvest losses. Microsoft Excel was used to analyze data.

Ethical considerations

The ARC and CSIR are the main centers of excellence in research in South Africa and are mandated to follow the law for all ethical procedures when conducting research. Ethical requirements were met and cleared before data collection. The Protection of Personal Information Act (POPIA) was followed in order to protect the personal information of individuals. Actual names of entities and contact details were treated with the confidentiality they deserve hence they are not published in this document.

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RESULTS AND DISCUSSIONS

Participants' demographic characteristics, yield and marketing avenues

The respondents in this study were dominated by men (80%). Most respondents were 31-45 years old and over 56 years (figure 1). The observation of males dominating in the survey, even though women are major players in agriculture might be explained as males owning the land/farms/entities. Closing this gender gap is important to increase participation of female farmers and their input in decision-making on sweet potato production so as to increase production sustainability. There is a need to look at some intervention strategies that could support the female group of farmers so that they can participate more. The age distribution of participants ranged from young adults to seniors (figure1). Out of the age categories identified, the largest proportion of sweet potato farmers falls in the young to middle-aged category, that is, between 31- 45 years. An interesting observation was also made on the data, all sweet potato producers categorized as small-scale producers were above 50 years old, while those under the commercial category were dominated by ages between 31 – 50 years old. Another striking observation was that the small-scale sweet potato producers above 56 years old were located in the same province (Limpopo). This might be due to the fact that their province is considered the bread and fruit basket of South Africa and constitutes the richest agricultural areas in the country [27]. Further to that, a study by Ouya *et al.* [28] also reported that older farmers tend to have access to more land than young farmers and they have higher propensity to test their preferred crops.

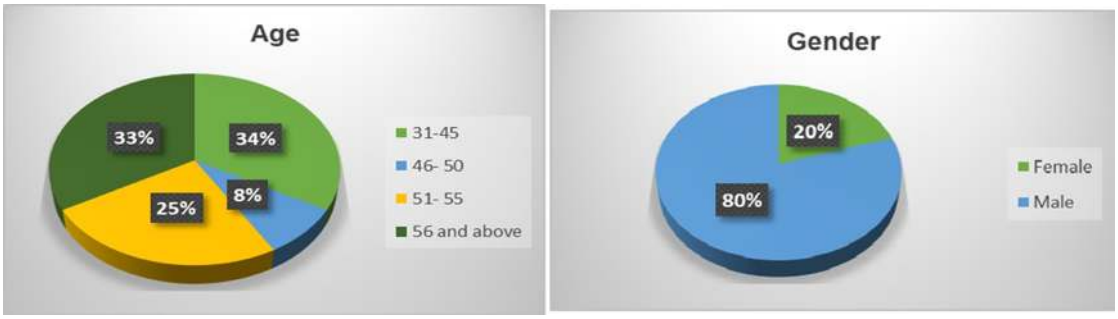

Figure 1: Age groups and gender of participants in the sweet potato value chain survey

Most (75%) of the sweet potato farmers and processors who participated in the survey have attained education at college or university level (Figure 2). Additionally, 17% have high school qualifications while 8% of the participants did not go beyond primary school level. This suggests that the level of education of sweet potato producers and processors in this study was not that low and this may have a positive impact on their farming practices, yields and post-harvest handling activities of the crop. The higher percentage of sweet potato farmers with college or university

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qualification may also have a positive impact towards adoption of technology to improve production and post-harvest skills, developing capacity and awareness on the impact of food loss in the value chain of the crop. The high percentage of college/university level farmers/processors participating in this study compared to other lower levels might also be the reason why there were few (38%) responses to the survey. Maybe the rest of the sweet potato producers/processors invited to participate were not literate enough to comprehend and respond to the questionnaire or did not understand the importance of the study due to a lower level of education.

Regarding the occupation structure of the sweet potato farmers, 67% were full-time farmers or producers, which makes them more concerned about primary production of sweet potato and related processes. The other positions represented included 9% processors, 8% researchers, 8% procurement manager, and 8% for other employment fields. This diversity implies that an interlinked value chain under which farmers, processors and researchers are involved in, can improve productivity and access to markets and further influence aspects allied to sweet potatoes' pre- and post-harvest. The occupationally diverse group shows that the knowledge gained from the surveyed respondents can create new information and help add value to sustainable sweet potato farming and value chain in South Africa.

