Sokoine University of Agriculture

MSc Dissertation

Assessment of Indoor Storage Technology on White Colour Sweet Potato Tubers (*Ipomoea batatas* L.Lam) in Morogoro, Tanzania

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ASSESSMENT OF INDOOR STORAGE TECHNOLOGY ON WHITE COLOUR SWEET POTATO TUBERS (*Ipomoea batatas* L.Lam) IN MOROGORO, TANZANIA

Dissertation Submitted to Sokoine University of Agriculture in Fulfilment of the Requirements for the Degree of Master of Science in Post-Harvest Technology and Management

By

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EXTENDED ABSTRACT

Sweet potato (*Ipomoea batatas* L.Lam.) is a dicotyledonous plant grown as a tuber crop. Sweet potatoes originated from tropical America (Coop, 2010). Sweet potatoes are widely cultivated mainly around the lake zone, eastern zones, southern highlands, and northern parts of Tanzania (URT, 2016). It is grown by 771,257 households during short rainy and long rainy seasons, with an estimated annual production of 504,346 tonnes (NBS 2012). Sweet potato tubers contribute to food security and income generation (Ahmad *et al.,* 2014). Sweet potatoes' high perishability after harvesting is one of the major factors limiting their potential.

Insufficient information concerning efficient storage technology limits farmers and traders from choosing the best technology to reduce losses. The research by Teye *et al*. (2011) compared two storage technologies: the Purpose-Built Evaporative Cooling Barn and Modified Pit Storage under Ghana conditions, neglecting other sweet potato storage technologies. Further research by Mpagalile *et al*. (2007) used the traditional pit, improved open pit, improved housed pit (mjinge) and raised woven structure (Kihenge) to evaluate the storability of sweet potato under Tanzania conditions neglecting other sweet potato storage technologies. Purpose Evaporative Cooling Barn and housed pit storage are still techniques used to attain optimum temperature and relative humidity for sweet potato storage with temperatures between 12.5°C and 15°C and relative humidity from 85% to 90%. Nevertheless, their adaptability to small-scale farmers and traders in developing countries like Tanzania is limited due to their high initial capital and high running costs for White-coloured sweet potato tubers. Small-scale farmers and traders are in high demand for storage technology, which is low in capital and running costs. Indoor storage technologies are a better choice as they maintain proper storage temperature and relative humidity through ventilation and are used in hot and arid areas (Baimey *et al.,* 2017). In this technology, White coloured sweet potato tubers can be stored with minimum changes in colour, weight, rotting and firmness (Gopala, 2015).This study aimed to assess indoor storage technology on white colour sweet potato tubers (*ipomoea batatas* l.lam) in Morogoro, Tanzania, that will help to minimise losses of white sweet potato tubers.

According to the findings, the most significant cause of post-harvest losses was rodent attack, which was reported by 26.53% and 25% of farmers and traders in Gairo and Morogoro municipalities, respectively, and the extent of white-coloured sweet potato tuber losses observed was 18.36% of farmers and traders in Gairo and 79% of farmers and traders in Morogoro municipality have reported to suffer from moderate post-harvest losses. White-coloured sweet potato tubers stored in ventilated bags and the improved traditional raised platform resulted in a weight loss of 49.4% and 68.7%, respectively. It was also observed that the improved traditional raised platform had a significantly high total soluble content /concentration, with a value of 21.27%. In comparison, Ventilated bags resulted in a Total soluble solid content of 17.02 %, which was significantly low. Furthermore, results show that Ventilated bags had the lowest beta carotene content (8.72 µg/g) compared to other treatments. Results indicate that traders' source of funding for their sweet potato selling activity was own/self-financing, estimated at 70%, loans estimated at 19.37%, and remittances estimated at 10.63%. Also, the study's findings demonstrate that the single and multi-stage channel systems are the two main sweet potato marketing channels. Retailers constitute 57.5% of respondents, wholesalers 27.5%, and other trades (Middlemen/SME processors) 15%. Furthermore, a study indicated that 21% of traders produce sweet potatoes on their farms, and 97% of merchants purchase sweet potatoes directly from farmers also, 42% purchase sweet potatoes through wholesalers/aggregators. Results continued to reveal that by using ventilated bags storage technology, farmers and traders could earn higher profits, which was Tsh 19,000/= more than other storage technologies (improved traditional raised bamboo buckets and woven Polypropylene Bags.

The study results indicate a need to improve post-harvest loss awareness among white-coloured sweet potato farmers and traders to reduce loss and thus begin producing profitably. Also, controlling rodents, avoiding injury, building a proper storage facility and inspecting the stores regularly are the most important aspects to consider when preventing losses. Also, findings suggest that storing white-coloured sweet potato tubers in ventilated bags is appropriate. Using ventilated bags can also be effective when storing undamaged sweet potato tubers. Farmers and traders are advised to sort and grade their tubers before storage.
Furthermore, additional research studies should be conducted to develop awareness of other types of storage and methods for reducing sweet potato losses to impact food security in society.

IKIRISI KUU

Viazi vitamu (*Ipomoea batatas L.Lam*.) ni mmea wa dicotyledonous ambao hupandwa kama zao la mizizi. Asili ya viazi vitamu ni kutoka Amerika ya kitropiki (Coop, 2010). Nchini Tanzania, viazi vitamu hulimwa kwa wingi kuzunguka Kanda ya Ziwa, Kanda za Mashariki, Nyanda za Juu Kusini na Kaskazini mwa Tanzania (URT, 2016). Viazi vitamu hulimwa na kaya 771,257 katika msimu wa mvua fupi na muda mrefu na wastani wa uzalishaji wa tani 504,346 kwa mwaka (NBS, 2012). Mizizi ya viazi vitamu huchangia katika usalama wa chakula na kuongeza kipato (Ahmad *et al.,* 2014). Kuna aina kadhaa za viazi vitamu, ikiwa ni pamoja na Viazi vitamu vyenye nyama ya rangi nyeupe, Viazi vitamu vyenye nyama ya rangi ya krimu, Viazi vitamu vyenye nyama ya rangi ya njano, Viazi vitamu vyenye nyama ya rangi ya nyekundu na Viazi vitamu vyenye nyama ya rangi ya zambarau (Rahman *et al*., 2003). Mizizi ya viazi vitamu yenye rangi nyeupe ni chanzo kizuri cha virutubisho ikijumuisha Kalori, Mafuta, Wanga, Protini, Nyuzinyuzi na Vitamini (De Albuquerque *et al*., 2019) Kula mizizi ya viazi vitamu yenye rangi Nyeupe huongeza afya ya macho, mfumo wa uzazi, moyo na figo (Johnson na Pace, 2010). Licha ya umuhimu wake, kuongezeka kwa uzalishaji wa mizizi ya viazi vitamu vya rangi Nyeupe nchini Tanzania bado kunakabiliwa na changamoto kadhaa. Upotevu wa viazi baada ya kuvuna ni changamoto kwa wasambazaji na watumiaji wa viazi vitamu vya rangi Nyeupe.

Upungufu wa vifaa vya kuhifadhia ni miongoni mwa sababu kuu za hasara kubwa baada ya kuvuna katika mizizi ya viazi vitamu yenye rangi nyeupe inayokadiriwa kufikia kati ya 25 na 50% ya jumla ya uzalishaji duniani (Robert *et al*., 2014). Nchini Tanzania, upotevu wa mizizi ya viazi vitamu baada ya kuvuna ni jambo linalotia wasiwasi mkubwa, Tafiti zinaonyesha wakati wa usafirishaji hadi kuhifadhi viazi vitamu, upotevu wa baada ya kuvuna unaweza kutofautiana kutoka 20 hadi 70% (Tomlins *et al.* , 2000). Kimsingi, uhaba wa vifaa vya uhifadhi husababisha hasara za ubora, kiasi na kiuchumi (Singh *et al.,* 2007). Licha ya umuhimu wa uzalishaji wa mizizi ya viazi

vitamu ya rangi nyeupe nchini Tanzania, taarifa duni kuhusu teknolojia bora ya uhifadhi huzuia wakulima na wafanyabiashara kuchagua teknolojia bora ya kupunguza hasara. Utafiti wa Teye *et a*l. (2011) ililinganisha teknolojia mbili za uhifadhi, ambazo zilikuwa Ghala la Kupooza na teknolojia ya kuhifadhi ya Shimo iliyoboreshwa katika mazingira ya Ghana akiacha teknolojia zingine za kuhifadhi viazi vitamu kama vile uhifadhi wa ndani, uhifadhi wa kubana na teknolojia ya nishati sufuri. Matokeo yalionyesha kuwa teknolojia ya Ghala la Kupooza lilihifadhi viazi vitamu vizuri kuliko teknolojia ya kuhifadhi kwa Shimo Iliyoboreshwa. Utafiti zaidi wa Mpagalile *et al.* (2007) alitumia shimo la kitamaduni, shimo la wazi lililoboreshwa, shimo lililoboreshwa (mjinge) na Kihenge kutathmini uhifadhi wa viazi vitamu na kuacha teknolojia nyingine kama uhifadhi wa ndani, uhifadhi wa kubana, na teknolojia ya nishati sifuri. Matokeo yalionyesha kuwa uhifadhi wa mashimo ulioboreshwa (mjinge) ulifanya kazi vizuri ilhali mbinu ya kitamaduni ilikuwa mbaya zaidi katika sifa zote.

Teknolojia ya Ghala la Kupooza na uhifadhi wa mashimo ulioboreshwa (mjinge) ni mbinu zinazotumiwa kupata joto la juu zaidi na unyevunyevu kiasi kwa ajili ya kuhifadhi viazi vitamu na halijoto kati ya 12.5°C na 15°C na unyevu kiasi kutoka 85% hadi 90%. Hata hivyo, uwezo wa teknolojia kutumika kwa wakulima wadogo na wafanyabiashara katika nchi zinazoendelea kama Tanzania ni mdogo kutokana na gharama kuwa kubwa ya awali na gharama kubwa za uendeshaji wa uhifadhi wa mizizi ya viazi vitamu yenye rangi Nyeupe,Hali hii inasababisha wakulima na wafanyabiashara wadogo kuchagua kuhifadhi kwa muda kwa kuzika mizizi ya viazi vitamu vyenye rangi Nyeupe ardhini huku vingine vikihifadhi kwenye za matenga kwa ajili ya kusubiri mlaji ambazo zote zilionekana kuwa na ufanisi mdogo katika utendaji.

Kuna mahitaji makubwa ya wakulima na wafanyabiashara wadogo kupata teknolojia ya uhifadhi ambayo ni ndogo katika mtaji na gharama za uendeshaji.Hivyo, utafiti huu umechunguza teknolojia za kuhifadhi viazi vitamu za rangi Nyeupe ambazo ni nafuu, zinazofaa na za kudumu. Utafiti huu unaangazia kutathmini teknolojia za uhifadhi wa ndani ambazo ili kurefusha maisha ya mizizi ya viazi vitamu yenye rangi Nyeupe wakati wa kuhifadhi.

Tathmini ya mbinu hizi za teknolojia zinazotumiwa na wakulima na wafanyabiashara ili kupunguza matukio ya hasara ambayo yatasaidia kupunguza hasara na kuongeza kipato.

Kupitishwa kwa teknolojia nzuri ya uhifadhi kutaleta matokeo ya matumaini katika suala la kurefusha maisha ya viazi vitamu na matokeo yake, kuongeza faida ya mizizi ya viazi vitamu baada ya mauzo ya bidhaa. Matokeo yatatumika kuwasaidia wakulima na wafanyabiashara katika kuchagua teknolojia sahihi ya uhifadhi wa ndani kwa ajili ya kupunguza hasara na hivyo kupata faida.

