2020-08

Development of quality dried cashew apple products

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NM-AIST

https://doi.org/10.58694/20.500.12479/1020

DEVELOPMENT OF QUALITY DRIED CASHEW APPLE PRODUCTS

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A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Master's in Life Sciences of the Nelson Mandela African Institution of Science and Technology

Arusha, Tanzania

August, 2020

ABSTRACT

Cashew apple is an important healthy fruit and yet is highly underutilized in developing countries. This study explored factors affecting utilization of cashew apple among farmers in Lindi and Mtwara regions. Semi-structured questionnaire was used on 600 cashew farmers to collect information on cashew apple consumptions, processing and utilization constraints. In addition, dried cashew apple product was developed, in which full matured, ripe and intact fruits were plucked from the cashew tree. Then they were washed, blanched, sliced and immersed in 70% sucrose prior to drying on an oven or solar drier. As a result, majority of farmers reported to consume raw cashew apples. The frequency of consumption was more than five fruits a day (61.87%) and almost every day (55.98%) during the season. Traditional technologies for processing cashew apple porridge and alcohol were employed by about 43.7% of farmers. Lack of knowledge on post-harvest handling (86.2%) and processing technologies (82.7%) were mostly claimed to hamper cashew apple utilization. Both dried products showed no significant different ($p > 0.05$) on carotenoids (0.28 - 0.33g/100g), vitamin C (0.73 - 0.85g/100g) and tannins contents (266.59 - 267.95 mg/100g). During storage at ambient temperature for 60 days: total phenolic, tannins and vitamin C were significantly reduced ($p < 0.05$) in both oven and solar dried products. Furthermore, both dried products showed similar ($p > 0.05$) overall sensory acceptability. The combination of blanching, osmotic dehydration and solar or oven drying provide economically feasible value added products that can be reproduced in both urban and rural settings to enhance reduction of postharvest losses of the fruit.

DECLARATION

I, Noel Dimoso do hereby declare to the Senate of Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being concomitantly submitted for the degree award in any other institution.

Signature____________________ Date 14/08/2020

Noel Dimoso

The above declaration is confirmed

Signature____________________ Date 14/08/2020

Dr. Neema Kassim (Supervisor 1)

Signature____________________ Date 14/08/2020

Dr. Edna Makule (Supervisor 2)

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CERTIFICATION

The undersigned certify that, they have read the dissertation titled, "Development of Quality Dried Product from Cashew Apples" and recommend for examination in fulfillment for the requirements for the degree of Master's in Life Sciences of the Nelson Mandela African Institution of Science and Technology.

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ACKNOWLEDGEMENT

First, I would like to give glory and thanks to God the Almighty for everything.

I would like to express my deep sincere gratitude to my supervisors; Dr. Neema Kassim and Dr. Edna Makule for their clear guidance, insightful discussions about the research and encouraging and unceasing support throughout the project. I extend a special thanks to Dr. Athanasia O. Matemu and Dr. Haikael D. Martin for their advice and input to this research.

I would also like to thank the two projects under the Nelson Mandela African Institution of Science and Technology (NM-AIST); Centre for Research, Agricultural Advancement and Teaching Excellence and Sustainability (CREATES) project for funding my studies and the Fruits and Vegetables for all Seasons (FruVaSe) project for co-funding my research.

I would also like to acknowledge NM-AIST laboratory scientists and everyone, not to mention all who have directly or indirectly been involved in this work. I am grateful to everyone at the Food Biotechnology and Nutritional Sciences Department for your warmth and friendship. Special thanks to my colleagues in the FruVaSe project, Mrs. Marynurce Kazosi, Ms. Angela Aluko and Mr. Frank Sangija for their love and support.

TABLE OF CONTENTS

ABSTRACT i
DECLARATION ii
COPYRIGHT iii
CERTIFICATION iv
TABLE OF CONTENTS vi
LIST OF TABLES ix
LIST OF FIGURES x
LIST OF APPENDICES xi
LIST OF ABBREVIATIONS AND SYMBOLS xii
CHAPTER ONE 1
INTRODUCTION 1
1.1 Background of the study 1
1.2 Statement of the problem 2
1.3 Rationale of the study 3
1.4 Objectives 3
1.4.1 General objective 3
1.4.2 Specific objectives 4
1.5 Research questions 4
1.6 Significance of the study 4
1.7 Delineation of the study 4
CHAPTER TWO 5
LITERATURE REVIEW 5
2.1 Cashew apple 5
2.1.1 Production of cashew apple 5
2.1.2 Description of cashew apple 5

2.2 Composition of cashew apple 6
2.2.1 Nutritional composition of cashew apple 6
2.2.2 Phytochemical composition of cashew apple 6
2.3 Application of cashew apple 7
2.3.1 Nutritional and therapeutic potential of cashew apple 7
2.3.2 Value added product from cashew apple 7
2.4 Drying technologies 8
2.4.1 Hot air oven drying 9
2.4.2 Solar drying 10
CHAPTER THREE 11
MATERIALS AND METHODS 11
3.1 Description of the study area 11
3.1.1 Study design and Sampling 11
3.2 Data collection 12
3.2.1 Sample collection for processing of dried cashew apples 13
3.2.2 Osmotic dehydration of cashew apples 14
3.2.3 Drying of osmotically dehydrated cashew apple slices 15
3.3 Laboratory analysis of fresh and dried cashew apples 16
3.3.1 Determination of moisture content, total titratable acidity (TTA) and pH 16
3.3.2 Determination of total sugar content 17
3.3.3 Determination of carotenoid contents 17
3.3.4 Determination of total ascorbic acid content 17
3.3.5 Determination of total phenolic content (TPC) and Tannin content 18
3.3.6 Rehydration efficiency of dried cashew apple products 18
3.3.7 Microbial analysis of dried cashew apple slices 19
3.4 Sensory evaluation of dried cashew apple products 19
3.5 Shelf life studies 20

3.6 Statistical analysis ... 20
CHAPTER FOUR ... 21
RESULTS AND DISCUSSION ... 21
4.1 Socio-demographic profile of participants and cashew nut production ... 21
4.1.1 Consumption of cashew apple fruits ... 23
4.1.2 Processing of cashew apples ... 26
4.1.3 Post-harvest constraints of cashew apple utilization ... 28
4.1.4 Opinions to improve cashew apple utilization ... 29
4.2 Processing of dried cashew apple products ... 30
4.2.1 Osmotic dehydration of cashew apples ... 30
4.2.2 Physicochemical parameters of fresh and dried cashew apples ... 31
4.2.3 Stability of dried cashew apple during storage at room temperature ... 34
4.2.4 Sensory analysis of dried cashew apple products ... 37
CHAPTER FIVE ... 38
CONCLUSION AND RECOMMENDATIONS ... 38
5.1 Conclusion ... 38
5.2 Recommendations ... 39
REFERENCES ... 40
APPENDICES ... 47
RESEARCH OUTPUTS ... 50

LIST OF TABLES

Table 1: Socio-demographic characteristics of the participants 22

Table 2: Socio-demographic characteristics of the participants and cashew nut production 23

Table 3: Farmers' consumption habits of raw cashew apples across the surveyed districts 25

Table 4: Reasons for not consuming raw cashew apples (N = 13) 25

Table 7: Influence of blanching and osmotic solution on kinetics of osmotic dehydration 31

Table 8: Physicochemical parameters of fresh and dried cashew apples 33

Table 9: Rehydration efficiencies of dried cashew apple products.................................... 33

Table 10: Quality parameters of dried apple products during storage at room temperature . 36

Table 11: Sensory evaluation scores of dried cashew apple products 37

LIST OF FIGURES

Figure 1: (a) Yellow and (b) red cashew apple attached to the tree on one side and to the nut on the other end 6

Figure 2: Tanzania map showing areas cultivating cashew (A) and study sites (wards): Nachunyu (1), Nahukahuka (2), Mandwanga (3), Mitumbati (4), Nangowe (5), Nambambo (6) in Lindi region (B) and Nanhyanga (1), Namikupa (2), Mchichira (3), Makong'onda (4), Mnavira (5), Chipolopola (6) in Mtwara region (C) 12

Figure 3: Processing of dried cashew apple products 14

Figure 4: Variation of drying temperature over time in a solar dryer 16

Figure 5: Reasons for consuming raw cashew apples 26

Figure 6: Reasons given by participants who do not process cashew apples 28

Figure 7: Cashew apples' post-harvest constraints encountered by cashew farmers 29

Figure 8: Opinions from the cashew farmers to improve cashew apple utilization 30

LIST OF APPENDICES

Appendix 1: Standard curves of the physiochemical parameters analysed, ascorbic acid, carotenoids, total phenolic content and total sugar content 47

Appendix 2: Equipment and material used during the processing of red cashew apples ... 48

LIST OF ABBREVIATIONS AND SYMBOLS

<	Less than
>	Greater than
%	Percentage
χ2	Chi square
Vol	Volume
Wt	Weight
masl	Meter above sea level
ANOVA	Analysis of variance
URT	United Republic of Tanzania
CBT	Cashewnut Board of Tanzania
TARI	Tanzania Agricultural Research Institute
UNIDO	United Nations Industrial Development Organization
FAO	Food and Agriculture Organization
AOAC	Association of Official Analytical Chemists
CARE	Cooperative for Assistance and Relief Everywhere
DAICO	District Agricultural Irrigation and Cooperatives Officer
WEO	Ward Executive Officer
FGD	Focus Group Discussion
TTA	Total Titratable Acidity
TPC	Total Phenolic Content
RR	Rehydration Ratio
RC	Rehydration Coefficient
PCA	Plate Count Agar
PDA	Potato Dextrose Agar
ODK	Open Data Kit
SPSS	Statistical Package for the Social Sciences

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Cashew apple is a non climacteric fruit from cashew tree (*Anacardium occidentale* L.), a tropical evergreen plant originated in Brazil (Zepka & Mercadante, 2009). The tree bears a nut, the true fruit which develops from an ovary of flower and an apple, the false fruit which develops from the receptacle of a flower. Though parallel produced, cashew cultivation in Africa is geared towards cashew nut production with less or no focus on the apples. The main cashew producing regions in Tanzania are Mtwara, Lindi, Pwani and Ruvuma (Cashewnut board of Tanzania [CBT]), 2018). Thirty million metric tons per year of cashew apple fruits are produced around the world, but more than 84% of the fruits left to rot (Michodjehoun-mestres *et al*., 2009).

Cashew apple fruit is rich in vitamin C, some amino acids, minerals, sugars and polyphenols (Daramola, 2013; Marc *et al*., 2012). Vitamin C content in cashew fruit is about five times than that of orange, pineapple, mango and other common fruits (Akinwale, 2000). Despite their nutritional potentials, they are normally left to rot in the fields during cashew production. However, this huge post-harvest loss is attributed by several factors including lack of proper post-harvest knowledge and skills and high perishability and astringency property of the cashew apples (Akinwale, 2000; Nwosu *et al*., 2016). Moreover, the fruits are used to process useful products such as jam, juice, wine, pickles and ethanol (David & Prasad, 2015; Nwosu *et al*., 2016; Runjala & Kella, 2017) in countries like Brazil, India, Nigeria and Ghana.

In Tanzania, much attention has been placed on cashew nut and many cashew farmers have benefited significantly in recent years due to market availability and most importantly, the price of the produce has been increased due to government intervention. Unlike cashew nut, the apples are not common or not even known to the people in the regions where cashew trees are not grown. In addition, there are little scientific information on their potentials to food and nutrition security in the country. A report by Msoka *et al*. (2017) investigated the physiochemical aspect of five cashew apple varieties. In this report, common and locally grown varieties contain comparable nutritive values in term of vitamin C and polyphenols as those reported by Daramola (2013) in Nigeria and Naka *et al*. (2015) in Côte d'Ivoire. Further to this, it is equally important to document constraints and utilization trends of cashew apple in order to build more insight on factors affecting their utilization. Therefore, the present study documented consumption, local processing technologies, constraints and opinions to improve the utilization of cashew apples as an attempt to reduce their massive losses. Furthermore, the study attempted to develop the dried form of cashew apple using osmotic dehydration process complimented with hot air oven drying and solar drying to overcome postharvest losses of the fruit. These techniques could be used for industries and small-scale entrepreneurs in a group or household level due to its convenience and cost-effectiveness to produce products for food and income generation. Thus, tremendous efforts on value addition of cashew apple need to be done to facilitate the utilization of cashew apple and promote the industrialization of cashew apple fruit produces.