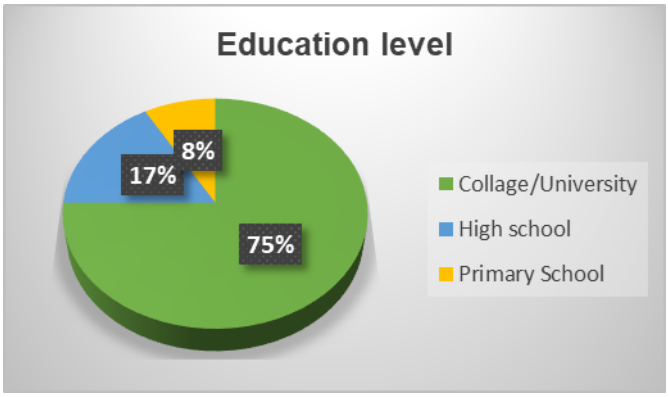

Figure 2: Education background of sweet potato producers and processors who participated in the survey

The size of land under sweet potato production among the sweet potato producers surveyed varied in size. It ranged from 0.08ha to 120 ha of land (Figure 3). Majority (55%) of the surveyed growers were producing sweet potatoes on land measuring 0.08ha – 2 ha while 18% were producing on land between 3 and 5 ha, those with land of 10-15 ha and 16-30 ha were 9% in each category. Growers with 120 ha and more cultivation land were 9% of the surveyed group. Based on the size of land under cultivation, 70% of the sweet potato producers are classified as small-scale farmers and they give an impression of practicing subsistence farming or small-scale

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commercial farming. The 9% of farmers with 120 ha and above size of land are categorized as large-scale farmers and are most likely commercialized.

About 80% of the small-scale sweet potato producers sold their harvest at local informal markets. Commercial producers with washing facilities, pack houses and distributors have an established market such as the National Fresh Produce Market (NFPM) and sell directly to supermarkets (Table 1). Entities that process sweet potatoes also export fresh and processed sweet potatoes to the United Kingdom and European Union (Table 1). The yield of sweet potatoes from commercial producers was recorded between 50 – 100t/ha. The small-scale producers on the other hand recorded yield within the range of 12 – 47t/ha (Table 1). The yield obtained by the small-scale producers was within the yield average range of 15.8 t/ha reported in an on-farm trial conducted on orange-fleshed sweet potato that was mainly produced for the informal market in South Africa [13, 8].

Only one commercial entity was strictly involved in sweet potato processing (Table 1) in the study, the other one was processing sweet potato on a small-scale basis. The commercial sweet potato processor dominates the vegetable processing industry in South Africa. This entity handles more than 13 000tons of sweet potato per season of which 6500 tons are orange-fleshed sweet potato varieties. About 95% of the orange-fleshed sweet potatoes processed in this entity are exported as battered frozen fries. This entity has 10 – 15 contracted sweet potato producers who supply their factory with fresh, washed produce industriously.

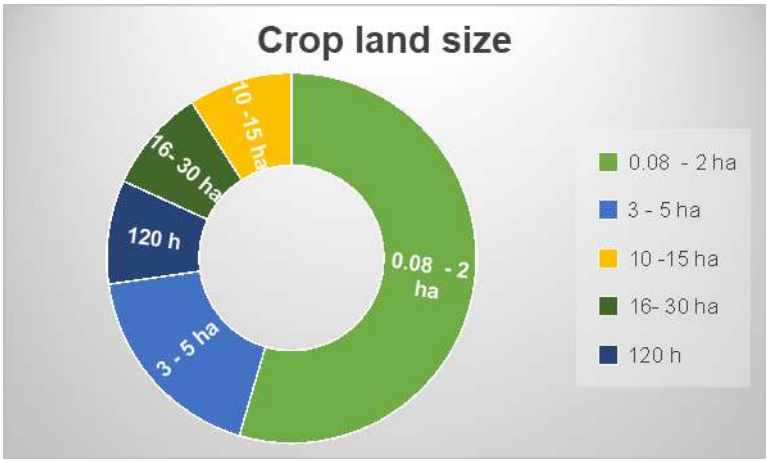

Figure 3: Cultivation land sizes used by sweet potato producers and processors who participated in the study

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Sweet potato losses experienced at different stages of the value chain

Losses before and during harvesting

Sweet potato producers experience loss of up to 25% before harvesting time (Table 2), i.e. during the growth stage of the crop. It should be noted though that small-scale producers only experience loss of up to 9% during the growing stage. The loss recorded during the production stage is usually associated with crop management including poor weed control, lack of irrigation, pests and diseases. The loss of up to 25% is an indication that poor management practices have a large impact on crop production right at the start of the process. Poor weed control was cited as the main contributing factor to the losses incurred during the production stage. Weed control is a crop management requirement, if not checked, it causes devastating losses due to crops competing with weeds for important resources such as nutrients, water and sunlight [33].