Matokeo yalionyesha kuwa wakulima na wafanyabiashara wengi wa viazi vitamu wanakabiliwa na hasara ya wastani baada ya kuvuna. Hasara ya upotevu wa mazao baada ya kuvuna zilikuwepo katika wilaya zote zilizofanyiwa utafiti kwa nguvu tofauti pengine kutokana na tofauti za njia za usafiri, utunzaji na uhifadhi katika kila wilaya. Ukubwa wa upotevu wa mizizi ya viazi vitamu yenye rangi nyeupe iliyoonekana ni 18.36% ya wakulima na wafanyabiashara wa Gairo na 79% ya wakulima na wafanyabiashara katika manispaa ya Morogoro wameripotiwa kupata hasara ya wastani baada ya mavuno. Matokeo ya utafiti huu yanapendekeza sana kwamba kuhifadhi mizizi ya viazi vitamu yenye rangi nyeupe kwenye mifuko inayopitisha hewa ni njia mwafaka ya kupunguza hasara baada ya kuvuna. Hili lilionyeshwa wakati wa jaribio ambalo lilifichua kuwa mizizi ya viazi vitamu yenye rangi Nyeupe iliyohifadhiwa kwenye mifuko inayopitisha hewa kiwango cha kupungua uzito kilikuwa kidogo baada ya kuhifadhi (49.4%) na kulingzanisha na kihenge kilichoboreshwa (68.7%). Zaidi, matokeo yanaonyesha kuwa mifuko yenye uingizaji hewa ilikuwa na maudhui ya chini zaidi ya beta carotene (8.72 µg/g) ikilinganishwa na teknolojia nyingine.

Matokeo ya utafiti huu yanapendekeza sana kwamba kuhifadhi mizizi ya viazi vitamu yenye rangi nyeupe kwenye mifuko inayopitisha hewa ni njia mwafaka. Zaidi ya hayo, matumizi ya mifuko ya uingizaji hewa pia inaweza kuwa na ufanisi wakati wa kuhifadhi mizizi ya viazi vitamu isiyoharibika. Wakulima na wafanyabiashara wanashauriwa kusafisha,kupanga mizizi ya viazi vitamu kabla ya kuhifadhi. Katika muktadha wa utafiti wa sasa, utafiti wa ziada katika aina zingine za vifaa vya ufungaji na uhifadhi unapendekezwa.

DECLARATION

I, **JOSEPH R. KIMAKO,** do hereby declare to the Senate of the Sokoine University of Agriculture that the work presented here is my original work done within the period of registration and that it has neither been submitted nor is concurrently submitted for degree award in any other Institution.

_______________________ _______________________

Joseph R. Kimako **Date**
(MSc. Candidate)

The above declaration is confirmed by;

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Prof. Valerian. C. K. Silayo **Date**
(Supervisor)

_______________________ _______________________

Prof. Geoffrey C. Mrema **Date**
(Supervisor)

LIST OF PUBLISHED PAPERS

1. Assessment of causes and extent of post-harvest losses of white sweet potato tubers during storage in Morogoro Region, Tanzania
   "The material contained in this chapter has been published in International Journal of Agriculture, Environment and Bioresearch"
   Link: https://ijaeb.org/link8.php?id=798

2. Performance evaluation of different storage technologies on storage stability of white-coloured sweet potato tubers under farmers' conditions in Tanzania
   "The material contained in this chapter has been received in International Journal of Scientific Research Updates (IJSRU)
   Link:
   https://journals.eanso.org/index.php/eajab/article/view/1473

3. Assessment of the Economic Suitability of Indoor Storage for White-Coloured Sweet Potatoes Tubers Under Tanzania Conditions
   "The material contained in this chapter has been published in East African Journal of Agriculture and Biotechnology (EAJAB)
   Link: https://doi.org/10.37284/eajab.6.1.1238

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DEDICATION

This priceless work is dedicated to my adored wife, Hadija Maarufu, and My daughter, Dazzling Kimako, as well as my mother, Prisca Kimako, for their unwavering support and encouragement during my academic career.

ORGANISATION OF THE DISSERTATION

This dissertation is developed in the format of publishable papers comprising six main chapters. Chapter one is a general introduction, chapter two, three and four consists of manuscripts in the form of publishable papers. Chapter five is the General/Integrated discussion and chapter six is the general conclusions and recommendations of the study.

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LIST OF ABBREVIATIONS AND SYMBOLS

ANOVA	Analysis of Variance
CBA	Cost benefit analysis
DMRT	Duncan’s multiple range test
NBS	National Bureau of Statistics
R	Regression
SPSS	Statistical Package for Social Science
TBS	Tanzania Bureau of Standards
TTS	Total Soluble solid
VETA	Vocational Education and Training Authority

CHAPTER ONE

1.0 INTRODUCTION, JUSTIFICATION, AND OBJECTIVES

1.1 Introduction

Sweet potato (*Ipomoea batatas* L.Lam.) is a dicotyledonous plant that is grown as a tubers crop (Mekonnen *et al*., 2015). The origin of sweet potatoes is from tropical America (Coop, 2010). In Tanzania, sweet potatoes are widely cultivated in Agro- ecological zones mainly around the Lake zone, Eastern zones, Southern highlands and Northern parts of Tanzania (URT, 2016). It is grown by 771 257 households during short rainy and long rainy seasons with an estimated annual production of 504,346 tonnes (NBS, 2012). Sweet potato tubers contribute to food security and income generation (Ahmad *et al*., 2014). There are several varieties of sweet potatoes, including white-coloured flesh, cream-coloured flesh, yellow, red and purple (Rahman *et al.,* 2003). White-coloured sweet potatoes tubers are a great source of nutrients including Calories, Fat, Carbohydrates, Protein, Fiber and Vitamins (De Albuquerque *et al.,* 2019) Consuming White-coloured sweet potatoes tubers enhances healthier eyes, reproductive system, heart and kidney functions (Johnson and Pace, 2010).

The quality of sweet potato tubers stored indoor is affected by several parameters associated with storage technology, including temperature, relative humidity, ventilation, lighting and length of storage. To Ensuring the ideal storage temperature is essential for maintaining the quality of sweet potatoes. The recommended storage temperatures to prevent chilling damage or sprouting normally fall within the range of 55-60°F (13-16°C). Lower temperatures might result in chilling harm, whilst warmer conditions may accelerate sprouting and decay. In addition, sweet potatoes necessitate levels of humidity (about 85-90%) to prevent the loss of moisture and shrinkage. Optimal humidity levels not only prevent sprouting but also decrease the likelihood of disease formation.

Proper ventilation is essential for maintaining consistent temperature and humidity levels in the storage facility, preventing the formation of localized hotspots or areas with excessive humidity that might cause decay or sprouting. Additionally, the sweet potatoes can turn green when exposed to light because chlorophyll is produced, resulting in a bitter taste and the probable creation of harmful substances. To prevent greening, sweet potatoes should be stored in a dark or low-light environment.

Despite its importance, increasing White coloured sweet potato tubers production in Tanzania is still facing some challenges. Post-harvest losses are challenging for suppliers and users of White coloured sweet potato tubers. Improper storage facilities have contributed to considerable post-harvest losses of White coloured sweet potato tubers in many developing countries. To reduce these losses, proper post-harvest handling practices, including packaging and good storage practices are inevitable.

1.2 Problem Statement

Insufficient storage facilities are among the critical causes of significant post-harvest losses in White coloured sweet potatoes tubers estimated to range between 25 and 50% of the total production of the world (Robert *et al.,* 2014). In Tanzania, post-harvest losses of white sweet potato tubers are a significant concern, Studies show during transport up to storage of sweet potatoes, post-harvest losses might vary from 20 to 70 % in the form of fresh tuber (Tomlins *et al.,* 2000). Principally, insufficient storage facilities lead to qualitative, quantitative and economic losses (Singh *et al*., 2007). Despite the importance of white-coloured sweet potato tubers production in Tanzania, insufficient information concerning efficient storage technology limits farmers and traders to choose the best technology to reduce losses. The research by Teye *et al*. (2011) compared two storage technologies, which were the Purpoe-Built Evaporative Cooling Barn and Modified Pit Storage under Ghana conditions, neglecting other sweet potato storage technologies such as indoor storage, clamp storage and zero energy technology. The results showed that Purpose Built Evaporative Cooling Barn stored sweet potatoes better than Modified Pit Storage. Further research by Mpagalile *et al*. (2007) used the traditional pit, improved open pit, improved housed pit (mjinge) and raised woven structure (Kihenge) to evaluate the storability of sweet potato, neglecting indoor storage, clamp storage, and zero energy technology. The results showed that improved housed pit storage (mjinge) performed comparatively well, whereas the traditional method was the poorest in all attributes.

Purpose Evaporative Cooling Barn and housed pit storage are still techniques used to attain optimum temperature and relative humidity for sweet potato storage with temperatures between 12.5°C and 15°C and relative humidity from 85% to 90%. Nevertheless, their adaptability to small-scale farmers and traders in developing countries like Tanzania is limited due to their high initial capital and high running costs for White-coloured sweet potato tubers storage which cause small-scale farmers and traders to choose temporary storage, which is to bury the White-coloured sweet potatoes tubers in the ground. In contrast, others store in bamboo buckets for waiting for a consumer both of which were observed to have low efficiency in performance. There is high demand by small-scale farmers and traders to get storage technology, which is low in capital and running costs. Therefore, there is a need to investigate White coloured sweet potato tuber storage technologies that are affordable, suitable and long-lasting. This study will focus on assessing indoor storage technologies ventilated to lengthen the shelf life of White-coloured sweet potato tubers during storage.

1.3 Justification

To maintain the quality and shelf-life of White coloured sweet potatoes tubers proper storage is required at 12.5°C - 15°C and relative humidity of 85% - 90%. (Sugri *et al*., 2017). In this study, proper control of White-coloured sweet potato tubers from losses during storage means controlling the storage area's temperature and relative humidity (Gopala, 2015).

Indoor storage technologies are a better choice as they maintain proper storage temperature and relative humidity through ventilation and are used in hot and arid areas (Baimey *et al.,* 2017). In this technology, coloured sweet potato tubers can be stored with minimum changes in colour, weight, rotting and firmness (Gopala, 2015).

The rationale for implementing indoor storage technology, particularly in sweet potatoes, arises from the necessity to extend the length of the shelf life, preserve quality, and reduce post-harvest losses. Indoor storage techniques provide regulated conditions that can reduce the impact of variables such as temperature changes, humidity levels, light exposure, and pest infestations. These factors can all lead to the deterioration and rotting of stored crops.

This study will assess the storability of White coloured sweet potatoes tubers indoor storage technologies which are improved traditional raised platforms, Woven Polypropylene Bags, and ventilated bags. The results will give the users confidence and allow them to choose the best-performing storage technologies for White coloured sweet potato tubers as strategies to increase shelf life and hence, reduce post-harvest losses. The results will also be used as a standard for policymakers who promote indoor storage technologies.

1.4 Objective

1.4.1Overall Objective

The overall objective of this research is to assess indoor storage technologies for the storage of White-coloured sweet potato tubers under Tanzanian conditions.

1.4.2 Specific Objectives

The following are specific objectives, which were undertaken to achieve the overall aim of the study

i. To assess the causes and extent of post-harvest losses of white-coloured sweet potato tubers during storage.
ii. To evaluate the performance of different storage technologies on the storage stability of white-coloured sweet potato tubers under farmers' conditions in Tanzania
iii. To assess the economic suitability of indoor storage technologies for the storage of White-coloured sweet potato tubers under Tanzania conditions.

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CHAPTER TWO

2.0 ASSESSMENT OF CAUSES AND EXTENT OF POST-HARVEST LOSSES OF WHITE SWEET POTATO TUBERS DURING STORAGE IN MOROGORO REGION, TANZANIA

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ABSTRACT
Many studies have revealed that losses of sweet potatoes occur due to mechanical injury, high moisture content of the tubers, attack by rodents, physiological spoilage and weevil. This study was conducted to assess the causes and extent of post-harvest losses of white-coloured sweet potato tubers during storage in Gairo district and Morogoro municipality in Morogoro region, Tanzania. The assessment was conducted in eight (8) wards of the two areas using a questionnaire to capture data on farmers' and traders' bio-data, awareness of white-coloured sweet potato tuber losses and storage practices. The collected data were analysed using Statistical Package for Social Science (SPSS) version 25. According to the findings, the most significant cause of post-harvest losses was rodent attack, which was reported by 26.53% and 25% of farmers and traders in Gairo and Morogoro municipalities, respectively, and the extent of white-coloured sweet potato tuber losses observed was 18.36% of farmers and traders in Gairo and 79% of farmers and traders in Morogoro municipality have reported to suffer from moderate post-harvest losses. The study results indicate a need to improve post-harvest loss awareness among white-coloured sweet potato farmers and traders to reduce loss and thus begin producing

profitably. Controlling rodents, avoiding injury, building a proper storage facility and inspecting the stores regularly are the most important aspects to consider when preventing losses

Keywords: Awareness, post-harvest losses, white-colored sweet potatoes tuber, storage

2.1 Introduction

Sweet potato (Ipomoea batatas L.Lam.) is a dicotyledonous plant that originated in tropical America (Coop, 2010). In Tanzania, sweet potatoes are widely cultivated mainly around the Lake zone, Eastern zone, Southern highlands and Northern parts (URT, 2016). Grown by 771 257 households during short rainy and long rainy seasons, annual production is estimated at 504 346 tonnes (NBS, 2012). Sweet potato tubers contribute to food security and income generation (Ahmad *et al.*, 2014). There are several varieties of sweet potatoes, including white-coloured flesh, cream-coloured flesh, yellow, red and purple (Rahman *et al.*, 2003). White-coloured sweet potato tubers are a great source of nutrients, including Calories, Fat, Carbohydrates, Protein, Fiber and Vitamins (De Albuquerque *et al*., 2019). Consuming white-coloured sweet potato tubers enhance healthier eyes, reproductive system, and heart and kidney functions (Johnson and Pace, 2010).