1.2 Statement of the problem

Cashew is a food and cash crop that has proven significant contribution to the economy of the countries where they are grown. In countries like Brazil, India, Ghana and Benin have realized the importance of cashew apples both as fresh fruits and processed to various products. For instance, products such as frozen pulp, juice concentrates and ready-to-drink juices are highly processed in Brazil and contribute up to 12% of the total cashew apples produced (Damasceno *et al*., 2008). Furthermore, cashew apple pomace have been used as animal feed in countries where cashew apple industry is well established like Brazil (Pinho *et al*., 2011). Moreover, TechnoServe through the BeninCaju project is collaborating with local entrepreneurs to process cashew apple into juice in Benin, hence improve nutrition and create employment particularly for women (Yantannou, 2017).

However, of the two food products from cashew tree, only nuts are considered for consumption and trade in Tanzania, while the cashew apple is underutilized despite their nutritional, therapeutic and economic potential. Cashew apple varieties grown in the country are rich in nutrients such as vitamin C (253 - 349 mg/100mL), total phenolics (1067 - 2887 mg/L GAE), carotenoids and minerals (Msoka *et al*., 2017). This indicates that, the home grown cashew apples have nutritive potentials which can only be realized by maximizing the consumption as fresh fruit and/or processed into useful products instead of being left to rot in the fields.

In addition, there is limited information regarding the status of cashew apples in the country. While the United nations industrial development organization [UNIDO] (2011) and Msoka *et al*. (2017) reported few local cashew farmers were using cashew apples to distil strong liquor named "*Uraka*" in Swahili, to date, there are no commercially available value added product (s) from cashew apples in the country. Thus, unleashing the potential of cashew apples will help minimize post-harvest losses while enhancing food and nutrition security as well as farmers' income and the country's economy.

Therefore, the present work aimed to document the utilization trends and constraints of cashew apple, and develop dried cashew apple product as dehydrated fruit using oven and solar dryer. Drying technology offers products which are easy to prepare, store, use and commercialize. These technologies are considered relatively compatible for use at household level and small scale industries in Tanzania due to their cost-effectiveness and conveniences. This endeavor is sought to promote cashew apple consumption and commercialization, which will ultimately reduce post-harvest losses of the fruit and improve livelihood of farmers through income generation.

1.3 Rationale of the study

Tanzania, and especially the regions of Mtwara and Lindi, has a long engagement with the cultivation and processing of cashew. The crop has been contributed significantly to the improvement of livelihood of people living in these areas as a source of food and income generator. These benefits come from cashew nuts alone, with cashew apples left to rot in the fields. This underutilization is attributed to the highly perishability nature (due to soft skin tissue of the fruit) and astringent taste of the fruit. However, value addition of this fruit is possible. To illustrate this, upon completion of this research, the value-added dried cashew apple products will be developed. Furthermore, more insight about the utilization pattern of cashew apples and challenges facing cashew farmers will be addressed. Through value addition, cashew farmers and country as a whole could benefit through income generation from both the nuts and cashew apples, and most importantly food security will be improved.

1.4 Objectives

1.4.1 General objective

The main aim of present work is to document utilization constraints and develop nutritious dried cashew apple product.

1.4.2 Specific objectives

(i) To investigate the utilization trends and constraints of cashew apples in main cashew growing regions of Tanzania named Mtwara and Lindi.

(ii) To develop dried cashew apple product using hot air oven and solar dryer.

(iii) To examine physical-chemical properties and nutrient retention of the dried product.

(iv) To evaluate the storage stability and sensory properties of the dried product.

1.5 Research questions

(i) What are the utilization trends and constraints of cashew apples in main cashew growing regions of Tanzania?

(ii) What is the best formulation for drying cashew apples?

(iii) What is the physical-chemical composition of the dried cashew apple products?

(iv) What is the storage stability of the dried cashew apple products?

(v) What is the sensory characteristics of the dried cashew apple products?

1.6 Significance of the study

The present study will contribute to the knowledge base on cashew apple utilization trend and constraints facing farming households, processors and consumers. It will at the end offer processing techniques which are convenient at both the rural and urban settings to aid reduction of post-harvest loss of these fruits. The study will benefit both the consumers and industries by offering healthy and natural products as well as promoting cashew production in the country. It will also aid alleviate poverty through income generation as most farmers in cashew producing regions depend on cashew production.

1.7 Delineation of the study

This study was investigating the utilization patterns and challenges facing cashew farmers regarding cashew apples. The baseline survey was conducted in Mtwara and Lindi regions in Tanzania. In addition to this survey, a value added product in form of dried cashew apple was formulated by using hot air oven and solar drier. The dried products were evaluated in term of nutrient content, shelf life stability and consumer acceptance.

CHAPTER TWO

LITERATURE REVIEW

2.1 Cashew apple

2.1.1 Production of cashew apple

Cashew (*Anacardium occidentale* L.) apple is a tropical fruit originated in Brazil and brought to Africa during colonization process (Zepka & Mercadante, 2009). It is cultivated in 32 countries globally, with Brazil, India, Vietnam and Nigeria as the leading producing countries of cashew nuts (Priya & Setty, 2019). Cashew production contributes significantly to the economy of Tanzania and the major production areas are Mtwara, Lindi, Pwani and Ruvuma region (CBT, 2018). Worldwide production of cashew apples is estimated to be more than thirty million metric tons per year, with more than 84% of the fruits left to rot (Michodjehoun-mestres *et al*., 2009). In Tanzania, 313 826.386 metric tones of cashew nuts were harvested (CBT, 2018), which is equivalent to about 3 922 829.825 metric tones of cashew apples lost during that season based on the weight ratio of about 1:12 (cashew nut:cashew apple) (Attri, 2009).

2.1.2 Description of cashew apple

Cashew apple fruit is a non-climacteric false fruit attached to the cashew tree and the nut (true fruit) on its terminal sides. Ripe and matured fruit is juicy, has typical size and color of particular variety, and easily detached from the cashew tree. In addition, when ripe they have their best flavor and aroma due to highest level of sugars, lowest astringency and acidity (Prommajak & Leksawasdi, 2014). The color of apples may be yellow, red and orange, with yellow and red (Fig. 1) mostly commercialized around the world (Assunc & Mercadante, 2003). Ripe and matured fruits are edible, nutritious and have therapeutic potentials.

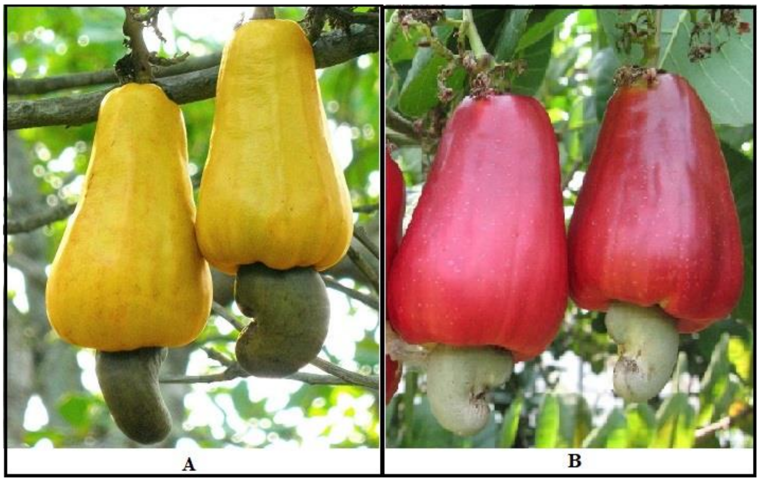

Figure 1: (a) Yellow and (b) red cashew apple attached to the tree on one side and to the nut on the other end

2.2 Composition of cashew apple

2.2.1 Nutritional composition of cashew apple

Cashew apple fruit is rich in vitamin C, some amino acids, simple and complex sugars, polyphenols and minerals (Lopes *et al*., 2007; Marc *et al*., 2012; Msoka *et al*., 2017). They contains about five times vitamin C content compared to tropical fruits including mango, lemon, pineapple and orange (Akinwale, 2000). Further to this, the fruit is a good source of dietary fibres (Pinho *et al*., 2011; Alves *et al*., 2010).

The level of nutrients in cashew apples mainly vitamin C, minerals and sugars reported to vary depending on variety and site. For instance, Assunc and Mercadante (2003) reported that the quantity of vitamin C to be higher in elongated red and yellow varieties compared to rounded red apples. Moreover, Msoka *et al*. (2017) documented that the level of vitamin C and sugars varied significantly with site and variety. Noteworthily, factors such as soil, temperature, solar intensity and genotypic factors influence the the level of nutrients in cashew apple fruits (Assunc & Mercadante, 2003; Naka *et al*., 2015).

2.2.2 Phytochemical composition of cashew apple

Phytochemical compounds are biologically active secondary metabolites produced by plant. They help plants to survive in hostile environmental conditions such as competitors, pathogens and predators. Phytochemical compounds are known to provide health benefits owing to their antioxidant activity, anti-inflammatory activity and anti-tumor activity (Correia *et al*., 2012).

Cashew apple fruit is rich in phytochemical compounds including polyphenols, carotenoids, ascorbic acid and insoluble dietary fibers (Marc *et al*., 2012; Msoka *et al*., 2017; Rufino *et al*., 2010). Polyphenolic constituents present in these fruits include anacardic acid, gallic acid, quercetin, caffeic acid, tannins and anthocyanins (Marc *et al*., 2012).

2.3 Application of cashew apple

2.3.1 Nutritional and therapeutic potential of cashew apple

Cashew apples may be considered as functional fruit due to the presence of ascorbic acid, carotenoids, insoluble fibers and polyphenolic compounds. Functional food must provides health beneficial claims beyond that of the basic nutritients it possess (Gul *et al*., 2016). Furthermore, the functional attributes of cashew apple fruit such as anti-tumor, antioxidant, antibacterial and antifungal properties are responsible for promotion or treating chronic diseases such as cholera, cancer and cardiovascular diseases (Runjala & Kella, 2017).

2.3.2 Value added product from cashew apple

Despite the fact that cashew apple has nutritional potentials, it is normally left as waste product of cashew production in less industrialized countries like Tanzania and many other African countries. It is noted that low utilization of cashew apple may be attributed to perishability and astringent characteristics (Akinwale, 2000; Nwosu *et al*., 2016). Nonetheless, the fruits can be processed into food products such as candy, juice, squash, wines, jam and marmalades (Araujo *et al*., 2011; Runjala & Kella, 2017). In Brazil for instance, frozen pulp, juice concentrates and ready-to-drink juices are highly processed products (Damasceno *et al*., 2008).

Cashew apples grown in Tanzania are rich in nutrients and phytochemicals (Msoka *et al*., 2017). This suggests that, they can be processed into useful products instead of being left to rot in the farms. However, few cashew farmers are reported to process strong liquor traditionally known as *Uraka* from cashew apples (UNIDO, 2011). To date, there is no any other information regarding the status of cashew apple in Tanzania and on top of that, no commercialized product (s) of cashew apples.

Cashew production contributes significantly both to the national economy and individuals who are involved in cashew value chain. Cashew farmers benefit mostly through selling of cashew kernels and raw cashew nuts, while the government earns cashew income through exportation of raw cashew nuts (UNIDO, 2011). For instance in year 2015, cashew nut export contributed about 497.4 billion to the national economy which is equivalent to 10.97% (Msoka *et al*., 2017). While the potential of cashew nuts is exploited, cashew apples are left to rot at the farm as waste. Some countries like Brazil, India and Benin have started realizing the benefit of cashew apples by producing products such as juice, jam and wine. For example, Brazil made about 4 854 342 USD from export of cashew apple juice in 2009 (Oliveira & Barros, 2009). Therefore, if cashew apples are similarly exploited as the nuts do, it will improve the socio-economic status of cashew farmers and the country as a whole.

2.4 Drying technologies

Processing of fruits into dried products is a feasible method both at industrial scale and in local situations compared to other products such as juice, jam and wine processing. Drying offers many advantages including the ease of preparation and storing, reduction of saving in packaging and energy, and products are of light-weight, hence convenient. It is estimated that more than 20% of the crops which are perishable around the world are dried in order to prolong shelf life and reduce food insecurity (Grabowski *et al*., 2003). It is noteworthy that, the issue is not just to dry the fruits but also to make sure that the resulting product is nutritious, convenient, stable at storage and acceptable to consumers. Drying of fruits has proven to be effective in many other fruits such as pineapple (Zapata *et al*., 2011), guava fruit (Kushwaha *et al*., 2018), mango (Kohayakawa *et al*., (2004), papaya (Jain *et al*., 2011), banana (Ali *et al*., 2010), mulberry fruit (Ojha *et al*., 2017) and cranberry (Beaudry *et al*., 2007).