Sweet potato producers with washing facilities only, lose about 19% of sweet potato at harvesting while producers with pack-houses and distribution units lose up to 9% of their crop at harvesting stage. This may be attributed to non-marketable roots excluded from distribution either due to size of roots (too small or too big), rotten roots of roots with tunneling from pest attack. A maximum of 70% loss was recorded for one particular entity, where most sweet potato roots were attacked by sweet potato weevil and thus, rendered not marketable (Table 2). When looking at the scale of production, it is those entities categorized under small-scale producers that are experiencing more sweet potato loss at harvesting than commercial producers. Maybe there is a lack of purposely established mechanisms for monitoring cases leading to losses among the small-scale farmers. During washing and sorting, losses ranged from 1 to 25% (Table 2) and this was mainly caused by breakage, bruising and skinning. This is another loss that can be reduced by improving the technology of washing the crop, such as installing gentle washers that reduce bruising and skinning. A low percentage (1 – 9%) of sweet potato loss was experienced during transportation to the market or to the processing plant. This is owed to the fact that sweet potato is packed neatly in crates for transportation purposes and those supplying processing companies adhere to certain transportation standards and environments such as transporting the crop in refrigerated trucks.

Losses at storage, packing and processing

Small-scale producers sell their sweet potato produce just after harvesting and washing. Since their produce is sold at local informal markets, the crop is harvested in piece meals and generally sold while still fresh. Storage is usually the responsibility of the retailer. This study did not assess losses incurred by informal markets at retail stage. All small-scale producers indicated a willingness to be trained on how to reduce sweet potato food losses especially at postharvest stage, so far

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there has not been training specifically on food loss; however, farmers have been trained on composting and sustainable crop production. This is a positive indication that farmers recognize and are aware of sweet potato food loss and realize the need for capacity building around food loss.

Establishments dealing with packing and distribution of sweet potato indicated that their total losses are 11% of which 2% constitute of cutting/trimming waste and 9% is due to out-of-specification produce (skin bruising/loose skin, rot, insect bites, non-marketable size). Since the study did not include a question on how they dispose of the out-of-specification products, it is difficult to tell if those sweet potatoes are given to people to consume for food security reasons or they are fed to animals or composted. Out-of-specification sweet potatoes are not necessarily nonedible or contaminated, just that they do not qualify for marketing due to size, blemishes or bruises. Opening a "waste-center/wholesale" can still contribute to food security where the out-of-specification and bruised products can be sold at a lower price to consumers, especially those in big cities where food security was reported as a concern [16]. In terms of food loss and waste, food that was initially produced for human consumption but removed from the chain is considered food loss, even though it could be later used as bioenergy or animal feed [1].

Sweet potato loss at processing and packaging stage ranged from 14 – 29%. This is a huge percentage of food loss considering that the produce would have already experienced loss at washing and sorting stages. This observation confirms reports by Gustavsson *et al.* [6], Salami *et al.* [23] and Oelofse *et al.* [24], that most of food loss takes place after leaving the farm, particularly at processing and packaging. Loss at packaging is mostly through improper handling of the sweet potato and using damaged packaging material.

Processing of agricultural products is an important and final stage in reducing food loss, as it was observed in this study that there were no further losses after processing. This is the most important stage to ensure food security. The 20 – 29% losses experienced during processing are due to off-bits, peels and insect infested parts. As normal for producing of fries, a 25% weight loss is experienced. The commercial processing company that participated in this study indicated that they reduce food loss by processing the sweet potatoes within 1 – 2 days after harvesting since they have not invested much in a storage facility prior to processing. No loss is experienced after processing and packaging since the processed products are stored as frozen foods. This stage of the sweet potato value chain is the final stage and is vital for the food product (sweet potato) to be presentable and appealing to the consumer hence peeling is inevitable. Moreover, for the value addition to be effective, which is adding butter in this case, the skin of the sweet potato needs to be removed because consumers are very picky and their level of acceptability is at

a high level. Consumers may evaluate the quality of a product using attributes such as sight, smell, taste, touch, and other attributes [29], thus food processors are in cognizance of this fact.

It is worth noting that both white-fleshed and orange-fleshed sweet potato cultivars were used in this study and producers/entities confirmed that they used both varieties to cater for a vast market base. The commercial sweet potato processing company was processing the orange-fleshed variety of which 95% of its product is exported. This means that food security is extended into other countries through processing of sweet potatoes. The major contribution to food security of the orange-fleshed sweet potatoes (OFSP) is through vitamin A-biofortified varieties to alleviate malnutrition [30]. Sweet potatoes are good sources of vitamins (such as, vitamin C, folic acid, and B vitamins) and minerals (such as, calcium, potassium, magnesium, iron, and zinc) [29, 30]. Thus, it is important to limit or prevent food losses in sweet potato since it plays a vital role in food and nutrition security.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