The primary causes and magnitude of post-harvest losses of white sweet potato tubers during storage are mostly attributed to various variables, such as infections, pests, mechanical injuries, weight reduction, sprouting, and alterations in tuber composition. Storage of white sweet potato tubers can result in post-harvest losses. These losses have negative effects on both the financial sustainability of farmers and the accessibility of nutritious food for consumers. Post-harvest losses are among the challenges faced by the suppliers and users of white-coloured sweet potato tubers. Improper storage facilities have contributed to considerable post-harvest losses of white-coloured sweet potato tubers (Jones *et al.,* 2012).

Efficient management techniques, such as appropriate storage facilities, regulation of temperature and humidity, pest control, and timely market access, are crucial for reducing these losses and guaranteeing food security.

This paper assesses the causes and extent of post-harvest losses of white-coloured sweet potato tubers during storage in Gairo district and Morogoro municipality in Tanzania. Questionnaires were used to collect information on practices that farmers and traders in Gairo and Morogoro municipalities use to abate the causes and extent of post-harvest losses of white-coloured sweet potato tubers during storage. The results will be used to assist farmers and traders to device good management approaches for reducing losses.

2.2 Methodology

2.2.1Study area

The study was conducted in two districts in Morogoro region: Gairo district (located between latitude 6.193°- 5.934° South and between longitude 36.882°- 37.063° East) and Morogoro District in which Morogoro municipality (located between latitude 6.847°- 6.77° South and between longitude 37.607°- 37.664° East) is situated. These locations were purposefully selected due to their different agro-ecological zones and previous reports on postharvest losses of white-coloured sweet potato tubers (Ngailo *et al*., 2016). These agro-ecological zones were different in terms of rainfall pattern, growing seasons, temperature, production practices and socioeconomic status.

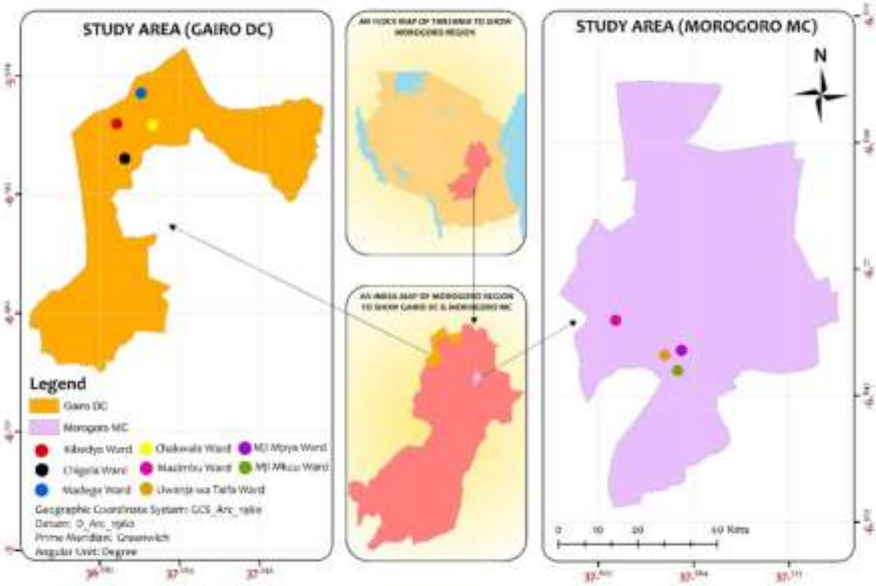

Figure 2.1: Morogoro region map showing Morogoro municipality and Gairo District

2.2.2 Survey and data collection

A survey of farmers' and traders' post-harvest handling and storage practices of white-coloured sweet potato tubers was conducted in Chakwale, Chigela, Kibedya and Madege wards in Gairo district and Mazimbu, Mji mkuu, Mji mpya and Uwanja wa Taifa wards in Morogoro municipality. A total sample size of 396, comprising 186 farmers and 210 traders was involved in the survey. Information on bio-data and farmer's and trader's awareness on causes of white-coloured sweet potato tubers losses and storage were collected through interviews using an electronic questionnaire mounted in the Kobo Collect Application and saved on the Kobo Toolbox platform. Specific information was sourced using the following questions: What are the main causes of postharvest losses of white-coloured sweet potato tubers? How long it takes to store white-coloured sweet potato tubers? Where do the major losses of white-coloured sweet potato tubers occur? What is the level of awareness of postharvest losses of white-coloured sweet potato tubers? What is the level of farmers and traders' awareness of storage technologies? How do the farmers and traders sort/grade white-colored sweet potatoes before storage? Is there any preventive measure against white-coloured sweet potato tubers losses.

2.2.3 Data analysis

Statistical analyses were performed using Statistical Package for Social Science (SPSS) version 25 to obtain frequency and percentage of the Sex, education, occupation, position in the household, level of awareness, storage size, source of post-harvest losses as the variables.

2.3 Results

2.3.1 Demographic characteristics of farmers and traders in Morogoro municipality and Gairo District

Table 2.1 summarizes the findings of the farmers and traders survey conducted in Morogoro municipality and Gairo district. It is shown that the respondents in this study were 68.69% females and 31.31% males. Irrespective of their sex, majority of them had completed primary school education (85.6%), and the rest had attained secondary school (9.85%) and tertiary (4.5%) education levels. Furthermore, the composition of traders and farmers were 53.03% and 46.97%, respectively. Based on the position in the household, findings show that most households were headed by mothers (61.10%) and the rest were headed by fathers (32.80%) and children (6.10%).

Based on Pearson Product-moment Correlation analysis, demographic factors such as sex, education level, occupation and house hold size had a significant relationship with farmers' and traders awareness of losses at 1% level of significance.

Table 2.1: Demographic information of farmers and traders in Morogoro municipality and Gairo district

Variable	Description	Frequency	Percent (%)	Cumm. Freq (%)
Sex	Male	124	31.31	31.31
	Female	272	68.69	100
Education	Primary education	339	85.6	85.6
	Secondary education	39	9.85	95.45
	Tertiary education	18	4.55	100
Occupation	Traders	210	53.03	53.03
	Farmer	186	46.97	100
Position in the household	Children	24	6.1	6.1
	Father	130	32.8	38.9
	Mother	242	61.1	100

2.3.2 Farmer's and traders' awareness of white-coloured sweet potato tubers losses in Morogoro municipality and Gairo district

In this study, farmers' and traders' awareness of white-coloured sweet potato losses is described in Table 2.2, indicating that 53.2% of the farmers and traders in Morogoro Municipality and 46.7% of farmers and traders in Gairo were aware of white coloured sweet potato tubers losses. Furthermore, 72.09% of farmers and traders in Gairo districts and 27.9 % of farmers and traders in the Morogoro municipality were not aware of white coloured sweet potato tubers losses.

Table 2.2: Farmer's and traders' awareness of white-coloured sweet potato tubers losses in Morogoro municipality and Gairo district

District	Status								Obs	Mean	Std. Dev
	Aware			Percent (%)	Not aware			Percent (%)			
	Male	Female	Total		Male	Female	Total				
Gairo	69	96	165	46.7	21	10	31	72.09	196	2.97	0.74
Morogoro	76	112	188	53.2	7	5	12	27.9	200	3	0.49
Total	**145**	**208**	**353**		**28**	**15**	**43**		**396**	**2.98**	**0.63**

2.3.3 Major causes of losses of white-coloured sweet potatoes tubers during storage

To reduce losses, proper post-harvest management is essential in the value chains of white-coloured sweet potato tubers. During the baseline survey, it was observed that farmers and traders in Morogoro municipality and Gairo district were constrained by post-harvest losses due to a variety of factors. Results indicate that farmers and traders incurred losses due to mechanical injury during handling, estimated at 8.16% and12.5% in Gairo district and Morogoro municipality, respectively. Moisture content of storage was among the cause of losses, which was 12.24% and 3% in Gairo and Morogoro municipality, respectively. Sweet potato tubers losses estimated at 26.53% and 25% in Gairo and Morogoro municipality respectively were due to attack by rodents. Furthermore, farmers and traders in Gairo and Morogoro municipality incurred losses due to tuber spoilage during storage, estimated at 14.28% and 19%, respectively. Sweet potato weevil also caused losses of the tubers, as reported by 17.34% and 13% of farmers and traders in Gairo and Morogoro municipality, respectively. Temperature was reported to be among the causes of losses, which were assessed at 2.5% and 13% in Gairo and Morogoro municipality, respectively. Also farmers and traders incurred losses due to weight loss at 18.87% and 14% in Gairo and Morogoro municipality respectively (Table 2.3).

Table 2.3: Frequency percentages on major cause of losses of White-coloured sweet potatoes tubers storage

Source	District				Total
	Gairo	Percent (%)	Morogoro	Percent (%)	
Mechanical injury	16	8.16	25	12.5	41
Moisture content of storage	24	12.24	6	3	30
Rodents	52	26.53	50	25	102
Spoilage	28	14.28	38	19	66
Sweet potato weevil	34	17.34	26	13	60
Temperature	5	2.55	27	13.5	32
weight loss	37	18.87	28	14	65

The Pearson correlation between product moments can be used to evaluate the relationship between the causes of losses and the awareness of white-colored sweet potato tuber losses among farmers and traders. This statistical measure can assess the magnitude and direction of the linear correlation between the factors contributing to losses, such as mechanical injury, excessive moisture content, and pest infestations, and the degree of awareness among farmers and traders regarding these losses.

Using the Pearson correlation, it is possible to measure the degree to which awareness levels correspond with the elements that contribute to post-harvest losses of white sweet potatoes. A positive connection implies that as awareness rises, improves the comprehension of the factors contributing to losses. In contrast, a negative correlation indicates the possibility of a deficiency in understanding or incorrect information concerning the factors that contribute to post-harvest losses.

Table 2.4: Relationship between causes of losses with farmers' and traders awareness on white-coloured sweet potato tubers losses using Pearson product-moment correlation

Variable	coef. corr (r)	Sign.
Mechanical injury	-0.0036	0.9423
Moisture content	0.1302	0.0095
Rodents	0.0166	0.7412
Spoilage	-0.1282	0.0107
Sweet potato weevil	0.0908	0.0712
Temperature	0.0528	0.2943
weight loss	-0.1074	0.0326

correlation is significant at 5% level

2.3.4 Extent of white-coloured sweet potato tubers losses during storage

Post-harvest losses occur at every stage of the value chain, from field production to consumption. Farmers and traders in Morogoro municipality and Gairo district experienced varying levels of post-harvest losses as a result of a range of variety of factors. Significant post-harvest losses were experienced by 63.26% and 12% of farmers and traders in Gairo district and Morogoro municipality, respectively. Moreover, 18.36% of farmers and traders in Gairo and 79% of farmers and traders in Morogoro municipality reported to suffer from moderate post-harvest losses. Furthermore, 18.36% of farmers and traders in Gairo and 9% of Morogoro farmers and traders experienced low level of post-harvest losses (Table 2.5).