Osmotic dehydration technique is widely used to dry fruits prior to actual drying. It is a partial reduction of water from the fruit when dissolved in hypertonic solution for a given time. In the meantime, the osmotic agent penetrates into the fruit. The movement of soluble constituents from the fruit such as minerals, some vitamins and organic acids also occur but to a lesser extent compared to water and osmotic agent. The variables that influence osmosis process include geometry of raw material, temperature, concentration of the solute, agitation of the solution and the ratio of raw material to osmotic solution (Ramya & Jain, 2016).

During osmosis, fruits are immersed in a concentrated solution for a specific period of time. Then, they are removed from the solution, drained and rinsed in running water to reduce excess sugars and placed on tissue paper to reduce excess water on the surface (Weerasooriya & Kaushalya, 2017). Osmotic dehydrated products are subject to further drying as osmotic treatment alone does not reduce enough water. It is noteworthy that the maximum allowable level of moisture for osmotic dehydrated fruit is 20% (dry basis) as per CODEX General Standard 130-1981 which was amended in 2019. Osmotic dehydration prior to further drying methods produces improved product quality as nutrients are less degraded due to low temperature employed as well as improve organoleptic attributes such as taste, texture and aroma compared to conventionally dried fruits (Mini & Archana, 2016; Ramya & Jain, 2016; Weerasooriya & Kaushalya, 2017; Yadav & Singh, 2014). Furthermore, osmotic treatment reduces the drying time and save energy.

Further methods of drying such as vacuum, hot air oven, freeze and solar drying can be employed to yield optimal dried products (Ramya & Jain, 2016). The choice of instrument depends on the need, availability and capital. Solar and open sun drying are cost-effective, user friendly and readily available than other sophisticated drying methods. Normally, in every drying method, processing parameters need to be monitored to obtain quality products. If the parameters left unchecked, dried products tend to be very hard, not easily rehydrated and severe shrinkage due to excessive water loss. Furthermore, negative changes in color, flavor and loss of nutrients could occur (Jain *et al*., 2011).

2.4.1 Hot air oven drying

Hot air oven provides a air temperature higher than that of the atmosphere, thus allowing the moisture to evaporate from the food material. The capacity of air in removing of moisture depends on temperature and the moisture amount of air. When air pass over a wet food, heat is transfered to the surface and leads to vapor of latent heat vaporization. The difference pressure between surface and inner parts of food materials is another reason of removing a part of moisture by steam (Mazandarani *et al*., 2014).

The food reaches a humid temperature in short time when placed in an oven. The drying process continues with a uniform rate which means equivalence in removing and absorbing of moisture in foodstuff. On the other hand, an air layer containing saturated steam is available on the food surface. The amount of drying depends on dryer properties such as temperature, relative humidity, air rate and food properties such as moisture and surface volume ratio (Mazandarani *et al*., 2014). The properties of food and its components effect on heat transfer and the quality of final product.

To remove moisture up to a level that can increase shelf life especially in food containing sugar (like fruits), high temperature and longer time are required, which adversely affect color, flavor, level of nutrients and reduce rehydration capacity of dried product (Mazandarani *et al*., 2014). However, hot air oven has proven to be effective in retaining quality attributes such as nutrients, taste and texture in many fruits such as guava fruit (Kushwaha *et al*., 2018), mango (Kohayakawa *et al*., 2004), papaya (Jain *et al*., 2011), banana (Ali *et al*., 2010), mulberry fruit (Ojha *et al*., 2017) and cranberry (Beaudry *et al*., 2007).

2.4.2 Solar drying

In solar drying, the produce is contained in an enclosed space, and the air in contact with it is heated by solar radiation. By heating the air, its humidity is reduced and thus its efficiency as a vehicle for removal of moisture is increased. The movement of air across the produce is generally induced by natural convection - the tendency of warm air to rise, while in a forced convection air is moved by means of a fan. The latter units are inherently more efficient, but they require a supplementary source of energy to drive the fan. The choice of a dryer and drying method depends on the type of the product, availability and cost of the dryer, energy consumption and the final quality of the dried product (Al-juamily *et al*., 2014; Sagar & Kumar, 2010).

Solar drying gives desirable product quality with minimal environmental impact (Al-juamily *et al*., 2014; Mulokozi & Svanberg, 2003). It is an effective, cheap and safe method of agricultural and food product drying. However, protection against ultra violet radiation, dust, insects, mold and other sources of contamination, as well as temperature and relative humidity control, are needed to improve the quality of the product. Likewise, the storage conditions of solar-dried products should be tailored to the crop and the packaging optimized if a long shelf-life is required. Solar drying was successfully applied in fruits such as banana, mango and blueberry.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the study area

The study was conducted in Tandahimba and Masasi districts of Mtwara region and in Nachingwea and Lindi districts of Lindi region in 2019. The regions are located in the south-eastern part of Tanzania along the Indian Ocean. Mtwara borders with Lindi to the North, Ruvuma region to the West and Mozambique to the South. Much of the region is coastal lowlands and level to rolling plains and plateau with an altitude of less than 500 m.a.s.l and rainfall range between 800 to 1000 mm/year. Lindi region borders with Morogoro and Ruvuma regions to the West, Mtwara to the South and Pwani to the North. Lindi's agro-ecological zones range from gently undulating to rolling plateau areas in the west with higher altitude between 200 – 1000 m.a.s.l and rainfall between 800 – 1200 mm/year, to coastal lowlands, highlands and level/flat to rolling plains areas with lower altitude of less than 750 m.a.s.l and rainfall between 800 – 1000 mm/year in the rest parts of the region (United Republic of Tanzania [URT], 2006). In addition, much of the western part is in the Selous Game Reserve. The regions and their corresponding districts were purposively selected because they are the leading cashew producers for cashew nut in the country (CBT, 2018) which is a potential cash crop for the people living in these regions.

3.1.1 Study design and Sampling

A cross-sectional design was adopted in the present work. This design is suitable for descriptive studies and assessment of relationship between studied variables (Kulwijila *et al*., 2018). The sampling units were individual cashew farming households and processors from the study locations. From each of the surveyed district, three wards were purposively selected based on their cashew production potential followed by a random selection of two villages from each ward (Fig. 2). The villages in their respective wards were Mkachima and Mapili (Chipolopola), Makong'onda and Mkwaya (Makong'onda), Mnavira and Manyuli (Mnavira), Miule and Mnaida (Nanhyanga), Namikupa and Chinati (Namikupa), Mnalani and Shangani (Mchichira), Mitumbati B and Mwenge (Mitumbati), Nambambo and Nampemba (Nambambo), Nangowe and Matangini (Nangowe), Nachunyu and Mmumbu (Nachunyu), Chiuta and Mikongi (Mandwanga), Nahukahuka B and Linoha (Nahukahuka). A total of 600 farmers (324 from Lindi and 276 from Mtwara) drawn from the list of registered cashew farmers were randomly selected based on probability proportional to size basis. The size was based on the total number of registered cashew farmers in respective villages.

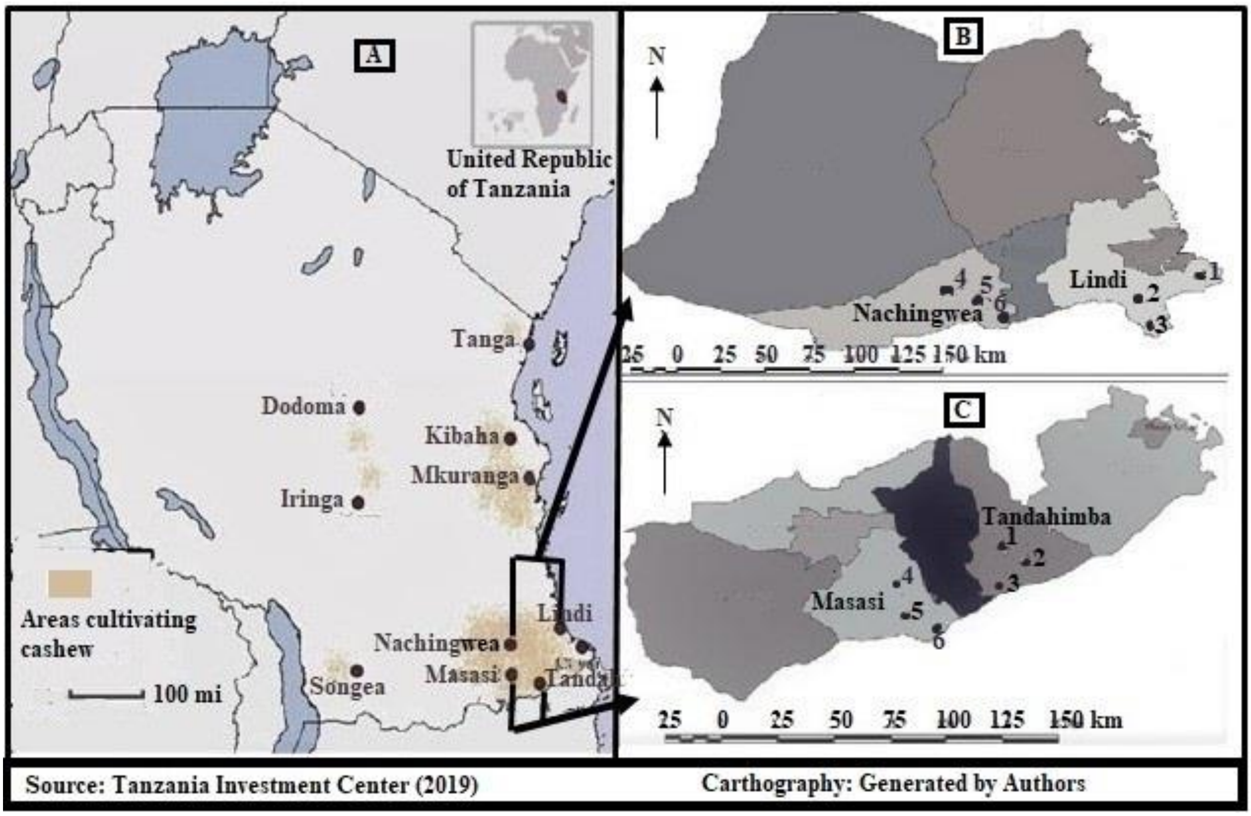

Figure 2: Tanzania map showing areas cultivating cashew (A) and study sites (wards): Nachunyu (1), Nahukahuka (2), Mandwanga (3), Mitumbati (4), Nangowe (5), Nambambo (6) in Lindi region (B) and Nanhyanga (1), Namikupa (2), Mchichira (3), Makong'onda (4), Mnavira (5), Chipolopola (6) in Mtwara region (C)

3.2 Data collection

Primary data were gathered from the individual cashew farmers, processors and key informants such as Agricultural Extension Officers. A semistructured questionnaire was employed to obtain general information on cashew production, consumption habits of cashew apples, availability of processing technology, market opportunities, challenges and opinions related to cashew apple utilization. Two Focus Group Discussion (FGD), one from each region and five Key Informant Interviews were conducted to validate the information given by individual farmers. Participants who took part in the FGD included the cashew nut processors, Agricultural Extension Officers, District Agricultural Irrigation and Cooperatives Officers (DAICO), Research Officers and Ward Executive Officers (WEO). Audio recordings and notes-taking were used to gather information during the discussions. Secondary data were obtained from various office records including DAICO, Land departments, Cashew Board of Tanzania (CBT) and online resources such as the Ministry of Agriculture and CBT.

3.2.1 Sample collection for processing of dried cashew apples

Red Brazilian Dwarf cashew apples were obtained at Nachingwea district (10°19′46″S, 38°46′46″E; 442 m.a.s.l) from the orchards owned by Tanzania Agricultural Research Institute (TARI). This variety was chosen because of high nutrients and low tannin contents *(Msoka et al*., 2017). Full matured ripe and intact fruits were hand-plucked from the tree, stored in a cool box at ambient temperature and transported to the laboratory within 20 hours for further preparation prior to processing. The average initial pH and total soluble solid of the fruits were 3.6 ± 0.3 and 13.3 ± 0.2 °Brix respectively. The values of pH and total soluble solid are good indicators of the ripeness of the fruit, with the range of pH from 3.5 to 4.6 and soluble solid from 9.8 to 14.0 °Brix be considered as mature and ripe (DaSilva *et al*., 2000). The fruits were sorted and washed with running tap water to reduce microbial load and soil debris and wrapped in polyethylene films before stored at -20 °C prior to processing as illustrated in Fig. 3.