This study showed that food loss in the sweet potato value chain happens throughout the process. Weed infestation and pest attack dominate losses during the crop production stage and it is prevalent among small-scale producers. This indicates a gap in good crop management practices and monitoring techniques from the farmers which can help prevent infestations (pest and weed) if checked. Pests do not play much of a role in sweet potato food loss at post-harvest stage; instead, breakage and skinning are predominant factors influencing loss during post-harvest stage. Ensuring that harvesting is done at optimum soil moisture is key to reducing skinning and breakage. During washing and sorting, careful handling and sanitation is of great importance. Major sweet potato food loss at packing and distribution is through “out of specification”, handling losses and improper packaging. This is rather a loss that can be curbed by investing in proper packaging material and opening a “waste-center/ warehouse” where consumers can buy food at a lower price compared to buying the premium product. Another recommendation is to process the out of specification roots into flour which can be consumed instead of consuming the actual root to ensure food security.

Correct processing of foods such as sweet potato is the ultimate solution to reduce food loss. Correct processing strengthens the agri-food system. It also extends the shelf-life of food crops and provides food security beyond local markets into the international world, thus improving the economy through employment opportunities and revenue. Minor losses encountered at processing are vital and they enhance value-addition. A study like this one should be conducted on other food security

crops so that a comprehensive programme on reducing food loss is developed and consequently implemented.

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Table 1: Respondents' location, marketing avenues, size of production and yield achieved

Entity category	Province	Cultivar produced	Yield (t/ha)	Production volume (tonnes)	Market type
Small-scale producer	Limpopo	[1]OFSPV	0.1	-	Local informal
	Limpopo	OFSPV	0.2	-	Local informal
	Mpumalanga	OFSPV & [2]WFSPV	OFSPV- 47.2 WFSPV- 46	1 – 2	Local informal
	Limpopo	[2]WFSPV	12	60	Local informal
	Gauteng	WFSPV	15	40	[3]NFPM
Small-scale producer and processor	Limpopo	WFSPV	0.32	500	Formal and informal market
Commercial Producer with Washing facility	Limpopo	WFSPV	45	1350	NFPM
	Mpumalanga	WFSPV & OFSPV	50	-	Direct to supermarkets, NFPM, local informal
	Limpopo	WFSPV	60 - 80	-	NFPM
Pack house and distribution	Western Cape	OFSPV & WFSPV	OFSPV – 65 WFSPV - 112	-	NFPM. Supermarkets, Export to EU & UK
	Gauteng	OFSPV & WFSPV	-	3500	Direct to supermarkets and Processors
	Gauteng	OFSPV & WFSPV	-	3600	Export market
Commercial Processing	Mpumalanga	OFSPV	80 - 100	13000	Export (95%) to EU SA markets (5%)

[1]Orange-fleshed sweet potato variety. [2] White-fleshed sweet potato variety. NFPM (National Fresh Produce Market)

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Table 2: Losses of sweet potatoes (%) experienced at different stages of the value chain

Entity category	Loss at growth stage (%)	notes	Harvest loss (%)	Handlingwashing sorting loss (%)	notes	Transportation loss (%)	Marketing loss (%)	Storage loss (%)		Processing &Packaging loss (%)	storage of processed products and marketing loss	Need training on reducing food loss
	Small-scale producer											
1	1-9		10 - 19	1-9		N/A	10-19			N/A	N/A	Yes
2	1-9		1 - 9	1-9		N/A	N/A			N/A	N/A	Yes
3	25	Poor weed control	19 - 70	-	Attack by sweet potato weevil	1-9	N/A			N/A	N/A	Yes
4	1-9		1-9	1-9		1-9	1-9	1-9		N/A	N/A	Yes
5	1-9		10 - 19	1-9		N/A	19	N/A		N/A	N/A	Maybe
	Small-scale producer and processor											
1	0			1 - 9		0	0	0		0	0	yes
	Commercial Producer with Washing facility											
1	1-9	-	10-19	1-9		N/A	Do not know	N/A		N/A	N/A	Maybe
2	-	-	5-7	Covered at harvesting	70 % are 1st grade	-	-	-		-	-	Maybe
3	-	-	5	Covered at harvesting		N/A	N/A	N/A		N/A	N/A	-
	Pack house and distribution											
1	1-9	-	1-9	1-9	-	1-9	1-9	1-9		0	N/A	-
2	N/A	-	N/A	25	76% prepacked					14	N/A	-
3	0	-	N/A	N/A		N/A	N/A	1-9		20-29	0	Maybe
	Commercial Processing											
1	N/A	-	N/a	0	-	0	N/A	0		20-29	0	Yes

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