Table 2.5: Extent of post-harvest lossess of white-coloured sweet potato tubers during storage

Response	District				Total
	Gairo	Percent (%)	Morogoro	Percent (%)	
Low	36	18.36	18	9	54
Moderate	36	18.36	158	79	194
High	124	63.26	24	12	148

2.3.5 Storage capacity of white-coloured sweet potato tubers

By using suitable storage conditions, white-coloured sweet potato tubers may be preserved adequately. During the survey, farmers and traders in Morogoro municipality and Gairo district indicated that they stored white-coloured sweet potato tubers after harvesting. Based on the findings, 51.5% and 29.5% of farmers and traders in Gairo and Morogoro municipality respectively stored 0.5 kg to 100 kg of white-colored sweet potato tubers. Also 34.1% and 67.5% of farmers and traders in Gairo and Morogoro municipality respectively stored 100 kg to 500 kg of white-colored sweet potato tubers. Farmers and traders who stored 500 kg to 1000 kg of white-colored sweet potato tubers were 9.1% in Gairo and none in Morogoro municipality, respectively. Furthermore, results show that storage of white-colored sweet potato tubers of 1000 kg and above was 5.1% and 3% of farmers and traders in Gairo district and Morogoro municipality, respectively.

Table 2.6: Proportion of storage capacity of white-coloured sweet potato tubers

Capacity	District				Total
	Gairo	Percent (%)	Morogoro	Percent (%)	
0.5-100kg	101	51.5	59	29.5	160
100 -500kg	67	34.1	135	67.5	202
500-1000kg	18	9.1	0	0	18
More than 1000kg	10	5.1	6	3	16

2.3.6 White-coloured sweet potato tubers storage methods

Proper food storage preserves the quality and nutritional content of sweet potato tubers. White coloured sweet potato tuber storage facilities differed between farmers and traders in Gairo and Morogoro municipality, with 42.9% of farmers and traders in Gairo and 37.6% Morogoro municipality respectively using the bamboo basket. Furthermore, the results show that the Clamp method was also used by 4.8%% and 2.09% of farmers and traders in Gairo and Morogoro municipality, respectively. Accordingly, 30.2% of all farmers and traders in Gairo and none in Morogoro Municipality used inground storage, whereas 13.6% and 56.02% of farmers and traders in Gairo and Morogoro Municipality respectively used polypropylene bags. Furthermore, 5.8% and 3.14% of farmers and traders in Gairo and Morogoro municipality respectively used improved technology (evaporative Cooling Systems and zero energy). However, the pit technique was used by 2.4% of farmers and traders in Gairo and 1.04% in Morogoro municipality (Table 2.7).

Pearson product-moment correlation was conducted to analysis the relationship between white-coloured sweet potato tubers storage methods with farmers' and traders awareness on white-coloured sweet potato tubers losses. The results in Table 2.8 show that white-coloured sweet potato tubers storage methods such as bamboo basket, clamp method, inground, improved technologies, pit and polypropylene bags had a significant relationship with farmers' and traders awareness of losses at 1% level of significance.

Table 2.7: Proportion of White-coloured sweet potato tubers storage methods

Method	District				Total
	Gairo	Percent (%)	Morogoro	Percent (%)	
Bamboo basket	88	42.9	72	37.6	160
Clamp method	10	4.8	4	2.09	14
Inground	62	30.2	0	0	62
Using improved technologies	12	5.8	6	3.14	18
Using pit method	5	2.4	2	1.04	7
Polypropylene bags	28	13.6	107	56.02	135

Table 2.8: Relationship between storage methods with farmers' and traders awareness on white-coloured sweet potato tubers losses using Pearson product-moment correlation

Variable	coef. corr (r)	Sign.
Bamboo basket	-0.2894	0.0000
Clamp method	0.1585	0.0016
Inground	-0.1212	0.0158
Using improved technologies	0.3551	0.0000
Using pit method	0.0038	0.9400
Polypropylene bags	0.1737	0.0005

correlation is significant at 1% level

2.4 Discussion

2.4.1 Demographic characteristics of farmers and traders in Morogoro municipality and Gairo District

Majority of the farmers and traders who participated in this research were females. This indicates that women appear more frequently in surveys than men, with nearly twice as many in Morogoro municipality and the Gairo district. This finding is analogous to that of Holder and Farmers (2021) which revealed that female farmers in Nigeria participated in the sweet potato agriculture more than their male counterparts. In this study, majority of the farmers and traders who participated in the survey in Morogoro municipality and Gairo district had primary education. This is in line with the observation of the Ministry of Education, Science and Technology in Tanzania which shows that the primary education gross enrolment rate has almost become universal (96.9%) with net enrolment at 84% (MOEST,2017).

2.4.2 Farmers' and traders' awareness of white-coloured sweet potato tubers losses in Morogoro municipality and Gairo District

Table 2.2 describes farmers' and traders' awareness of white-coloured sweet potato losses in the study areas. Based on the findings that majority of the farmers and traders were aware of white-coloured sweet potato tuber losses, the level of awareness is more apparent in females compared with their male counterparts. Loss awareness facilitates excellent loss-reduction practices, which in the case of post-harvest losses, can reduce food insecurity. This is consistent with the findings of Blight *et al*. (2015), which indicated that female farmers in Uganda were more aware of white-coloured sweet potato tuber losses than male farmers.

2.4.3 Causes and extent of white-coloured sweet potato tubers losses during storage

Post-harvest losses occur along the value chain, from field production to consumption. Farmers and traders in Morogoro municipality and Gairo district encountered varying degrees of post-harvest losses as a consequence of several causes based on a variety of factors. The major cause of post-harvest losses was rodents followed by spoilage and sweet potato weevils. This is consistent with the findings of Abrham *et al*. (2021) and Shee *et al*. (2019), who found that the primary constraints of sweet potato production were rodents. To prevent these, ecologically-based rodent management was created based on two fundamental approaches: community action and early intervention (Jackson, 2015). In this study majority of the farmers and traders in Morogoro municipality and Gairo district experienced moderate levels of sweet potato losses. This is similar with the finding of Pankomera (2015) in New Zealand and Van Oirschot *et al.* (2007) in Tanzania which indicated that farmers and traders experienced moderate weight loss during storage. Efforts to minimize extent of losses of sweet potato tubers must consider carefully selecting the range of suitable storage techniques (Kiaya, 2014).

2.4.4 White-coloured sweet potato tubers storage

To maintain the quality and shelf-life of white coloured sweet potato tubers proper storage is suggested as a critical way to reduce losses during storage (Sugri, *et al.*, 2017). In the study by Gopala (2015), it was found that proper control of white-coloured sweet potato tubers from losses during storage means controlling both temperature and relative humidity of the storage area. In the current study, it has been shown that farmers and traders in Morogoro and Gairo district used various storage facilities for white-coloured sweet potato tubers, in capacity ranging between 100 and 500 kg. A substantial number of farmers and traders stored their white-colored sweet potato tubers in bamboo baskets as a traditional practice in less than 15 days duration period. In a similar study, farmers and traders in India used bamboo baskets to store white- coloured sweet potato tubers (Ayam *et al*., 2021). Moreover, results in these surveys have shown that farmers and traders used polypropylene bags, similar to the findings of Tomlins *et al*. (2000) in Tanzania, that farmers and traders used polypropylene bags for transportation and storage of tubers to the markets. Accordingly, in this study results have shown that farmers and traders used inground storage corresponding to the findings of Robert *et al.* (2014) in Uganda, that farmers and traders stored tubers inground for delayed harvesting for better market prices and access to food at a later period. Furthermore, farmers and traders in Gairo and Morogoro municipality used improved technology to store white cololured sweet potato tubers. This is similar to the findings of Teye (2010) in Ghana, that improved technology was used for sweet potatoes storage because it reduces general deterioration. Also, surveys have shown that the clamp method was used by all farmers and traders in Gairo and Morogoro. This compares well with the survey performed by Siregar (2022) in

Kenya which found that farmers and traders used the clamp method to store sweet potatoes and the method was usually better since it had a stronger sensory attribute. The minority of farmers and traders employed the pit method to store tubers, probably due to reasons mentioned in the study by Mpagalile *et al.* (2007) in Tanzania that Sweet potatoes stored using the pit storage method were heavily infested, damaged and rotten.

2.5 Conclusion and Recommendation

This study summarized the causes and extent of post-harvest losses of white-coloured sweet potato tubers during storage in the Gairo district and Morogoro municipality where practicable procedures to prevent losses of white-coloured sweet potato tubers were identified. The main aspects to consider in preventing losses are controlling rodents, avoiding injury, constructing proper storage facility, and inspecting the stores regularly. Also, the results suggest that there is need to Improve post-harvest loss awareness among the white-colored sweet potato farmers and traders to minimize and so produce profitably is required. Any intervention to increase awareness on sweet potato post-harvest losses should be prioritized for male farmers as they are less aware of such losses. Furthermore, additional research studies should be conducted to develop awareness of other types of storage and methods for reducing sweet potato losses to impact food security in society.

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CHAPTER THREE

3.0 TO EVALUATE THE PERFORMANCE OF DIFFERENT STORAGE TECHNOLOGIES ON THE STORAGE STABILITY OF WHITE-COLOURED SWEET POTATO TUBERS UNDER FARMERS' CONDITIONS IN TANZANIA.

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ABSTRACT
Sweet potatoes' high perishability after harvesting is one of the major factors limiting their potential. The lack of appropriate storage methods exacerbates this. This study aimed to evaluate different storage technologies for the storage stability of white-coloured sweet potato tubers under farmers' conditions in Tanzania. The study was carried out at the Crop Science laboratory at Sokoine University of Agriculture (SUA) for 77 days in a completely randomised experimental design. The experiment included four treatments: improved traditional raised, woven Polypropylene Bags, bamboo buckets, and ventilated bags. Each treatment was replicated three times. Physiological loss in weight, hardness, total soluble solids, colour, and beta-carotene content were measured at the Food Science laboratory at SUA during the experiment storage period. Analysis of variance and comparison of means for the sample collection was performed using GenStat® Executable release 16 Statistical Analysis Software. White-coloured sweet potato tubers stored in ventilated bags and the improved traditional raised platform resulted in a weight loss of 49.4% and 68.7%, respectively. It was also observed that the enhanced traditional raised platform had a

significantly high total soluble content /concentration, with a value of 21.27%, while Ventilated bags resulted in a Total soluble solid content of 17.02 %, which was significantly low. Furthermore, results show that Ventilated bags had the lowest beta carotene content (8.72 µg/g) compared to other treatments. The findings of this study strongly suggest that storing white-coloured sweet potato tubers in ventilated bags is an appropriate method. In the context of the current study, further research on different sweet potato tuber packaging materials is recommended.

Keywords: sweet potato storage, beta-carotene content, colour, hardness, total soluble solids, Weight loss

3.1 Introduction

Sweet potato (*Ipomoea batatas* L.Lam.) is a dicotyledonous tuber crop from tropical America (Coop, 2010). In Tanzania, the crop is mainly cultivated around the Lake zone, Eastern zone, Southern highlands and Northern parts (URT, 2016). It is grown by 771,257 households during short rainy and long rainy seasons, with an estimated annual production of 504,346 tonnes (NBS 2012). Sweet potato tubers contribute to food security and income generation (Ahmad *et al.,* 2014). There are several varieties of sweet potatoes, including white-coloured flesh, cream-coloured flesh, yellow, red and purple (Rahman *et al.,* 2003). White-coloured sweet potato tubers are a great source of nutrients, including Calories, Fat, Carbohydrates, Protein, Fiber and Vitamins (De Albuquerque *et al.,* 2019). Consuming white-coloured sweet potato tubers enhances healthier eyes, reproductive system and heart and kidney functions (Johnson and Pace, 2010).

Despite its importance, white-coloured sweet potato tuber production in Tanzania still faces some challenges. The major challenge is the high post-harvest losses that suppliers and consumers experience due to the lack of appropriate storage methods. Inappropriate storage facilities have contributed to considerable post-harvest white-coloured sweet potato tubers losses in many developing countries. The losses are estimated to range between 25 and 50% of the world's total production (Robert *et al.,* 2014). Inappropriate storage facilities lead to qualitative, quantitative and economic losses (Singh *et al.,* 2007). Despite the need to improve the production of white-coloured sweet potato tubers in Tanzania, insufficient information concerning efficient storage technology limits farmers and traders from choosing the best technology to reduce post-harvest losses.