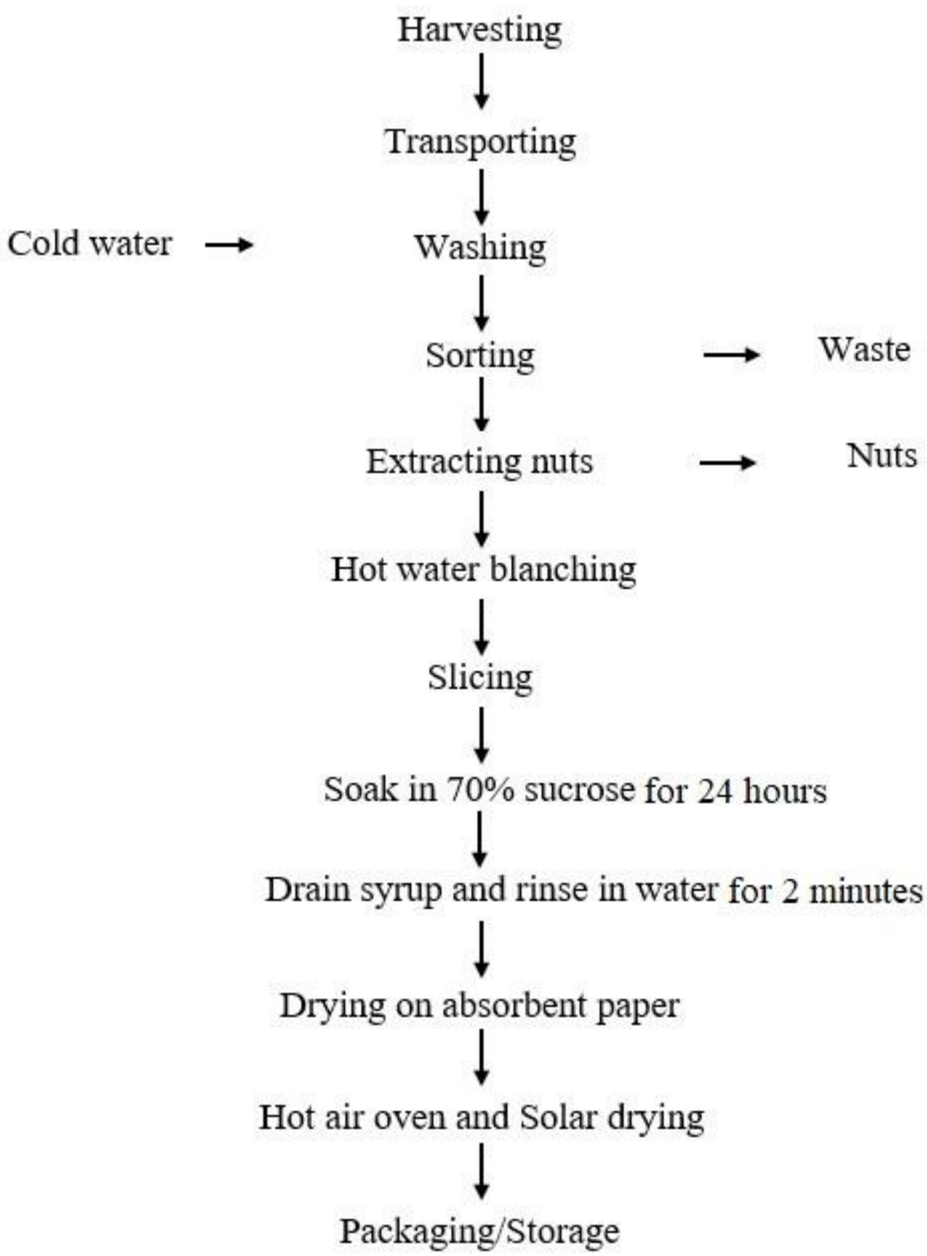

Figure 3: Processing of dried cashew apple products

3.2.2 Osmotic dehydration of cashew apples

Prior to osmotic treatment, the fruits were thawed by dipping in water at room temperature and nut removed. Four treatments were conducted: Treatment A; Hot water blanched and soaked in 60%, wt/wt sucrose syrup, Treatment B; Hot water blanched and soaked in 70%, wt/wt sucrose syrup, Treatment C; Non-blanched and soaked in 60%, wt/wt sucrose syrup and Treatment D; Non-blanched and soaked in 70%, wt/wt sucrose syrup. Blanching in hot water took place at 90 °C for 5 minutes in a thermostatic water bath. Then they were manually transversely sliced into ~10 mm thickness using sharp stainless steel knife, weighed and then immersed into sucrose syrups in a 1 L beaker for 24 hours at 27 - 29 °C. Fruit sample to syrup ratio used was 1:4 (wt/wt). After 24 hours, sliced cashew apples were immediately removed, drained, rinsed with running water and placed on absorbent paper to reduce excess moisture from the surface. Then the sliced fruit samples were weighed and oven-dried at 105 °C for 24 hours. Mass transfer indices *i.e.* Water loss and Solid gain were calculated using the following formulae (Singh *et al.*, 2008).

$$\text{Water loss (\%)} = \frac{(M0 - m0) - (M - m)\ X\ 100}{M0}$$

$$\text{Solid gain (\%)} = \frac{m - m0\ X\ 100}{M0}$$

Where; M_0 = Mass of fresh fruit prior to osmosis (g), M = Mass of fruit sample after time‘t’ of osmosis (g), m = Dry mass of fruit sample after time‘t’ of osmosis (g) and m0 = Dry mass of fresh fruit prior to osmosis (g)

3.2.3 Drying of osmotically dehydrated cashew apple slices

(i) Hot air oven drying

Following the osmotic treatment, samples from the selected treatment were placed in a perforated aluminum trays (Appendix 2E) and further dried to reduce moisture content to about 15% by using a natural convention hot air oven (Appendix 2D) at 60 °C for 48 hours. The samples were analyzed to check if the moisture content is within the predetermined range (10-16%). Thereafter, dried samples were allowed to cool, packaged in a low-density polyethylene laminated aluminum pouches (Appendix 2F) and stored at room temperature.

(ii) Solar drying

Following the osmotic treatment, samples from the selected treatment were placed in a perforated aluminum foils wrapped onto the drying trays and further dried to reduce moisture content to about 15% by using natural convection mixed solar drier (Appendix 2C) for 5 ± 1 days. The temperature inside the solar drying chamber ranged from 31.00 ± 1.11 °C for the down hours to 62.12 ± 0.63 °C for the pick hours, making an average drying temperature of 47.53 ± 1.09 °C (Fig. 4). After sun set, the products were removed from the solar drier to avoid regaining of moisture from the surrounding. Similar to hot air drying, solar dried samples were allowed to cool, then packaged in a low-density polyethylene laminated aluminum pouches (Appendix 2G) and stored at room temperature.

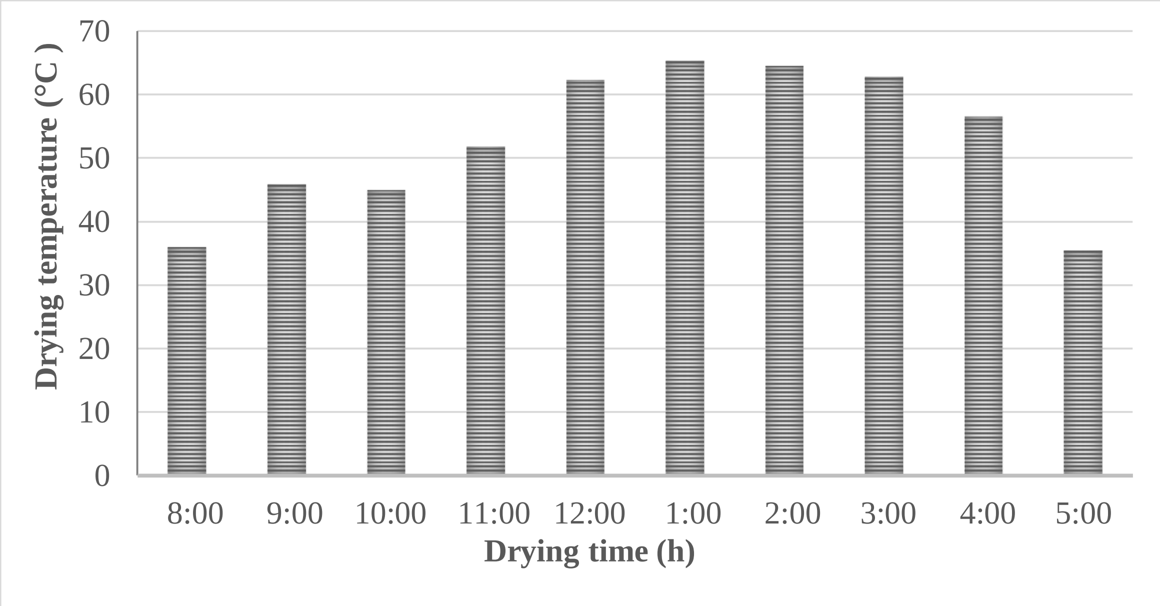

Figure 4: Variation of drying temperature over time in a solar dryer

3.3 Laboratory analysis of fresh and dried cashew apples

3.3.1 Determination of moisture content, total titratable acidity (TTA) and pH

The level of moisture, total titratable acidity (TTA) and pH of fruit samples were determined as described by (Bidaisee & Badrie, 2001) with some modifications. Briefly, moisture content (%) was obtained by drying fruit samples for 24 hours in an oven at 105 °C.

The pH of the sample was determined by homogenizing 20 g of well pulped fruit sample in 100 mL distilled water and allowed to stand for 30 minutes. Filtrate was collected and centrifuged (Eppendorf Centrifuge 5810, Germany) at 3000 rpm for 10 minutes. The pH of the extract was measured on a digital pH meter (GHM 3531, Germany).

The TTA (%) of the fruit sample extract (as prepared for pH) was determined by placing 25 mL of extract in a beaker placed on a magnetic stirrer of a digital titration burette (TITRONIC Basic module 2, Germany) and titrated against 0.1 N NaOH (Loba Chemie Pvt. Ltd, India) until the end point at pH 8.2 and calculated based on the following formulae (Sadler & Murphy, 2010).

$$\% \, acid \, (wt/wt) = \frac{0.1 \, mEq/mL \, NaOH \, X \, volume \, NaOH \, (mL) \, X \, 64 \, mg/mEq}{weight \, of \, sample \, (g) \, X \, 10}$$

Where, 64 mg/mEq = Equivalent weight of citric acid and 10 is a factor relating mg to g (1/10 = 100/1000)

3.3.2 Determination of total sugar content

Total sugars in both fresh and dried sample were extracted twice by dissolving 3 g of pulped sample in 30 mL 80%, wt/vol methanol (Wagtech Projects Ltd, Thatcham, Berks) and incubated at 60 °C for 30 minutes. The mixture was centrifuged at 4000 rpm for 10 minutes. One milliliter of supernatant was diluted with deionized water 100 times. Phenol-sulphuric acid method was used to determine the concentration of sugars (Dubois *et al*., 1956). Briefly, 2 mL of the diluted sample was mixed with 80%, wt/wt phenol (Loba Chemie Pvt. Ltd, India). After 15 minutes, 5 mL of concentrated sulphuric acid (Loba Chemie Pvt. Ltd, India) was added, left for 10 minutes at ambient temperature and placed in a thermostatic waterbath (S/N A114120801-64 Wagtech Project) at 27 °C for 10 minutes. The absorbance of the sample mixture was measured at 490 nm on the Ultraviolet visible spectrophotometer (UNICO-Spectrophotometer, USA). The standard calibration curve of glucose (Merck Chemicals (Pty) Ltd, Gauteng, RSA) (Appendix 1) was used to determine sugar concentration of fruit sample. Result was expressed as g/100 g (dry basis).