Teye *et al.* (2011) compared two storage technologies, the Purpose-Built Evaporative Cooling Barn and Modified Pit Storage under Ghana conditions, neglecting other sweet potato storage technologies such as indoor storage, clamp storage and zero energy. The results showed that the Purpose-Built Evaporative Cooling Barn stored sweet potatoes better than the Modified Pit Storage. Furthermore, research by Mpagalile *et al.* (2007) used the traditional pit, improved open pit, improved housed pit (*mjinge*) and raised woven structure (*kihenge*) to evaluate the storability of sweet potato tubers, neglecting indoor storage, clamp storage, and zero energy technology storage. The results showed that improved housed pit (*mjinge*) storage performed comparatively well, whereas the traditional pit method was the poorest in all attributes.

The Purpose Built Evaporative Cooling Barn and housed pit storage are used to store sweet potato tubers to attain optimum temperature and relative humidity of 12.5°C - 15°C and 85% - 90%, respectively (Teye *et al.*, 2011). Nevertheless, their adaptability to small-scale farmers and traders in developing countries like Tanzania is limited due to their high initial capital and high running costs, prompting the choice of temporary storage measures, including burying the sweet potato tubers in the ground and using bamboo baskets with low storage performance. This situation calls for high demand by small-scale farmers and traders for storage technology with low capital and running costs.

Indoor storage technologies can maintain proper storage temperature and relative humidity through ventilation in hot and arid areas (Baimey *et al.,* 2017). Using these technologies, white-coloured sweet potato tubers can be stored with minimum changes in colour, weight, and firmness and minimum rotting (Gopala, 2015). This study assessed the storability of white-coloured sweet potato tubers using indoor storage technologies, including the improved traditional raised platforms, Woven Polypropylene Bags, and ventilated bags. The intention was to obtain results that would give the users confidence and allow them to choose the best-performing storage technology for white-coloured sweet potato tubers to increase shelf life and hence reduce post-harvest losses and also guide policymakers in promoting indoor storage technologies.

3.2 Materials and Methods

3.2.1 Site description

The experiment was conducted in the Entomology Laboratory, Department of Crop Science, at Sokoine University of Agriculture in Morogoro, Tanzania (6° 72' 56" S, 37° 32' 14" E). The experimental site was selected based on the availability of research materials. It was conducted under indoor conditions for 77 days, from July 2022 to September 2022, during which temperature and relative humidity were 20 to 29°C and 53-99%, respectively.

3.2.2 Sourcing of raw materials and treatment

Freshly harvested sweet potato tubers were collected during the night from eight villages in the Gairo district and delivered to the experimental site on the same day. The tubers were sorted and cleaned at the site before the storage methods were applied. The injured tubers were discarded.

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3.2.3 Experimental layout

White sweet potato tubers were stored using the four storage treatments adopted for this study: the improved traditional raised platforms, the Woven Polypropylene Bags, ventilated bags, and bamboo baskets. Bamboo baskets posed as the control experiment because they are widely used by both farmers and traders. In each treatment, 50 kg of white-coloured sweet potato tubers was used in a completely randomized design with three replications.

3.2.4 Sampling and data collection

After every five days, samples of ten white-coloured sweet potato tuber pieces were sampled randomly from each experimental trial. As outlined, the data collected were in-storage temperature and humidity, Weight, Hardness, TSS, Color, and Beta carotene content.

3.2.4.1 Temperature and humidity

After every 10 minutes for 77 days, data on temperature and humidity in each treatment was collected by using a data logger (Model - DHT22, Power supply - 3.3-6V DC, Output signal - digital signal via single-bus, Sensing element - Polymer capacitor, Operating range - humidity 0-100%RH; temperature -40~80Celsius, Accuracy - humidity +-2%RH (Max +-5%RH); temperature <+-0.5Celsius, Resolution or sensitivity - humidity 0.1%RH; temperature 0.1Celsius, Repeatability - humidity +-1%RH; temperature +-0.2Celsius, Humidity hysteresis - +-0.3%RH, Long-term Stability - +-0.5%RH/year, Sensing period Average: 2s, Interchangeability - fully interchangeable, Dimensions - small size 14*18*5.5mm; big size 22*28*5mm).

Plate 3.1: Datta collected by using a data logger

3.2.4.2 Physiological loss in weight (%)

During the 77 days of storage, the physiological loss in weight (PLW) was evaluated at 5-day intervals. The initial tuber weight was determined using an analytical balance and recorded at the start of the storage period. The tubers were weighed, and the value recorded was referred to as the final weight on the observation date. For each observation day, the PLW was calculated as follows (Prathiksha and Ramachandra, 2017):

$$\textbf{Physiological loss in weight } (\%) = \frac{(\textbf{Initial Weight} - \textbf{Final weight})\textbf{g}}{\textbf{Initial Weight } (\textbf{g})} * \textbf{100}$$

Plate 3.2: Weight measurement by using weight balance to determine physiological loss in weight (%).

3.2.4.3 Hardness

A texture analyser (Model, CT3 10K) was used to analyze raw sweet potato tuber flesh's hardness qualities (internal and external). The sample was cleaned with a cloth after being washed with clean tap water to eliminate any dust. Using the procedure described in Prathiksha and Ramachandra (2017), a two-bite compression test with 10.0 mm deformation was performed using a cylinder probe (2 g trigger) at a test speed of 10.0 mm/s, and the results were shown and recorded.

Plate 3.3: Hardness measuring by using a texture analyzer

3.2.4.4 Total soluble solids (TSS)

The total soluble solids (TSS) of the sweet potato tubers were estimated by using a Refractometer on the different days of observation. A small amount of the flesh of the tubers was crushed using a mortar and pestle and the obtained slurry was filtered using multiple layers of muslin cloth. The obtained clear juice was applied in drops on the prism of the calibrated refractometer and the values were read (Prathiksha and Ramachandra, 2017).

Plate 3.4: Total soluble solids measured by using Refractometer

3.2.4.5 Color

The colour was analyzed by the calorimetric method (Sherwood calorimeter model 260, voltage 12V DC 300 mA, weight 2.2 kgs, RS 232 Printer).

3.2.4.6 Beta-carotene content /Vitamin A (mg/100g)

The petroleum ether method was used to measure beta-carotene content in the different treatments for the different tubers. In each treatment, Beta carotene was determined according to Delia (2004), with slight modifications, where a 2.0g homogenised sample was taken into a Polytron bottle followed by extraction using 50 ml of cold acetone. Then, a portion of the extract was transferred into a separating funnel containing 25 ml of petroleum ether (400C-600C Bp) for partitioning, followed by washing with about 125 ml of distilled water until the extract was acetone-free. The washed sample was then passed through anhydrous sodium sulphate to free it from any trace of water. The dried carotene extract was collected into a clean and dry volumetric flask in which it was subjected to measurements by the UV-visible spectrophotometer at 450nm ((Double beam UV-3000 model X-ma3000 spectrophotometer Human Corporation, England).

Beta carotene standard solution with 110mg/ml concentration was prepared by taking 0.0110g of β-carotene standard powder from Sigma-Aldrich into a 100 volumetric flask. 10ml petroleum ether was added and swirled to dissolve and finally petroleum ether was added until the volume made to 100ml mark of the volumetric flask. Serial dilutions of 0mg/ml, 0.1mg/ml, 0.2mg/ml, 0.4mg/ml and 0.6mg/ml were prepared by taking 0ml, 0.2ml, 0.4ml, 0.8ml and 1.0ml of the stock standard solution (110mg/ml) into 25ml volumetric flask. Petroleum ether was added to complete volumes (25ml). Absorbencies of the diluted standards were read, a standard calibration plot was constructed, and the linear regression equation was obtained, which was used to calculate the Beta carotene content of the samples (Rasaki, 2009).

Plate 3.5: Beta carotene standard solution on volumetric flask

3.3 Data Analysis

Analysis of variance and comparison of means for Temperature and Humidity, Weight, Hardness, TSS, Color, and Beta carotene content was performed using GenStat® Executable release 16 Statistical Analysis Software. The means were compared by the Tukey Honest Significance Difference (HSD) test at 5% probability. Analysis of variance (ANOVA) was used to validate the variability of all collected data based on storage treatments and time of data collection. Regression (R^2) and Pearson correlation (r) relationships between all numeric variables were done using R-software to determine their relationships between all variables (Barret *et al.*, 2021; Wickham, 2016).

3.4 Results

3.4.1 Physiological loss in weight (%)

The mean per cent weight loss of sweet potatoes stored using different storage methods for 77 days is shown in Table 3.1. Significant differences existed among treatments for physiological weight loss for the 77 days of storage ($p<0.05$). Ventilated bags registered significantly low (49.4%) weight losses compared to all other treatments, consistently followed by Woven Polypropylene Bags (50.1%), Bamboo buckets (62.4%) and improved traditional raised platforms (68.7%), the highest during storage.

Table 3.1: Weight loss (%) in White coloured sweet potato tubers stored for 77 days in indoor technologies

Storage methods	Initial weight (grams)	2 weeks (grams)	4 weeks (grams)	6 weeks (grams)	8 weeks (grams)	10 weeks (grams)	PLW (%)
Woven Polypropylene Bags	310.8a	36.38ab	43.26a	60a	79ab	98.4ab	50.1ab
Ventilated bags	340.5a	16.93a	27.85a	42.7a	59.9a	78.6a	49.4a
Bamboo buckets	373.6a	88.33ab	123.37ab	142.4ab	178.6ab	224.3c	62.4ab
An improved traditional raised platform	449.9a	137.02b	151.52b	169.5b	197.4b	211.8bc	68.7b
Grand mean	369	70	87	104	129	153	57.7
SE	48.4	31.3	29.2	29.3	37.5	36.1	5.83
LSD	118.4	76.6	71.5	71.6	91.7	88.3	13.45
cv	23.1	21.3	24.3	22.2	26.5	33	12.4
p	0.113	0.031	0.014	0.012	0.023	0.013	0.027

Key: FWL=Physical final weight loss, PLW=Physiological final weight loss

3.4.2 Hardness

Aspects of textural parameters of white-coloured sweet potato tubers were observed in all treatments as the most critical factor in determining consumer acceptance of sweet potato tuber products (Delia, 2004). The results on hardness of white-colored sweet potato tubers indicate the firmness of the tubers.

a. External Hardness

Treatments, duration, and their interactions have shown significant differences in external Hardness ($p<0.05$) (Tables 3.2). It is also demonstrated that the four different treatments resulted in different external hardness, with the highest value (10909(g)) for the improved traditional raised platform, followed by Bamboo buckets (7405(g)), Woven Polypropylene Bags (7281(g)), and Ventilated bags (7194(g)).

b. Internal Hardness

The results on internal hardness 2 are in Table 3.2. The four storage treatments have significantly influenced the internal hardness of white-coloured sweet potato tubers ($p<0.001$). Results obtained indicate that the traditional raised platform achieved a significantly higher hardness of 7360(g), followed by Bamboo buckets (7283(g)), Woven Polypropylene Bags (6965(g)) and Ventilated bags resulted (6920(g)), the lowest in the list.

3.4.3 Total soluble solids (TSS).

Total soluble solids (TSS) were highly significantly influenced by the storage treatments and storage ($p<0.001$). In this study, TSS in sweet potato tubers stored in the improved traditional raised platform, Bamboo buckets, Woven Polypropylene Bags and Ventilated bags were 21.27%, 17.91%, 17.74% and 17.02%, respectively.

3.4.4 Color

Storage methods have been shown to affect sweet potato tuber color significantly ($p<0.001$) (Table 3.2). Storage in Ventilated bags resulted in the lowest colour value (11.2 (E10.), RYB) compared to other treatments, while the colour value recorded on Woven Polypropylene Bags was 16.82 (E10.), RYB. The Colour value recorded due to storage in the Bamboo buckets was 16.92 (E10.), RYB, while the Improved traditional raised platform storage resulted in the highest (17.13 (E10.), RYB) colour value (Table 3.2).

3.4.5 Beta carotene content

Beta carotene content (µg/g) was highly significantly influenced by the treatments and storage duration ($p<0.001$) (Table 3.2). Beta carotene content in sweet potato tubers stored in Ventilated bags was 8.72 (µg/g), the lowest. The highest Beta carotene content was 12.53 (µg/g), recorded in sweet potato tubers stored in Bamboo buckets. Beta carotene content in sweet potatoes stored in the Woven Polypropylene Bags and the improved traditional raised platform was 11.46(µg/g) and 10.881(µg/g), respectively.

Table 3.2: Hardness (g), Total soluble solids (%), Beta Carotene (µg/g) and Colour value (E10.), RYB in White-coloured sweet potato tubers stored for 77 days in indoor technologies

Storage methods	Hardness External Hardness (g)	Internal Hardness (g)	Total soluble solids (%)	Beta Carotene (µg/g)	Colour value (E10.), RYB
Woven Polypropylene Bags	7281a	6965a	17.74a	11.46b	16.82a
Ventilated bags	7194a	6920a	17.02a	8.72a	11.2a
Bamboo buckets	7405a	7283a	17.91a	12.53c	16.92a
An improved traditional raised platform	10909a	7360a	21.27b	10.82b	17.13a
Grand	8197	7132	18.48	10.881	15.52
se(+/-)	1847.3	206.8	0.35	0.3166	3.029
CV	17	1.9	3.1	2.7	93.4
P-Value	0.132	0.082	<.001	<.001	0.162

Correlation and regression analysis

A significant relationship was observed between the following parameters; hardness 1 and 2 ($p<0.001$, $r=0.78$, $R^2=0.6$), cohesiveness and weight ($p<0.001$, $r=0.63$, $R^2=0.39$), springiness and weight ($p<0.05$, $r=0.32$, $R^2=0.089$), beta carotene and weight ($p<0.05$, $r=0.32$, $R^2=0.09$), springiness and hardness 2 ($p<0.05$, $r=0.36$, $R^2=0.12$), cohesiveness and springiness ($p<0.05$, $r=0.33$, $R^2=0.09$), beta carotene and cohesiveness ($p<0.001$, $r=-0.53$, $R^2=0.27$), color and cohesiveness ($p<0.05$, $r=0.32$, $R^2=0.084$),

Table 3.3: Correlation and regression analysis in White coloured sweet potato tubers stored for 77 days in indoor technologies

	Hardness1	Hardness2	Cohesiveness	Springiness	Beta Carotene	Colour value
Weight	p=0.052, r=0.25, R2=0.046	p=0.24, r=0.15, R^2=0.007	p<0.001, r=0.39, R^2=0.63	p=0.0.012, r=0.32, R^2=0.089	p=0.011, r=0.32, R^2=0.09	p=0.48, r=0.092, R^2=-0.0088
External Hardness		p<0.001, r=0.78, R^2=0.6	p<=0.66, r=0.059, R^2=0.014	p=0.52, r=0.086, R^2=0.0098	p=0.4, r=0.11, R^2=0.0046	p=0.98, r=0.0.0028, R^2=-0.017
External internal			p=0.53, r=0.082, R^2=0.011	p=0.0042, r=0.36, R^2=0.12	p=0.73, r=0.53, R^2=-0.015	p=0.69, r=0.052, R^2=0-0.015
Beta Carotene						p=0.12, r=-0.2, R^2=0.025

3.5 Discussion

3.5.1 Physiological loss in weight (%)

The experiment was conducted indoors to imitate the sweet potato storage requirements of farmers and traders. The weight loss (%) after 77 days of storage at indoor conditions was substantially lower than the weight loss without storage. The primary cause of weight loss was the evaporation of moisture, implying that the none-stored tubers incurred higher moisture loss. Storage in Ventilated bags incurred less weight loss than Polypropylene Bags, improved traditional raised platforms and Woven Bamboo buckets. The higher and lower PLW of the tubers implies the respective higher and lower rates of moisture evaporation during storage, reflecting the quality of the storage system used. These findings are consistent with the results by Edun *et al.* (2019), who revealed that moisture reduction correspondingly results in weight loss, and hence, the tubers can be easily damaged. The results also concur with Sugri *et al*. (2017) who revealed that the lowest percentage of weight loss after storage occurred due to low moisture reduction. Furthermore, Degras (2003) observed that increased temperature in storage might have enhanced the moisture reduction rate, resulting in weight loss.

3.5.2 Hardness

Food acceptance is significantly influenced by texture. Sweet potato tubers' textural properties depend upon their structure and composition. As some experiment treatments led to high hardness while others displayed low values, it implies that the storage significantly influenced the hardness of the sweet potato tubers. These observations are similar to the previous findings by Fuentes *et al.* (2014) in potatoes, in which an extreme reduction in the textural hardness of potatoes during storage was obtained. Zhang *et al*. (2002) also reported that during storage and before the processing of sweet potatoes, the firmness of the tubers was significantly reduced. Also, similar findings by Song *et al*. (2011) show that storage time increased the hardness of sweet potato tubers and decreased water loss and respiration rate, which resulted in better storability with minimised weight loss.

3.5.3 Total soluble solids (%)

In the current study, total soluble solids (%) were significantly affected by the treatments and storage period ($p<0.001$). In a similar survey of Sugri *et al.* (2019), moisture reduction in sweet potato tubers resulted in an increase in total soluble solids. TSS content is an essential quality parameter that indicates the quality of a food product. This is directly related to the availability of starch, which can be converted to sugars (sucrose, glucose, and fructose). The breakdown of starch into sugars might have increased total sugar content, which is directly responsible for the increase of TSS during storage. Similar results were obtained by Thriveni *et al.* (2019) and Rosero *et al*. (2020), who observed that moisture reduction resulted in an increase in total sugar content, which is directly responsible for high TSS during storage.

3.5.4 Color

One of the most essential appearances that contribute to customers' acceptability is colour. In the food industry, the colourimetric method is commonly used to monitor and control product quality. The common qualitative values associated with colour analysis are colour value (E10) and RYB. The R-values used to characterise the samples' reddish colour gradually decreased with storage time. This change could be attributed to increased respiratory activity during storage (Hernandez *et al*., 2014). The reddish colour is usually associated with water-soluble anthocyanin. The results indicate a decreasing trend in redness during storage, corresponding to reduced moisture content. The decrease in the redness values in the samples was probably attributed to the degradation of red anthocyanin pigments.

Tani *et al*. (2019) discovered that storage time significantly affected the colour value of sweet potatoes. The Y-value is a measurement for yellowish colour. The yellowish colour is related to the carotenoid and flavonoid pigments. The results from this study are similar to the findings by Kim *et al.* (2021), which indicated that in the stored sweet potato tubers, color varied significantly between the different varieties of sweet potato, ranging from white to light yellow and deep yellow. The parameter B-values is used to indicate the Blue colour. The blue colour is related to anthocyanins, which are responsible for the colouration of tissues (Yang *et al*., 2020). The results of this study concur with the findings by Pankomera, 2015 and Lee *et al*., 2013, which indicated Anthocyanins were present in sweet potato tubers during storage.

3.5.5 Beta carotene content

Beta carotene concentration of sweet potato tubers varied during storage, similar to the findings by Zhang *et al.* (2019) that variations in storage time cause carotene concentration. Consequently, it is unlikely that the variation in carotene content between the four treatments in the current study was caused by a change in storage conditions. Weather data collected during storage revealed that Woven Polypropylene Bags had higher average humidity (64%), followed by other treatments during storage. In a similar study by Faber *et al.* (2013), differences in weather conditions might have led to the variation in beta-carotene content. Furthermore, comparable results were found by Siregar (2022), showing that changes in storage conditions might have led to the variance in beta-carotene concentration.

3.6 Conclusion and Recommendations

Storage is a critical component of the sweet potato post-harvest value chain, and it has been identified as the most crucial point in minimising losses. The vast majority of sweet potato losses among farmers and traders are due to inadequate storage facilities. Farmers and traders should be encouraged to use effective sweet potato post-harvest storage technology to reduce such losses. The findings of this study strongly suggest that storing white-coloured sweet potato tubers in ventilated bags is an appropriate method. Furthermore, using ventilated bags can also be effective when storing undamaged sweet potato tubers. Farmers and traders are advised to sort and grade their tubers before storage. In the current study context, additional research in other types of packaging materials is recommended.

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CHAPTER FOUR

4.0 ASSESSMENT OF THE ECONOMIC SUITABILITY OF INDOOR STORAGE FOR WHITE-COLOURED SWEET POTATOES TUBERS UNDER TANZANIA CONDITIONS

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ABSTRACT

The study aimed to reduce sweet potato post-harvest losses while increasing income from sweet potato-based products in Morogoro, Tanzania. The economic suitability of indoor storage technologies for the storage of white-coloured sweet potato tubers under Tanzania conditions was assessed. The sample composed of sweet potato marketers and traders in Morogoro, Tanzania. They were selected after an extensive step-wise sampling procedure. The first step involved using Kothari's recommended purposive sampling method to select wards. Simple random sampling was used in the second step to choose the markets, and the snowballing sampling approach was used in the third stage to select the respondents. 160 sweet potato vendors (from four markets in four wards) were selected. Data collected were the cost of labour, purchasing and transportation of white-coloured sweet potato tubers and the selling price of white-coloured sweet potato tubers to determine net income. Data were analysed using cost-benefit analysis. Results indicate that traders' source of funding for their sweet potato selling activity was own/self-financing, estimated at 70%, loans estimated at 19.37%, and remittances estimated at 10.63%. Also, the study's findings demonstrate that the single and multi-stage channel systems are the two main sweet potato marketing channels. Retailers constitute 57.5% of respondents, wholesalers 27.5%, and other trades (Middlemen/SME processors) 15%. Furthermore, a study indicated that 21% of traders produce sweet potatoes on their farms, and 97% of merchants purchase sweet potatoes directly from farmers—also, 42% purchase sweet potatoes through wholesalers/aggregators. Results continued to reveal that by using ventilated bags storage technology, farmers and traders could earn higher profits, which was Tsh 19,000/= more than other storage technologies (improved traditional raised bamboo buckets and woven Polypropylene Bags. Therefore, the study recommended that ventilated bags be used as a proper storage technology for white-coloured sweet potato tubers. Their use will assist farmers and traders to reduce losses and hence improve profitability.

Keywords: cost, indoor storage, net profit, sales, sweet potato tubers.

4.1 Introduction

Sweet potatoes are grown for subsistence and commercial purposes (Foley et al., 2021). Most Tanzanians grow and consume sweet potatoes as one of their main staple food crops (United Republic of Tanzania [URT], 2021). Tanzania is the fifth-largest producer of sweet potatoes in the world (Jones *et al.*, 2012), with a total of 1,076,320 farmers engaged in production, out of which 1,040,772 (96.7%) are in the mainland and 35,549 (3.3%) in Zanzibar islands (United Republic of Tanzania [URT], 2017). Sweet potato tubers contain vitamins A, C and minerals but are also a good source of calories that benefit human health (Senthilkumar *et al*., 2020).

Sweet potato is one of Tanzania's significant crops with good export potential if postharvest degradation and storage losses are effectively controlled. Besides, sweet potato marketing opportunities abound and demand for sweet potato tubers, particularly in urban areas, is high (Nabay *et al.*, 2020). However, farmers, traders, and consumers in Tanzania remain confronted with significant challenges such as soft rot and physiological changes (reduction of starch and increase in sugars and dextrin) in extending the shelf life of the tubers *(Jones et al.,* 2012). Furthermore, improper produce handling contributes significantly to sweet potato postharvest losses (Okoth, 2021). Processing and appropriate storage constitute some measures to minimise post-harvest losses, including decay. To minimise decay losses, traders and farmers frequently sell their sweet potato produce within 1-2 weeks of harvesting as the only solution and hence avoid investment in storage (Sugri *et al*., 2017). The adoption of good storage technology has generated promising results in terms of extending the shelf life of sweet potatoes and, as a result, increasing the profit of tubers after product sales (Nabay *et al.,* 2020). The study is set to assess the economic suitability of indoor storage technologies for storing white-coloured sweet potato tubers under Tanzania conditions to reduce post-harvest losses and increase profitability. The results will be used to assist farmers and traders in selecting proper indoor storage technology for reducing losses and, hence, profitability.