3.3.3 Determination of carotenoid contents

Carotenoid content of fresh and dried fruit sample was extracted and determined as described by Perez-lopez (2010) and AOAC (1980) with little modification. Five grams of well pulped sample was placed into a 50 mL falcon tube. Then, 40 mL of extraction solvent; Hexane (Gato Perez, 33-P.I.Mas d'En Cisa, Spain): Acetone (Loba Chemie Pvt. Ltd, India): Ethanol (Wagtech Projects Ltd, Thatcham, Berks) at the ratio of 2:1:1 (vol/vol/vol) was added and the mixture was centrifuged at 4000 rpm for 5 minutes. The residue was re-extracted until became colorless. The top layer of hexane was transferred into a separating funnel and 50 mL of 10%, wt/vol sodium chloride (Uni-Chem, Chemical Reagents) was added to remove residual acetone. The upper phase was recovered, dried over anhydrous sodium sulphate (Loba Chemie Pvt. Ltd, India) and absorbance was measured at 450 nm. The level of carotenoids of fruit sample was expressed as g/100 g (dry basis) based on the calibration curve of β-carotene (Sigma-Aldrich, USA) (Appendix 1).

3.3.4 Determination of total ascorbic acid content

Sample (fresh and dried products) and reagent preparation and subsequent determination of total ascorbic acid was conducted as described by Kapur *et al*. (2012). Briefly, 5 g of fruit sample was mixed with 25 mL of 3% metaphosphoric acid – 8% acetic acid solution (Loba

Chemie Pvt. Ltd, India) and centrifuged at 4000 rpm for 15 minutes. Four millilitres of the extract was treated with 0.23 mL of bromine water followed by 0.13 mL of 10% thiourea solution (Loba Chemie Pvt. Ltd, India) and then 1 mL of 2, 4-dinitrophenylhydrazine solution (B.D.H Laboratory Chemicals Group, England). The mixture was kept in a waterbath (S/N A114120801-64 Wagtech Project) at 37 °C for 3 hours, cooled in an icebath (Ice maker S/N 14728341, China) for 30 minutes and then mixed with 6 mL of chilled 85% sulphuric acid solution. Absorbance of the resulted red solution was measured at 521 nm by using spectrophotometer (UNICO-spectrophotometer, USA). The total ascorbic acid content (mg/100 g on dry basis) was estimated from the calibration curve of ascorbic acid (Merck Chemicals (pty) Ltd, RSA) (Appendix 1).

3.3.5 Determination of total phenolic content (TPC) and Tannin content

Sample assay solution from fresh and dried fruits was prepared as described by Ojha *et al*. (2017). Ten grams of pulped fruit sample was mixed with 30 mL 80% methanol and centrifuged at 3000 rpm for 15 minutes. The residue was re-extracted twice. One milliliter (1 mL) of the methanol extract was diluted to 10 mL with extraction solvent. The total phenolic content (TPC) was estimated according to Folin-Ciocalteu method as described by Mahdavi *et al*. (2011). Briefly, an aliquot (0.5 mL) of the diluted sample was mixed with 2.4 mL of deionized water, 2 mL of 2%, wt/vol sodium carbonate (Loba Chemie Pvt. Ltd, India) and 0.1 mL of Folin-Ciocalteu reagent (Loba Chemie Pvt. Ltd, India). The mixture was incubated in dark place at room temperature for 60 minutes. Absorbance of the sample was measured at 750 nm. TPC (mg/100g GAE dry basis) was estimated based on the calibration curve of gallic acid (Loba Chemie Pvt. Ltd, India) (Appendix 1).

The non-tannin phenolic content was determined by mixing 2 mL of the diluted sample with 100 mg of polyvinyl-polypirrolidone (Merck, E. Merck, Darmstadt). The mixture was vortexed, left for 15 minutes at 4 °C and centrifuged for 3000 rpm for 10 minutes, followed by the determination of non-tannin phenolics in the extract. The level of tannins was estimated as the difference between total phenolics and non-tannin phenolics in the fruit samples.

3.3.6 Rehydration efficiency of dried cashew apple products

Dried cashew apple products (10 g) were rehydrated by immersing in boiling water contained in a beaker placed on a magnetic stirrer with a heater (MR Hel-Standard, Germany) for 20 minutes at a ratio of 1:10 (weight of product: weight of water). The immersed wet products were removed, drained and allowed to cool at room temperature. Rehydration coefficient (RC), rehydration ratio (RR), and water content were computed according to formulae by Srivastava and Kumar (2012).

$$RR = \frac{drained\ weight\ of\ rehydrated\ sample, g}{weight\ of\ dehydrated\ sample\ taken\ for\ rehydration\ test, g}$$

$$RC = \frac{drained\ wt.of\ rehydrated\ sample - dry\ matter\ of\ sample\ for\ rehydration}{drained\ weight\ of\ rehydrated\ sample} x100$$

3.3.7 Microbial analysis of dried cashew apple slices

Bacterial and fungal count were analyzed separately by pour plate technique as described by (Kaushalya & Weerasooriya, 2017) with little modification. Briefly, 1 g of dried cashew apple slices was mixed with 9 mL of sterile peptone salt and vortexed for 5 minutes. Then, 1 mL of the suspension was transferred into the peptone salt diluents (9 mL) up to 10^{-3} of dilution series. From each dilution, 1 mL of diluted sample was inoculated into the respective growth medium: Plate count agar (PCA) for bacteria and potato dextrose agar (PDA) for yeast and mold. The incubation conditions were 1 day at 30 °C for bacteria and 3 days at 30 °C for yeast and mold.

3.4 Sensory evaluation of dried cashew apple products

The organoleptic attributes of the dried products were evaluated using a 5-point hedonic scale with respect to taste, color, aroma, texture, astringent and overall acceptability. The scale except for astringency was ranged from 1 ‘dislike very much’ to 5 ‘like very much’ as described by (Bidaisee & Badrie, 2001). The scores for astringency were ranged from 5 ‘no astringent’ to 1 ‘extremely astringent’. Two hundred untrained panelists from Morogoro region (non-cashew producing area) and Mtwara region (cashew producing area) were used to evaluate the samples in a well-designed room with appropriate condition of fragrance, wind, sound and light. The panelists who were between 18 - 60 years old and registered as a cashew farmer were included in a study in Mtwara. Meanwhile, panelists who were aged between 18 - 60 years old and do not know cashew apples were included in a study in Morogoro. Samples were given to the panelists in a randomized order. Samples were coded alphabetically: A = Solar dried sample; B = Hot air dried sample; C = Hot air dried sample without osmotic treatment as a control.

3.5 Shelf life studies

The dried cashew apple products in a low-density polyethylene laminated aluminum pouches (Appendix 2F and 2G) were stored at ambient temperature (26 ± 1 °C) and away from sunlight. Thereafter, the dried products were analyzed for shelf life stability at a time frame of 0, 30 and 60 days on the following parameters; pH, moisture content, total acidity, total ascorbic acid, total phenolic contents, tannin contents, carotenoid contents and microbial quality. Physico-chemical parameters and microbial colony count were determined as described in section 3.3.

3.6 Statistical analysis

In exploratory survey, the information were collected using the Open Data Kit (ODK) software, coded, organized and uploaded to the Statistical Package for the Social Sciences (SPSS) version 20.0. Data were analyzed and presented using descriptive statistics (mean, standard deviation and percentages). The percentages were obtained for each group with similar responses in multiple answered questions. Comparative analysis was performed by using Chi square test to evaluate the differences regarding farmers' consumption patterns, knowledge on the importance of cashew apples, processing of cashew apples, post-harvest constraints and socio-demographic characteristics. For laboratory experiment, data were analyzed by one-way analysis of variance, except on rehydration efficiency where independent t-test was applied with the aid of statistical package (SPSS). All measurements were conducted in triplicate and results presented as mean ± standard error of the mean. The Duncan's Multiple Range Test was applied to evaluate the significant difference of the means at $p < 0.05$.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Socio-demographic profile of participants and cashew nut production

The finding from this study shows a fair participation of both female (45.3%) and male (54.7%) ($\chi^2 = 4.33$; $p = 0.23$) (Table 1). This could be due to similarity in ratio of both gender in a study area and each gender could own cashew farm. It is noteworthy that, the contribution of women in agriculture and cashew industry in particular is well recognized (Njuki *et al*., 2013). The average age of the farmers significantly varied ($p = 0.04$) across the four districts, with the overall mean age of 46.02 years (Table 1), which is in middle age category. Though due to the importance of cashew farming as a cash crop in the area, the contribution of youth and elders cannot be ignored. This is attributed by the fact that, the government raised the price of cashew nuts from 2000 to about 3500 TZS per Kg in 2018/2019 season, with the government being the primary market of cashew nuts. A fair selling price of the produce may encourage more individuals especially young to engage in cashew farming. According to Segrè *et al*. (2014), the availability of a reliable market influence the higher production of crops and hence more participation of people in farming. Most of the participants had primary school education (81.98%) ($\chi^2 = 18.88$; $p = 0.09$). About 83.28% of the participants had between 2 to 5 individuals in their household. In addition, the average number of individual did vary ($p = 0.001$) across the surveyed districts with the average of four individuals per household (Table 1). Moreover, the majority of the participants in all districts owned less than 5 ha (58.83%) ($\chi^2 = 73.43$; $p = 0.001$) and had a cashew farming experience of more than 10 years (64.25%) ($\chi^2 = 17.86$; $p = 0.01$) (Table 2). Furthermore, cashew nut yields varied significantly ($p = 0.01$) across the districts, with 69.7% of farmers obtained more than 600 Kg per season (Table 2).

Table 1: Socio-demographic characteristics of the participants

Variable		District					
		Tandahimba	Masasi rural	Lindi rural	Nachingwea	Mean (SD)	Chi square
Gender (%)	Male	60.7	56.0	47.6	54.5	54.7 (5.42)	χ^2 = 4.33; df = 3; *p* = 0.23
	Female	39.3	44.0	52.4	45.5	45.3 (5.42)	
Education level (%)	None	12.0	13.2	10.5	8.5	11.05 (2.03)	χ^2 = 18.88; df = 12; *p* = 0.09
	Primary	78.6	79.2	87.1	83.0	81.98 (3.93)	
	Secondary	6.0	3.8	2.4	8.0	5.05 (2.46)	
	College	3.4	3.7	0.0	0.5	1.90 (2.05)	
Age (%)	18-29	6.8	9.4	8.9	7.0	8.03 (1.32)	χ^2 = 22.22; df = 12; *p* = 0.04
	30-39	29.9	31.4	26.6	20.5	27.10 (4.84)	
	40-49	23.1	24.5	33.9	32.5	28.50 (5.49)	
	50-59	21.4	20.1	24.2	19.0	21.18 (2.24)	
	> 59	18.8	14.5	6.5	21.0	15.20 (6.40)	
Age (Years)	Mean (SD)	45.99 (12.92)	44.21 (11.85)	44.70 (10.30)	48.28 (14.03)	46.02 (12.63)	
Household size (%)	1	0.9	1.9	0.0	5.0	1.95 (2.18)	χ^2 = 43.35; df = 6; *p* = 0.001
	2-5	74.4	76.7	93.5	88.5	83.28 (9.20)	
	> 5	24.8	21.4	6.5	6.5	14.8 (9.68)	
Household size	Mean (SD)	4.64 (1.63)	4.41 (1.58)	3.64 (1.09)	3.58 (1.35)	4.02 (1.50)	

Table 2: Socio-demographic characteristics of the participants and cashew nut production

Variable		District					
		Tandahimba	Masasi rural	Lindi rural	Nachingwea	Mean (SD)	Chi square
Years in cashew farming (%)	1-5	13.7	12.6	13.7	16.0	14.00 (1.43)	χ^2 = 17.86; df = 6; p = 0.01
	6-10	23.1	22.6	29.8	11.5	21.75 (7.58)	
	> 10	63.2	64.8	56.5	72.5	64.25 (6.57)	
Cashew farm per household (%)	0.5-5.0	61.5	44.0	61.3	68.5	58.83 (10.44)	χ^2 = 73.43; df = 9; p = 0.001
	5.5-10.0	17.1	18.9	29.0	20.0	21.25 (5.30)	
	10.5-15.0	0.9	18.2	6.5	3.5	7.28 (7.63)	
	> 15.5	20.5	18.9	3.2	8.0	12.65 (8.40)	
Cashew farm per household (ha)	Mean (SD)	22.83 (54.29)	11.26 (14.32)	5.78 (4.10)	6.10 (7.81)	10.64 (26.18)	
Yields in Kg (%)	< 200	7.7	6.9	0.0	6.0	5.15 (3.50)	χ^2 = 26.93; df = 12; p = 0.01
	200-400	14.5	10.1	3.2	7.0	8.70 (4.79)	
	401-600	17.9	17.0	17.7	12.5	16.28 (2.55)	
	> 600	59.8	66.0	79.0	74.0	69.7 (8.50)	

4.1.1 Consumption of cashew apple fruits

Unlike the nuts, cashew apple (the *pseudo* fruit) has not been given any attention in cashew farming and therefore there were no information on cashew apple production and yield. Instead, incidential seasonal consumption and utilization of the fruit were collected. On average, 97.68% (χ^2 = 4.29; p = 0.23) of farmers across the surveyed districts reported to consume raw cashew apples, out of which about 54.63% (χ^2 = 126.56; p = 0.001) consume only at farm during farming activities to quench thirst and hunger (Table 3). This provides minor reason (s) such as inconveniences to carry the fruits all way back home. This could be due to the lack of knowledge on post-harvest handling as well as lack of electricity in some areas which is necessary for modern cold storage to increase shelf life of the fruits (Nwosu *et al.*, 2016). About half of consumers consume both at home and farm, and this could be due to the fact that, in some areas cashew farms are near to the residential houses, thus consumption at both places seem to be possible regardless of the lack of preservation technologies. In addition, a handful of fruits could be brought home not only for raw consumption but also for the preparation of local products such as porridge "*mkongohu*" and an alcoholic drink "*uraka*". Based on district, majority of respondents who claimed to consume cashew apples only at their farm come from Lindi rural (87.7%), while those who consume both at home and farm come from Nachingwea (73.5%).