4.2 Materials and Methods

4.2.1Study locations

The four main markets in Morogoro, Tanzania, represent other markets. The markets included in the study are Mawenzi Market from Uwanja wa Taifa ward, Mji mpya Market from Mji mpya ward, Mazimbu Market from Mazimbu ward, and Chief Kingalu Market from Sultan area ward. High sales of sweet potato tubers served as the basis for choosing those markets.

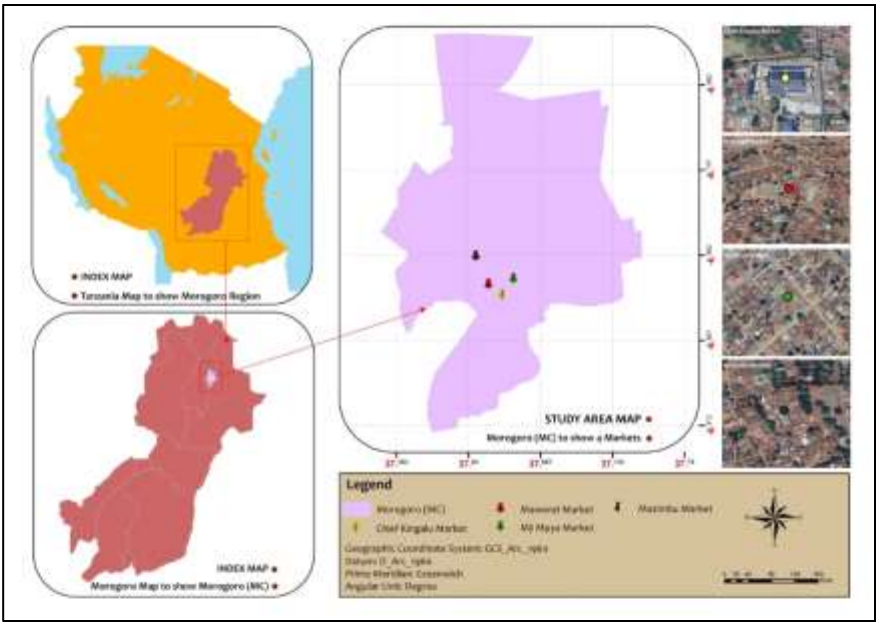

Figure 4.1: Morogoro Municipal map showing four markets

4.2.2 Sampling frame, selection procedure and size

The sample composed of sweet potato marketers and traders in Morogoro, Tanzania. They were selected after an extensive step-wise sampling procedure. The first step involved using Kothari's recommended purposive sampling method to select wards. Simple random sampling was used in the second step to choose the markets, and the snowballing sampling approach was used in the third stage to select the respondents. In addition, market chairpersons participated in the suggestions of traders of sweet potatoes and their locations. The snowball sampling technique is frequently utilised in populations that are difficult for scientists to approach and are disguised populations (Atkinson and Flint, 2015). While there were a few dispersed sweet potato traders in Morogoro, Tanzania, the majority of those traders throughout the data-collecting period were included in the research. 160 sweet potato vendors (from four markets in four wards) were selected.

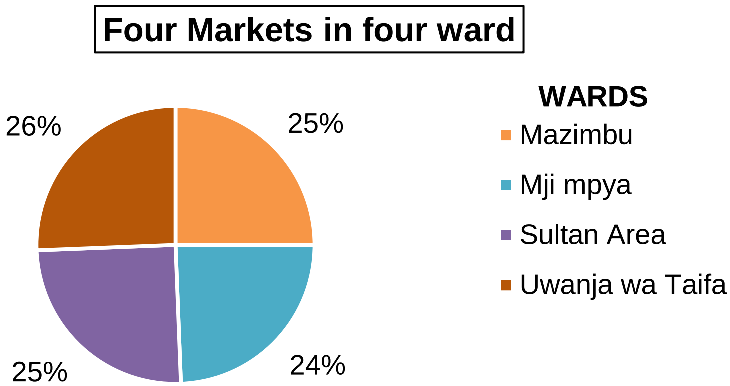

Figure 4.2: A sample size of the study

4.2.3 Data collection

Both primary and secondary data were collected for this study to gather adequate and accurate information from traders. Secondary data were collected through scientific evidence and statistical abstracts utilised as supplementary data sources. In contrast, primary data included both qualitative and quantitative acquired through individual interviews (140 sweet potato vendors) and personal observation (20 sweet potato vendors). The Census and Survey Processing System (CSPro 6.3) software program was used to conduct the one-on-one interviews on an Android smartphone. General trading activities, market distributional channels, and profitability coefficients were among the information gathered.

4.2.4 Data analysis

Statistical Analysis Systems (SAS 9.3), Microsoft Excel 2010, and Statistical Package for the Social Sciences (IBM SPSS Statistics 21) were used to analyse collected data from each marketer's interview for analysis using analytical tools. The study also calculated Net profit using straightforward budgeting approaches**.** Total sales were obtained by multiplying the number of packed white-coloured sweet potato tubers in storage technology and the market price at the selling time. The net profit was obtained by deducting the total cost from the sales of white-coloured sweet potato tubers at the market.

NET PROFIT=Sales- (fixed cost +operation cost)

4.3 Results

4.3.1 Source of Funds in Sweet Potato Trading Activities

During the baseline survey, it was observed that traders in Morogoro Municipality were getting funds from different sources. Results indicate that traders' source of funding for their sweet potato selling activity was own/self-financing, estimated at 70%, loans estimated at 19.37%, and remittances estimated at 10.63%.

Table 4.1: The source of funds for traders involved with sweet potato trading activities in Morogoro municipality

Source	Market				Total	%
	Mazimbu	Mji Mpya	Chief Kingalu	Mawenzi		
Loan	10	6	8	7	31	19.37
Own/Self-finance	26	30	30	26	112	70
Remittance	4	3	2	8	17	10.63

4.3.2 Sweet Potato Tubers Distributional Channels in Morogoro Municipal, Tanzania

Table 4.2 depicts the sweet potato marketing channels. In both rural and urban markets, sweet potatoes are distributed or marketed via the actions of several players. The study's findings demonstrated that the single and multi-stage channel systems were the two main sweet potato marketing channels. Retailers constitute 57.5% of respondents, wholesalers 27.5%, and other trades (Middlemen/SME processors) 15%.

Table 4.2: Distribution methods for sweet potato tubers in Morogoro, Tanzania

Source	Market				Total	%
	Mazimbu	Mji Mpya	Chief Kingalu	Mawenzi		
Other traders (Middlemen/SME processors)	5	7	3	9	24	15
Retailers	24	21	27	20	92	57.5
Wholesalers	11	11	10	12	44	27.5

4.3.3 Traders' Source of Bought Sweet Potato

In this study, Table 4.3 describes traders' sources of bought sweet potatoes, indicating that 21% of traders produce sweet potatoes on their farms. Furthermore, 97% of merchants purchase sweet potatoes directly from farmers. Also, 42% purchase sweet potatoes through wholesalers/aggregators.

Table 4.3: Source of sweet potato tubers purchased by traders in Morogoro, Tanzania

Source/Channel	Market				Total
	Mazimbu	Mji Mpya	Chief Kingalu	Mawenzi	
Direct from farmer	24	21	29	23	97
Wholesaler/Aggregator	10	13	11	8	42
Own farm	6	5	0	10	21

4.3.4 Cost-Benefit Analysis

The cost-benefit analysis was done, and the economic aspects of proper postharvest storage technology were justified/ presented. Tables 4.4, 4.5, 4.6 and 4.7 show the fixed cost, operation cost, sales and net profit generated from the sale of sweet potato tubers. Farmers and traders can earn more profit using ventilated bags storage technology compared with other storage technologies, estimated at Tsh 19,000/= (Table 4.3, 4.4, 4.5 and 4.6). Cost-benefit analysis has shown that farmers and traders get a net profit of Tsh 13,000/= after selling sweet potato tubers when storing tubers using woven Polypropylene Bags. Furthermore, when selling the tubers that had been stored in bamboo buckets for 60 days, the net profit was Tsh 7,000/=. Also, farmers and traders get a loss of Tsh -35,000/= when selling the tubers after 77 days of storage on improved traditional raised structure as a storage technology.

Table 4.4: Cost-benefit analysis of using an improved traditional raised platform

S/N	Item	Quantity	Unit	Price (TZS)	Total (TZS)
A	FIXED COST				
	sweet potato tubers	60	Kg	7 00	42,000
	Sub Total				42 000
B	OPERATION COST				
	Storage equipment cost	3	Pc	10 000	30 000
	Labour cost	1	Person	14 000	14 000
	Sub Total				44 000
C	SALES				
	Sales of sweet potato tubers after storage	60	Kg	850	51 000
	Sub Total				51 000
D	NET PROFIT	on cost)			
	Sales- (fixed cost + operation cost)				-35 000

Table 4.5: Cost-benefit analysis of using bamboo buckets

S/N	Item	Quantity	Unit	Price (TZS)	Total (TZS)
A	FIXED COST				
	sweet potato tubers	60	Kg	7 00	42,000
	Sub Total				42 000
B	OPERATION COST				
	Storage equipment cost	3	Pc	1 000	3 000
	Labour cost	1	Person	14 000	14 000
	Sub Total				17 000
C	SALES				
	Sales of sweet potato tubers after storage	60	Kg	11 000	66 000
	Sub Total				66 000
D	NET PROFIT	on cost)			
	Sales- (fixed cost + operation cost)				7 000

Table 4.6: Cost-benefit analysis of using woven Polypropylene Bags

S/N	Item	Quantity	Unit	Price (TZS)	Total (TZS)
A	FIXED COST				
	sweet potato tubers	60	Kg	7 00	42,000
	Sub Total				42,000
B	OPERATION COST				
	Storage equipment cost	3	Bags	1 000	3 000
	Labour cost	1	Person	14 000	14 000
	Sub Total				17 000
C	SALES				
	Sales of sweet potato tubers after storage	60	Kg	12 000	72 000
	Sub Total				72 000
D	NET PROFIT	on cost)			
	Sales- (fixed cost + operation cost)				13 000

Table 4.7: Cost-benefit analysis of using ventilated bags

S/N	Item	Quantity	Unit	Price (TZS)	Total (TZS)
A	FIXED COST				
	sweet potato tubers	60	Kg	7 00	42 000
	Sub Total				42 000
B	OPERATION COST				
	Storage equipment cost	3	Bags	1 000	3 000
	Labour cost	1	Person	14 000	14 000
	Sub Total				17 000
C	SALES				
	Sales of sweet potato tubers after storage	60	Kg	13 000	78 000
	Sub Total				78 000
D	NET PROFIT	on cost)			
	Sales- (fixed cost + operation cost)				19 000

4.4 Discussion

4.4.1 Source of Funds in Sweet Potato Trading Activities

The origin of sweet potato traders' funds at the beginning of a business transaction is regarded as the source of funds, during survey. Most (70%) of the sweet potato traders depended on their funding/Self-finance as the source of trading funds. This result agrees with the prior findings by Nabay *et al*. (2020) in Sierra Leone, which shows that most sweet potato traders own the trading fund.

4.4.2 Sweet Potato Tubers Distributional Channels in Morogoro Municipal, Tanzania

The sweet potato's several (alternative) pathways from the producer to the buyer are depicted in Table 4.2 (marketing channel). Single-stage and multi-stage sweet potato marketing channels exist in the study area. The movement of sweet potato goods from the producer directly to the customer, without the use of intermediaries, constitutes a single channel. Before reaching the end user, the multi-stage channel system goes via middlemen (intermediaries). This is similar to the findings of Tewe *et al.* (2003) in Nigeria, which indicate that in sweet potato producers' options to sell directly to wholesalers and retailers, all three kinds of intermediaries have mutually agreed upon their usage.