Of those who consume cashew apple fruits, about 38.13% (χ^2 = 81.62; p = 0.001) reported to consume between 1 to 5 fruits a day while other respondents could consume more than 15 fruits a day. In addition, the number of fruits eaten a day significantly depended on the district of respondents. For instance, in Tandahimba majority (60.2%) of respondents could consume between 1 to 5 fruits a day, while in Lindi rural majority (52.5%) claimed to consume between 6 to 10 fruits a day. Furthermore, 55.98% (χ^2 = 215.81; p = 0.001) of the consumers consume cashew fruits almost every day during the season (Table 3). This could be influenced by low astringency in some varieties or high sugar content that mask the astringency taste. Most cashew apple varieties grown in the country were found to contain a significant amount of sugars (Msoka *et al*., 2017), thus increase sweetness of the fruits that might have triggered the high rate of consumption. The frequency of consumption significantly depended on respondents' district, with the large number of respondent (94.3%) who could consume cashew apples almost everyday come from Lindi rural.

Regarding the knowledge on the importance of cashew apples, about 53% (χ^2 = 75.19; p = 0.001) of the consumers reported to mainly consume cashew apples simply because they are fruits. Other reasons such as sweetness (26%) (χ^2 = 7.25; p = 0.06), good for health (23%) (χ^2 = 69.20; p = 0.001), quench thirst and hunger (10%) (χ^2 = 20.77; p = 0.001), and due to appetite (1%) (χ^2 = 4.31; p = 0.23) (Fig. 5) were also pointed out. On the other hand, a small proportion of those who do not consume these fruits claimed due to astringency, health problems, feeling of dislike and fear to pesticides used during cashew production (Table 4). The small proportion of those who associate cashew apples with health problem claimed that, consuming raw cashew apples raises heartbeat rates due to high sugar content. These reasons clearly reflects the lack of knowledge on the importance of cashew fruits, even though some responses show that consumers are aware of the contribution of fruits to human health. From the scientific point of view, cashew apple fruits have antioxidant and anti-inflammatory characteristics which are known to prevent or treat chronic diseases such as cholera, cancer, cardiovascular diseases (Runjala & Kella, 2017). Thus, the observed lack of knowledge could be attributed partly by the low education level of the consumers. Therefore, training on the importance of cashew apple particularly at village level is necessary to increase awareness of the vital health benefit of cashew apples in human health and also to promote postharvest handling, value addition and market demand.

Table 3: Farmers' consumption habits of raw cashew apples across the surveyed districts

Variables		District					
		Tandahimba	**Masasi rural**	**Lindi rural**	**Nachingwea**	**Mean (SD)**	**Chi square**
Raw consumption (%)	Yes	95.7	99.4	97.6	98.0	97.68 (1.53)	χ^2 = 4.29; df = 3; *p* = 0.23
	No	4.3	0.6	2.4	2.0	2.33 (1.53)	
Place (%)	Home	0.0	0.6	0.8	0.0	0.35 (0.41)	χ^2 = 126.56; df = 6; *p* = 0.001
	Farm	61.9	42.4	87.7	26.5	54.63 (26.38)	
	Both	38.1	57.0	11.5	73.5	45.03 (26.62)	
Number of fruits per day (%)	1-5	60.2	37.3	21.3	33.7	38.13 (16.23)	χ^2 = 81.62; df = 9; *p* = 0.001
	6-10	26.5	23.4	52.5	41.3	35.93 (13.53)	
	11-15	6.2	19.0	14.8	3.6	10.90 (7.22)	
	> 15	7.1	20.3	11.5	21.4	15.08 (6.92)	
Number of days per week (%)	1	15.0	6.3	0.0	6.6	6.98 (6.15)	χ^2 = 215.81; df = 12; *p* = 0.001
	2	11.5	3.2	0.0	11.7	6.60 (5.92)	
	3	11.5	8.9	4.1	14.8	9.83 (4.53)	
	4-5	37.2	41.1	1.6	2.6	20.63 (21.45)	
	6-7	24.8	40.5	94.3	64.3	55.98 (30.27)	

Table 4: Reasons for not consuming raw cashew apples (N = 13)

Reasons	Frequency	Percentage (%)
Astringency	4	33
Health problems	3	25
Do not like cashew apples	3	25
Pesticide	2	17

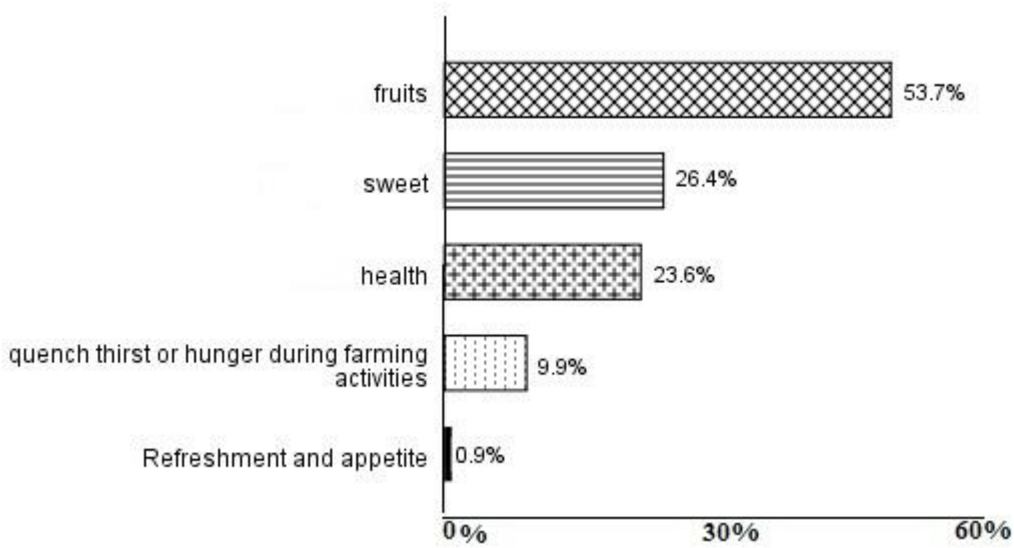

Figure 5: Reasons for consuming raw cashew apples

4.1.2 Processing of cashew apples

In this survey, majority of the farmers (56.3%) across the surveyed districts did not process cashew apples (Table 5). Based on the analysis it shows that, processing of cashew apples was significantly influenced by the farmers' location (χ^2 = 146.34; p = 0.001), and household size (χ^2 = 14.59; p = 0.001), however it was not significantly influenced by farmers' gender (χ^2 = 3.32; p = 0.07), age (χ^2 = 7.90; p = 0.10), and cashew farming experience (χ^2 = 0.69; p = 0.71). The results also revealed that, a large proportion of respondents who process cashew apples come from Lindi rural (77.4%) and those who do not process come from Tandahimba district (84.6%).

Moreover, amongst the processing methods applied in the study areas, cooking of cashew apples into porridge locally known as *Mkongohu* was mentioned by 64.7% of the farmers, followed by fermentation of local brew (30.6%), sun drying (21.2%) and juice processing by smallest proportion (1.5%) of farmers (Table 6). Cashew apple honey was reported to have been practiced years back but had phased out due to dominance of the widely available bee honey and which sales more in the market. The study also revealed that, value-added products such as jams, wine, marmalades and ethanol, which are produced in industrialized countries were not familiar in the study area. This could be due to the low level of awareness due to low acess to modern media, education and training of the individuals in the study areas. *Mkongohu* is the major traditional processed product due to the fact that, it is easy to prepare and cost-effective, sweet and non-alcoholic. Unlike *Mkongohu*, the fermented "*Uraka*" and distilled

"*Nipa*" beverages are preferred mainly as a source of income. For instance, *Uraka* normally sold at 500 TZS per litre, while 200 mL of *Nipa* is sold at 500 – 1000 TZS.

Nipa is prepared by soaking sun-dried cashew apples in water for about one week and thereafter simple distillation of the filtered liquid. Unlike *Uraka*, *Nipa* is processed throughout the year due to the fact that it uses dried apple fruits which could be stored for about a year. From the market perspective, *Nipa* is a good income generator for cashew farmers, but very unfortunately the Government of Tanzania banned the production of local distilled alcohol due to their considerable potentially high and unregulated alcohol contents. Therefore, better alternatives should be addressed in this regard to help people in these areas to efficiently exploit the benefits out of the cashew apple fruits. On the other hand, majority of participants who do not process cashew apple (55.2%), claimed due to lack of skills and quality processing technologies (Fig. 6).

Table 5: Processing of cashew apples by some demographic characteristics

Variable		**Processing of cashew apples**		
		Process	**Do not process**	**Chi Square**
Districts (%)	Tandahimba	15.4	84.6	
	Masasi Rural	22.0	78.0	
	Lindi Rural	77.4	22.6	
	Nachingwea	60.0	40.0	
	Mean (SD)	43.7 (29.85)	56.3 (29.85)	χ^2 = 146.34; df = 3; p = 0.001
Gender (%)	Male	41.5	58.5	
	Female	48.9	51.1	
	Mean (SD)	45.2 (5.23)	54.8 (5.23)	χ^2 = 3.32; df = 1; p = 0.07
Age (%)	18-29	39.6	60.4	
	30-39	38.4	61.6	
	40-49	52.0	48.0	
	50-59	48.0	52.0	
	> 59	41.1	58.9	
	Mean (SD)	43.82 (5.89)	56.18 (5.89)	χ^2 = 7.90; df = 4; p = 0.10
Household size (%)	1	35.7	64.3	χ^2 = 14.59; df = 2; p = 0.001
	2-5	48.2	51.8	
	> 5	26.2	73.8	
Years in cashew farming (%)	1-5	41.2	58.8	χ^2 = 0.69; df = 2; p = 0.71
	6-10	43.9	56.1	
	> 10	45.9	54.1	

Table 6: Technologies employed by participants to process cashew apples

Technologies	Products	Percentage (%)
Cooking	Porridge (*Mkongohu/Totori/Togwa*)	64.7
Alcohol fermentation	Fermented drink (*Uraka*) and distilled (*Nipa*)	30.6
Sun drying	Dried cashew apples (*Kochoko*)	21.2
Juice processing	Juice	1.5

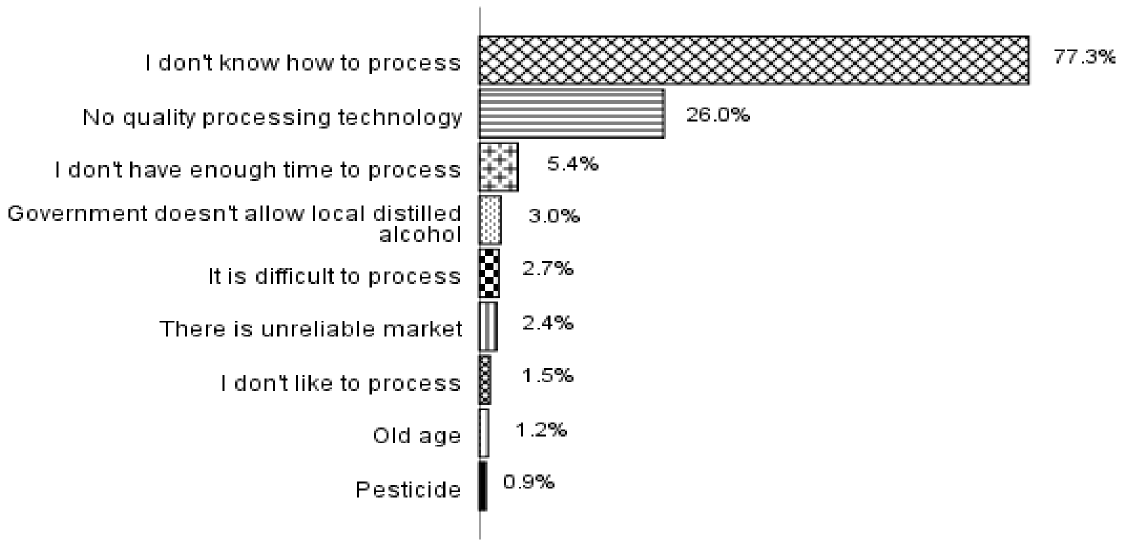

Figure 6: Reasons given by participants who do not process cashew apples

4.1.3 Post-harvest constraints of cashew apple utilization

Amongst the constraints that hinder efficient utilization of cashew apples (Fig. 7), the lack of knowledge on handling the produce after harvest was mentioned by 86.2% (χ^2 = 58.19; p = 0.001) of farmers, followed by the lack of quality processing technology (82.7%) (χ^2 = 60.58; p = 0.001), and absence of reliable market (39.8%) (χ^2 = 13.07; p = 0.004). Other constraints included the low price of the produce (10.5%) (χ^2 = 21.20; p = 0.001), lack of reliable power source such as electricity (4.5%) (χ^2 = 35.58; p = 0.001) and astringent properties of the fruit (0.7%) (χ^2 = 16.62; p = 0.001). Therefore a large proportion of cashew apples are left to rot in the field, and some are used for feeding domesticated animals such as cows, sheep and goats.

From the nutrition perspective, the rural dwellers benefit the potential of cashew apples mostly through direct consumption of the fruit and locally processed products like *Mkongohu* and *Uraka*. However, this benefit disappears during the off-season due to the very short shelf life of the fruits and the two products. As a result, a huge post-harvest loss of the fruits is encountered due to the lack of knowledge on proper post-harvest handling and processing technologies. These challenges, among others, hinder the efficient utilization of cashew apples. The results are in agreement with that of Nwosu *et al*. (2016) who claimed the same constraints to limit utilization of cashew fruits in Nigeria. Therefore, it is important to acknowledge that the establishment of processing industries, reliable market and provision of education and training could reduce post-harvest losses of the fruits, increase consumers' awareness on its health benefit and economic value.

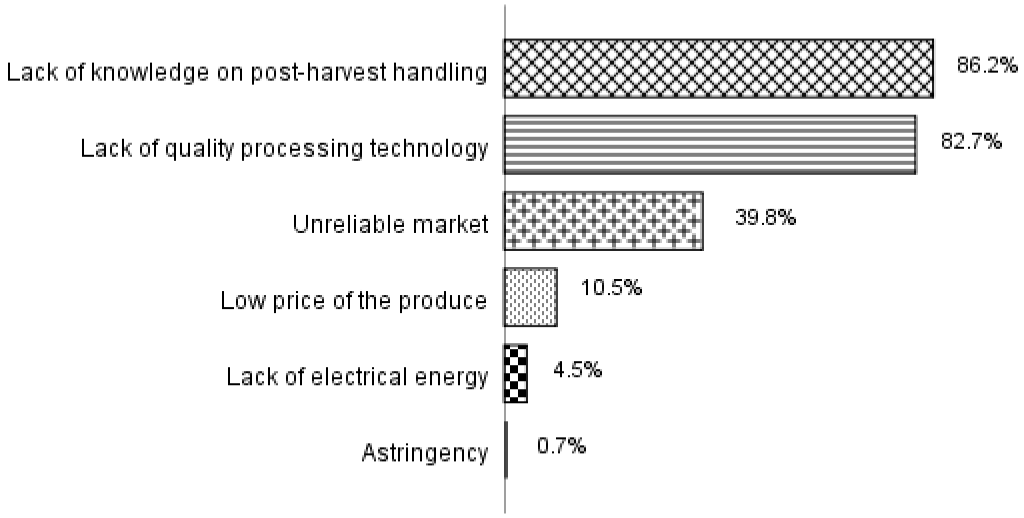

Figure 7: Cashew apples' post-harvest constraints encountered by cashew farmers

4.1.4 Opinions to improve cashew apple utilization

When the participants were asked to give their opinions on ways to efficiently utilize cashew apples, the majority proposed establishment of processing industries, education to the community on suitable processing techniques and importance of cashew apples (Fig. 8). Furthermore, some participants urged the government to guide of ways to improve the quality of "*nipa*", regulate and legalize its production as it is the convenient way to utilize cashew apples and increase both an individual's income and government revenues.

At present in Tanzania, there is no standardized and commercialized cashew apple product in the market. Similarly, in other African countries such as Ghana, Benin and Guinea-Bissau there is little effort regarding cashew apple usage. It is reported that, no country in Africa is processing greater than 1% of its total cashew apple production (Yantannou, 2017). Therefore, there is a clear post-harvest loss of cashew fruits which on the other hand create a window of market opportunities for value added products in the country and Africa as a whole.

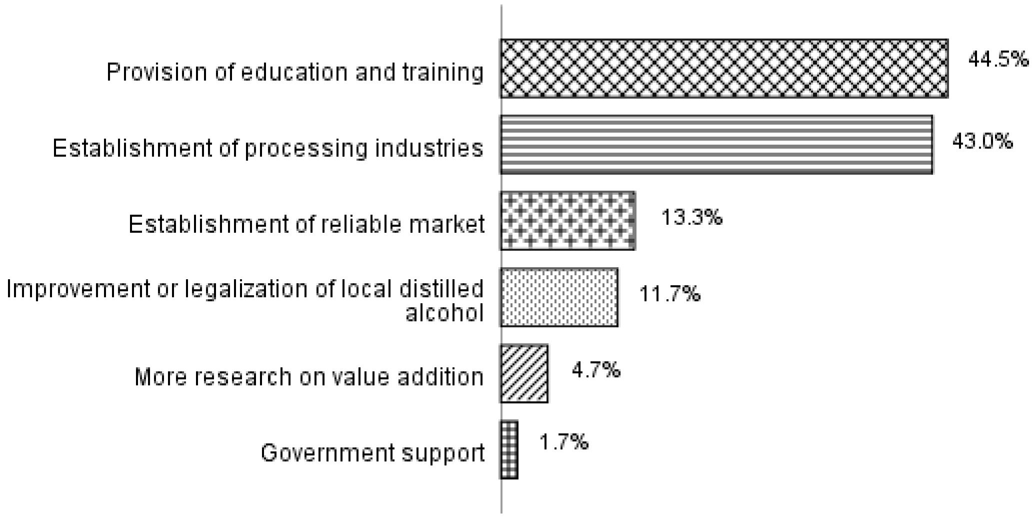

Figure 8: Opinions from the cashew farmers to improve cashew apple utilization

4.2 Processing of dried cashew apple products

4.2.1 Osmotic dehydration of cashew apples

The results (Table 7) revealed that, sucrose concentration and blanching have positive effect on water loss and solid gain ($p < 0.05$). Samples dehydrated in 70% sucrose concentration with or without blanching showed significantly higher water loss and solid gain. This is attributed by the increase in osmotic gradients as solute concentration increases hence higher loss of water and solid gain (Djendoubi *et al.*, 2013; Yadav & Singh, 2014). The percent water loss was observed to be higher in samples immersed in sucrose solution without blanching. However, there is no significant difference on water loss in samples immersed in 70% sucrose solution without blanching and with hot water blanching ($p > 0.05$). On the other hand, hot water blanched fruit slices at 70% sucrose concentration had significantly ($p < 0.05$) higher percent of solid gain.

Before drying, fruits are blanched for several factors to maintain product quality such as, denaturation or inactivation of enzymes, removal of intracellular air, reducing drying time, softening of the texture and reducing tannin contents (Bidaisee & Badrie, 2001; Emelike & Ebere, 2016; Lewicki, 1998). However, during blanching in boiled water, the selective permeability of plant cellular membranes to water increased due to the alteration of microstructure as a result of the physical damage of the fruit hence improved water absorption (Lewicki, 1998). In addition, blanching could have increased the permeability of cell structures to sugar solution. This could in part explain the observed changes of water loss and solid gain between the blanched and non-blanched samples. Hot water blanched samples in 70% sucrose solution were chosen for product development.

Table 5: Influence of blanching and osmotic solution on kinetics of osmotic dehydration

Pretreatment	Sucrose concentration (%)	Water loss (%)	Solid gain (%)
No blanching	60	37.63 [b]	22.78 [a]
	70	46.11 [c]	26.65 [b]
Hot water blanching	60	32.53 [a]	27.42 [b]
	70	43.47 [c]	30.88 [c]

Means with the similar letter in the same column are not statistically different from each other ($p > 0.05$)

4.2.2 Physicochemical parameters of fresh and dried cashew apples

The physicochemical parameters of fresh cashew apples, mixed solar dried, and hot air oven dried fruit product were compared (Table 8). The level of moisture in the dried fruit samples was maintained below 16% on dry basis to inhibit the growth of spoilage microorganism hence prolong the shelf life of product. Moreover, the maximum permissible moisture content for osmotic dehydrated fruits is 20% on a dry basis as per the CODEX General Standard (CODEX STAN 130-1980). Both dried fruit products had significantly ($p < 0.05$) lower total acidity and higher pH values than fresh fruit. This could be due to leaching of organic acids during osmosis (Ramya & Jain, 2016; Yadav & Singh, 2014). There was significant increase of total sugar content in dried products due to the uptake of sugars during osmotic treatment. Furthermore, the reduction of organic acids and uptake of sugars during osmotic treatment resulted in sweeter products compared to conventionally dried products (Yadav & Singh, 2014).

Ascorbic acid is the principle nutritional compound in cashew apple. The edible portion is reported to contain about four times the amount of ascorbic acid as compared to other fruits including mango, orange and pineapple (Akinwale, 2000). The dried products had significantly ($p < 0.05$) lower total ascorbic acid content than in the fresh fruit (Table 8). The loss of ascorbic acid could be due leaching during osmotic dehydration (Ramya & Jain, 2016), oxidation at higher temperature (Reis *et al*., 2013) and to a lesser extent during blanching (Lagnika *et al*., 2019). The lower ascorbic acid content of solar dried sample could be attributed by the longer drying time, exposure to sunlight and higher temperature inside the drier. The retained amount of ascorbic acid (850 mg/100g and 730 mg/100g for hot air and solar dried samples respectively) is still higher compared to fresh fruits such as strawberry, lemon, orange and grapefruit reported by (Szeto *et al.*, 2002). The retained amount of ascorbic acid in both dried products suggests that the products could still save as a good source of ascorbic acid.

Cashew apples contain significant amount of polyphenolic constituents such flavonoids and phenolic acids (Marc *et al.*, 2012). Polyphenols possess antioxidant and anti-inflammatory activities, hence important in prevention and treatment of chronic diseases such as cancer and cardiovascular diseases (Zhang *et al.*, 2015). Total phenolic content of dried cashew apples was significantly ($p < 0.05$) lower than in fresh fruit (Table 8). Leaching during osmotic dehydration and hot water blanching, and thermal degradation during blanching could be responsible for the decrease in total phenolic contents as reported previously (Bamidele *et al.*, 2017; Lagnika *et al.*, 2019; Larrauri *et al.*, 1997). Solar dried samples had significantly lower ($p < 0.05$) total phenolic content compared to hot air dried samples. This could be due to higher temperatures inside the drier. Larrauri *et al.* (1997) reported a significant loss of total phenolic content and anthocyanin in red grape peels dried at over 60 °C. Similar to red grapes, anthocyanin is also found in red cashew apples. After blanching red cashew apples turned yellow, indicating the loss of anthocyanin.