4.4.3 Cost-Benefit Analysis

The value of ventilated bags using CBA in the storage of sweet potatoes emanates confidence in recommending that farmers use this method rather than other methods and their CBA values obtained in research. It was evident that using ventilated bags during storage loss can be reduced compared with other storage techniques, and the tubers are safe for selling and profit maximization. This is similar to the findings of Chakraborty *et al.* (2017) in India, which show that maintaining tuber quality and ensuring an adequate quantity throughout the year are the main objectives of proper storage, which are accomplished by reducing losses. When losses are reduced, profits may also be created. Also, findings showed that using an improved raised platform for storing white-coloured sweet potato tubers causes a reduction in quality, hence a loss of profit. This is consistent with the findings of Mpagalile *et al.* (2007) in Tanzania, which indicated that the raised platform was unsuitable for storing sweet potato tubers for a long time since it causes storage losses and tends to make it unprofitable. Similarly, the findings of Sugri *et al.* (2017) in Ghana showed that improved traditional methods of storage are practiced, including raised platform results, but caused extreme losses and hence unprofitable. Net profit per selling of a 50 kg bag of sweet potato tubers (*shown in Tables* 4.4, 4.5, 4.6, and 4.7) is higher than others. This demonstrates how profitable and lucrative sweet potato trading is. This is in line with the findings of Amengor *et al*. (2017) in Ghana, Nyiatagher and Monica (2017) in Nigeria, and Nabay et al. (2020) in Sierra Leone, who state that sweet potato tuber trading is a commercially viable and financially beneficial business venture worth investing in.

4.5 Conclusion

This study summarised the assessment of the economic suitability of indoor storage technologies for the storage of white-coloured sweet potato tubers under Tanzania conditions where practicable and profitable storage technology procedures for farmers and traders were identified. In the cost-benefit analysis, the net profit of ventilated bags storage technology was higher than other storage technologies (improved traditional raised bamboo buckets and woven Polypropylene), indicating that the sweet potato tuber trading business is profitable. Adopting good storage technology has generated promising results in terms of prolonging the shelf life of sweet potatoes and, as a result, increasing sweet potato tuber's profit after product sales. The results will be used to assist farmers and traders in selecting proper indoor storage technology for reducing losses and, hence, profitability.

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CHAPTER FIVE

5.0 GENERAL DISCUSSION

Proper post-harvest handling practices, including packaging and good storage practices, are inevitable to reduce white sweet potato losses (Case, 2010). Creating awareness at the level of the farmers and traders should also be considered to capture those practices (Abrham *et al*., 2021). The management methods for postharvest practices that reduce white sweet potato losses are highlighted in this study. Good post-harvest management practices can prevent or limit sweet potato losses. Among the post-harvest practices that reduce losses are controlling mechanical injury, controlling the moisture content of storage, controlling rodents, controlling spoilage, controlling sweet potato weevil, controlling temperature and controlling weight loss (Kiaya, 2014).

The primary cause of weight loss was the evaporation of moisture, implying that the none-stored tubers incurred higher moisture loss (Thornton, 2016). Storage in Ventilated bags incurred less weight loss than Polypropylene Bags, improved traditional raised platforms and Woven Bamboo buckets. The higher and lower Physiological loss in weight (PLW) of the tubers implies the respective higher and lower rates of moisture evaporation during storage, reflecting the quality of the storage system used. Also, hardness, total soluble solids, colour and beta carotene variation in the result are influenced by moisture during storage.

Moreover, most of the sweet potato traders depended on their funding/Self-finance as the source of trading funds. Also, the sweet potato farmers and traders have several (alternative) pathways from the producer to the buyer to purchase the tubers. Single-stage and multi-stage sweet potato marketing channels exist in the study area. The movement of sweet potato goods from the producer directly to the customer, without the use of intermediaries, constitutes a single channel. Before reaching the end user, the multi-stage channel system goes via middlemen (intermediaries).

Similarly, the value of ventilated bags using CBA in the storage of sweet potatoes emanates confidence in recommending to farmers to use ventilated bag storage technology rather than other methods and their CBA values obtained in research. It was evident that using ventilated bags during storage loss can be reduced compared with other storage techniques, and the tubers are safe for selling and, hence, profit maximization.

The presence of white sweet potato tubers causes a variety of issues, including skin quality, appearance, spoilage, sprouting, sweet potato weevil, and weight loss, which affect the quality of sweet potato tubers. Furthermore, there is a need to improve post-harvest loss awareness among white-coloured sweet potato farmers and traders to minimize this, and so production profitably is required. Any intervention to increase awareness of sweet potato post-harvest losses should be prioritised for male farmers as they are less aware of such losses.

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CHAPTER SIX

6.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Storage is a critical component of the sweet potato post-harvest value chain, and it has been identified as the most crucial point in minimising losses. From this study, it was found that the majority of farmers are not aware of proper storage practices of white sweet potato tubers that could reduce losses in sweet potato tubers. The main aspects to consider in preventing losses are controlling rodents, avoiding injury, constructing proper storage facilities, and inspecting the stores regularly. The vast majority of sweet potato losses among farmers and traders are due to inadequate storage facilities. Farmers and traders should be encouraged to use effective sweet potato post-harvest storage technology (ventilated bags) to reduce such losses.

Furthermore, the assessment of the economic suitability of indoor storage technologies for the storage of white-coloured sweet potato tubers under Tanzania conditions where practicable and profitable storage technology procedures for farmers and traders were identified. In the cost-benefit analysis, the net profit of ventilated bags storage technology was higher than other storage technologies (improved traditional raised bamboo buckets and woven Polypropylene), indicating that the sweet potato tuber trading business is profitable.

The adoption of ventilated bags has generated promising results in terms of prolonging the shelf life of sweet potatoes and, as a result, increasing the profit of sweet potato tubers after product sales. The results will be used to assist farmers and traders in selecting ventilated bags as storage technology for reducing losses and, hence, profitability when ventilated bags are applied.

6.2 Recommendations

There is a need to improve post-harvest loss awareness among white-coloured sweet potato farmers and traders to minimize and produce profitably. Awareness-raising campaigns can be carried out through different methods, such as village meetings, television programs, newspapers and drama. Any intervention to increase awareness of sweet potato post-harvest losses should be prioritised for male farmers as they are less aware of such losses. Also, proper post-harvest management such as controlling mechanical injury, controlling the moisture content of storage, controlling rodents, controlling spoilage, controlling sweet potato weevil, controlling temperature and controlling weight loss. Similarly, ventilated bags can also be effective when storing undamaged sweet potato tubers. Farmers and traders are advised to sort and grade their tubers before storage. Furthermore, additional research studies should be conducted to develop awareness of other types of storage and methods for reducing sweet potato losses to impact food security in society, which was recommended.

APPENDICES

Appendix 1: Survey Questionnaire to Generate Information for Establishing Proper and Adequate Postharvest Storage Facilities for White-Colored Sweet Potatoes Tubers

To be filled in by research team:

Date ______________________ Interview ____________________

District ____________ Ward ____________ Village ____________

<u>Personal Information: this part should be filled by the enumerators by asking the respondents</u>

Phone number ____________________________________

Age (years) ___________

Sex: (1) Male ☐

(2) Female ☐

1. **Level of Education**
   (1) No formal education ☐
   (2) Primary school education ☐
   (3) Secondary school education ☐
   (4) Tertiary education ☐
2. Region……………………………..
3. District…………………………………
4. Ward…………………………………

5. **Occupation**
   (1) Farmer ☐
   (2) Livestock keeping ☐
   (3) Business ☐
   (4) Other occupations (mention)
   ………………………………………………………

6. Position of the respondent in the household
   (1) Father ☐
   (2) Mother ☐
   (3) Children ☐
   (4) Others ☐

(mention)……………………………………………………………

7. How many people (including yourself) are there in your household?
   (1) Alone ☐
   (2) 2-3 ☐
   (3) 4-5 ☐
   (4) 6-7 ☐
   (5) > 7 ☐
8. How many people (including yourself) in your family earn an income? ………………
9. Where do most of your family income come from? (Choose one answer)
   (1) Farming ☐
   (2) Livestock keeping ☐
   (3) Business ☐
   (4) Fishing ☐
   (5) Other sources (mention)
   ……………………………………….
10. Do you have any land for farming?
   (1) Yes ☐
   (2) No ☐
11. Do you cultivate crops on your farm?
   (1) Yes ☐
   (2) No ☐
   (3) If yes, mention the crops:
   ……………………………………………

Knowledge

12. Have you heard about Indoor storage technologies?
   (1) Yes ☐
   (2) No ☐

13. If yes, what was the source of information (more than one answer is possible)?
(1) Friends ☐
(2) Poster ☐
(3) Radio ☐
(4) Extension officers ☐
(5) School ☐
(6) Parents/family ☐
(7) Never heard/seen ☐
(8) Other sources (mention) ☐
…………………………………………

14. Have you used indoor storage technologies?
(1) Yes ☐
(2) No ☐
(3) If yes, how will use
……………………………………………

15. Have you understood the losses of white-coloured sweet potato tubers?
(1) Yes ☐
(2) No ☐
(3) If yes, explain it
……………………………………………..

16. What is the life span of White-coloured sweet potato tubers after harvest/buy in your area
(1) less than ten days ☐
(2) less than 15 days ☐
(3) more than 15 days ☐

17. Is there a way to the preventive method for white-coloured sweet potato tuber loss?
(1) Yes ☐
(2) No ☐
(3) If yes, mention the ways
……………………………………

Attitude

18. Would you report to an agriculture extension officer when you get a White-coloured sweet potato tuber loss?
    (1) Agree ☐
    (2) Disagree ☐
    (3) Neutral ☐

I agree, give reasons

…………………………………………………………

19. During the White-coloured sweet potato tubers value chain, one is a major loses
    (1) During their journey ☐
    (2) due to spoilage ☐
    (3) physiological decay ☐
    (4) mechanical damage ☐
    (5) During storage ☐

Practices

20. Do you cultivate/buy crops?
    (1) Yes ☐
    (2) No ☐
21. If yes, which crops do you cultivate/buy? (More than one answer is possible)
    (1) sweet potato ☐
    (2) Groundnuts ☐
    (3) Maize ☐
    (4) Sunflower ☐
    (5) Other, list

…………………………………………………………………………….

22. What amount of White coloured sweet potato tubers do you harvest/buy?
    (1) 0.5-100kg ☐
    (2) 100 -500kg ☐
    (3) 500-1000kg ☐
    (4) More than 1000kg ☐

23. Do you store White-coloured sweet potato tubers after harvest/buy?
    (1) Yes ☐
    (2) No ☐

24. Do you practice sorting/grading before storage
    (1) Yes ☐
    (2) No ☐

25. Which means are you using for the temporary storage of White coloured sweet potato tubers
    (1) Inground ☐
    (2) clamp method ☐
    (3) Using pit method ☐
    (4) bamboo basket ☐
    (5) Using improved technologies ☐

26. .What is the size of your storage??
    (1)) 0.5-100kg ☐
    (2) 100 -500kg ☐
    (3) 500-1000kg ☐
    (4) More than 1000kg ☐

27. Do you store different crops in the same store?
    (1) Yes ☐
    (2) No ☐
    (3) If yes, give reasons

……………………………………………………………..

28. To whom are you selling your crops (more than one answer is possible)?
    (1) Residents ☐
    (2) Retailer traders ☐

(3) Other merchants (specify)
……………………………………………

29. What is your opinion regarding the control and elimination of post-harvest loss on White-coloured sweet potato tubers?
………………………………………………………………………
………………………………………………………………………
…………..

Kuhusu Tasnifu Hii

Utafiti huu ulifanyika kwa lengo la kuangalia ufanisi wa aina nne za teknolojia ya kuhifadhi viazi vitamu vyenye rangi nyeupe katika kuthibiti upotevu wa hasara wa mazao baada ya kuvuna. Jaribio lilifanyika katika maabara ya Chuo Kikuu cha Kilimo cha Sokoine kwa muda wa siku 77. Utofauti mkubwa wa ufanisi ulijitokeza miongoni mwa teknolojia nne za kuhifadhia. Katika uchanganuzi wa faida, faida iliyotokana na teknolojia ya kuhifadhi kwa kutumia mifuko ya uingizaji hewa ilikuwa kubwa kuliko teknolojia nyingine za kuhifadhia (matenga, kihenge cha mbao kilichoboreshwa na mifuko ya viroba). Aidha tathmini ya sababu na kiwango cha upotevu wa mazao baada ya kuvuna ilifanyika kuonyesha kuwa chanzo kikubwa cha hasara baada ya kuvuna ni mashambulizi ya panya.Aidha kiwango cha upotevu wa viazi vitamu kimeripotiwa ni hasara ya wastani baada ya mavuno. Matokeo haya ni msingi kwa serikali na wadau kusambaza teknolojia hii ili kupunguza upotevu wa mazao wakati wa uhifadhi.