The astringent property of cashew apples is attributed mainly by tannins which is intentionally reduced to improve product acceptability. Blanching in hot water or steam is reported to reduce tannin content in cashew apples (Bidaisee & Badrie, 2001; Emelike & Ebere, 2016). Tannins are mainly found in the waxy layer of cashew apple skin, with the hydrolysable tannins present in higher concentration than condensed tannins (Emelike & Ebere, 2016). In this study, tannin contents in dried products is significantly reduced ($p < 0.05$) compared to that of fresh fruit (Table 8) owing mainly due to hot water blanching.

Carotenoid contents were varied between dried products and fresh fruit (Table 8). Dried samples had significantly lower ($p < 0.05$) amount of carotenoids compared to fresh fruit. Though solar dried samples presented the lowest carotenoid content than hot air dried samples, the difference was not significant ($p > 0.05$). The loss of carotenoids could be due to blanching and higher drying temperature. Carotenoids are reported to be more susceptible to drying temperature than drying time. According to Mohamed and Hussein (1994), carotenoids were highly retained for samples dried at 40 °C for longer time than above 40 °C for shorter time. The values of carotenoid content of dried products were similar to those reported by Mini and Archana (2016).

Table 6: Physicochemical parameters of fresh and dried cashew apples

Parameters	Fresh fruit	Hot air oven dried products	Solar dried products
Moisture content (%)	81.31±0.18 [b]	15.02±0.66 [a]	13.81±0.28 [a]
pH	3.80±0.01 [a]	4.31±0.05 [b]	4.55±0.03 [c]
Total titratable acidity (%)	0.32±0.01 [b]	0.20±0.01 [a]	0.19±0.01 [a]
Sugar content (g/100g db)	101.10±1.80 [b]	298.75±5.05 [a]	297.99±5.75 [a]
Carotenoids (g/100g db)	1.33±0.02 [b]	0.33±0.03 [a]	0.28±0.01 [a]
TPC (mg/100g GAE db)	815.32±9.59 [c]	671.26±29.97 [b]	542.75±6.15 [a]
Tannins (mg/100g GAE db)	388.96±7.37 [b]	267.95±18.06 [a]	266.59±1.89 [a]
Total ascorbic acid (g/100g db)	1.95±0.09 [b]	0.85±0.01 [a]	0.73±0.01 [a]

Means with similar letter in the same row are not significantly different from each other (p > 0.05). GAE: Gallic acid equivalent; db = dry basis; TPC: Total phenolic content

Rehydration capacity of dried products could be used as quality indicator that determines the ability of the products to acquire moisture when in contact with moisture. Pretreatments (such as blanching and ultrasound) and drying conditions influence many changes to plant material subjected to rehydration (Lewicki, 1998). When the internal matrix of the fruit remains intact during drying, the collapse of fruit solid matrix is prevented after drying. The resulting product will have large voids or porous structure, and no shrinkage hence increase in rehydration efficiency (Lewicki & Pawlak, 2003). Solar dried products had higher values of rehydration ratio (p = 0.001), rehydration coefficient (p = 0.03) and percent water content (p = 0.024) than hot air oven dried products (Table 9). This could be attributed to porosity of solar dried samples due to good air movement inside the drier. Ultrasound as a pretreatment and freeze drying of fruits improve the rehydration of dried products than blanching and drying techniques such as hot air, microwave and vacuum drying (Beaudry *et al.*, 2004; Lagnika *et al.*, 2019; Ricce *et al.*, 2016).

Table 7: Rehydration efficiencies of dried cashew apple products

Fruit products	Rehydration ratio	Rehydration coefficient	Water content (%)
Solar dried products	1.39±0.01	0.38±0.03	71.94±0.32
Hot air oven dried products	1.21±0.02	0.29±0.01	69.68±0.55

4.2.3 Stability of dried cashew apple during storage at room temperature

Storage stability of dehydrated products was investigated for a period of 60 days (Table 10). No growth of bacteria or fungi observed during this period. In addition to nutrient loss during blanching, osmotic dehydration, and drying, a significant reduction could occur during storage. This loss could be attributed to packaging material, pH, storage temperature, light and oxygen exposure and organic acids present (Sablani, 2006). In this study, moisture content of dried products was significantly ($p < 0.05$) declined with the increase in storage days (Table 10). This could be due to continuous evaporation occurred during storage. It is noteworthy that, the loss of moisture in dehydrated products could be reduced by proper packaging material. Similar trends have also been reported by Kushwaha *et al*. (2018) on osmotic dehydrated guava fruit.

Total titratable acidity of dried products decreased significantly while pH values increase significant during storage (Table 10). A study by Mini and Archana (2016) showed similar trend on the reduction of total acidity of dehydrated cashew apple in a course of 6 months, while Kushwaha *et al*. (2018) observed an increase of total acidity of dehydrated guava during 45 days of storage. According to Sablani (2006), the nature of food material itself plays a significant part on nutrient retention. Both drying methods showed the same pattern of changes on pH and total acidity during storage.

Total ascorbic acid of dried products was observed to change during storage (Table 10). Hot air oven dried samples showed no significant difference ($p > 0.05$) in ascorbic acid after 30 days of storage and between 30 to 60 days of storage. However, the total ascorbic acid decreased significantly ($p < 0.05$) from day 0 to day 60 during storage. For solar dried samples, a significant decrease ($p < 0.05$) of total ascorbic acid after 30 days and 60 days of storage was observed. The observed loss could be due to water solubility and oxidation of ascorbic acid to furfural compounds (El-Gharably *et al*., 2014). Similar reduction of total ascorbic acid during storage has been reported in osmotic dehydrated cashew apples (Mini & Archana, 2016) and osmotic dehydrated guava (Kushwaha *et al*., 2018).

Hot air oven dried samples showed no significant difference ($p > 0.05$) in carotenoid content during 60 days of storage (Table 10). In contrast, there was a significant decrease ($p < 0.05$) of carotenoid content in solar dried samples during 60 days of storage. This could be attributed to high porosity nature of solar dried sample compared to hot air dried sample. Porosity of dried samples facilitates oxygen transfer, hence the oxidation of carotenoids (Sablani, 2006). For example, air dried carrots were observed to retain more carotenoids than freeze-dried carrots during storage at room temperature due to the fact that freeze dried carrots were more porous than air dried carrots (Kaminski *et al*., 1986). Storage of dehydrated products in a packaging material filled with nitrogen or vacuum could minimize the loss of carotenoids (Mini & Archana, 2016).

Total phenolic and tannin contents were significantly decreased ($p < 0.05$) after 60 days of storage at room temperature. Phenolic compounds, particularly in fruits and vegetables are very unstable to storage conditions such as storage time and temperature. A study by Mirsaeedghazi *et al*. (2011) has found that, total phenolic contents in pomegranate juice to be reduced (29%) when stored at -25 °C for 15 days. In addition DeOliveira *et al*. (2017) investigated the effect of storage temperatures (4, 25 and 40 °C) and storage time on total phenolic contents, total anthocyanin contents and tannin content of sorghum during 180 days of storage. The authors (DeOliveira *et al*., 2017) concluded that the reduction on total phenolics, total anthocyanins and tannins was greatly influenced by the storage time, with greater loss observed after 60 days of storage.

Table 8: Quality parameters of dried apple products during storage at room temperature

Parameters	Hot air oven dried products			Solar dried products		
	0 days	30 days	60 days	0 days	30 days	60 days
MC	15.02±0.66 [c]	10.19±0.18 [b]	8.37±0.03 [a]	13.81±0.28 [c]	9.95±0.14 [b]	8.05±0.15 [a]
pH	4.31±0.05 [a]	5.67±0.03 [b]	5.77±0.03 [c]	4.55±0.03 [a]	5.68±0.02 [b]	5.81±0.02 [c]
TTA	0.20±0.01 [b]	0.16±0.01 [a]	0.15±0.01 [a]	0.19±0.01 [c]	0.16±0.01 [b]	0.14±0.01 [a]
CC	0.33±0.03 [a]	0.31±0.01 [a]	0.30±0.01 [a]	0.28±0.09 [b]	0.24±0.01 [a]	0.23±0.01 [a]
TPC	671.26±29.97 [c]	519.34±2.03 [b]	360.84±1.58 [a]	542.75±10.66 [c]	412.00±3.94 [b]	274.44±4.85 [a]
TC	267.95±18.06 [b]	241.41±1.36 [b]	158.19±1.31 [a]	266.59±1.89 [c]	223±14±3.17 [b]	160.12±5.48 [a]
TAA	0.85±0.01 [b]	0.84±0.01 [ab]	0.83±0.01 [a]	0.74±0.01 [c]	0.70±0.01 [b]	0.60±0.01 [a]

Means with similar letter in the same row and within the same column *i.e.* Column for hot air oven dried products, and column for solar dried products are not statisticaly different from each other ($p > 0.05$). TTA: Total titratable acidity (%); MC: Moisture content (%); TPC: Total phenolic content (mg/100g GAE dry basis); TC: Tannin content (mg/100g GAE dry basis); GAE: Gallic acid equivalent; TAA: Total ascorbic acid (g/100g dry basis); CC: Carotenoid content (g/100g dry basis)

4.2.4 Sensory analysis of dried cashew apple products

Organoleptic characteristics of formulated products are important to be considered before the product is launched into the market (Fillion & Arazi, 2002). The scores for sensory attributes of dried products were summarized in Table 11. Products of treatment B (Hot air oven dried sample) exhibited significantly higher ($p < 0.05$) scores for texture. The texture of products of treatment A (Solar dried sample) was indicated by panelists to be tough than that of B, while that of treatment C (Hot air oven dried sample without osmotic treatment) was very tough hence the lowest score. There was no significant difference ($p > 0.05$) of scores between treatment A and B with respect to color, taste, aroma, astringent and overall acceptability. Products of treatment C had significantly lower score for all sensory attributes than other products, thus the lowest preferences. This was expected as treatment C had no osmotic pretreatment, and according to (Yadav & Singh, 2014) osmotic pretreatment prior to drying improves organoleptic attributes of dried products compared to conventionally dried products.

Table 9: Sensory evaluation scores of dried cashew apple products

Treatment	Color [1]	Texture [1]	Taste [1]	Aroma [1]	Astringent [2]	Overall acceptability [1]
A	4.91 [a]	4.86 [b]	4.92 [a]	4.94 [a]	4.90 [a]	4.87 [a]
B	4.96 [a]	4.93 [a]	4.95 [a]	4.95 [a]	4.96 [a]	4.93 [a]
C	3.54 [b]	3.18 [c]	2.81 [b]	3.25 [b]	2.77 [b]	3.07 [b]

Means with similar letters in the same column are not significantly different ($p > 0.05$). A: Solar dried sample; B: Hot air oven dried sample; C: Hot air oven dried sample without osmotic treatment. [1] Mean values based on 5 point Hedonic scale (5 = like very much; 1 = dislike very much); [2] Mean values on 5 point scale (5 = no astringent; 1 = extremely astringent)

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Cashew apple fruits are important source of nutrients and bioactive compounds beneficial to consumers' health, farmers' income and the economy of the country. Cashew apples in the selected areas were found to be highly underutilized and the small utilized proportion is mostly consumed in their raw state, with the frequency and number of fruits consumed by an individual being high. In addition, processing of the fruits into value added products was found to be a major concern, with few cashew farmers claimed to traditionally process cashew apples and all processed products are seasonal except distilled alcohol which is processed throughout the year. This implies that, the large quantity of fruits are being wasted. Among others lack of knowledge on proper post-harvest handling, lack of quality processing technology and lack of reliable market are the major constraints which hinder the proper utilization of cashew apples. Addressing these constraints would be a clear pathway towards the reduction of post-harvest losses.

This study also attempted to develop dried cashew apples with good acceptability as an approach to utilize the potential of these fruits. Blanching and osmotic dehydration could be used as a pretreatment prior to the actual drying to improve the quality of dried products in aspects such as astringent reduction, nutrient retention and improved organoleptic properties. It was revealed that, hot air oven dried and solar dried fruit slices had almost the same nutrient retention after processing and storage. Furthermore, both drying methods had similar overall acceptability. From these findings, hot air dried method is superior to solar dried method as less time is required for drying, hence reduced risk of spoilage. Sun's energy is abundant in nature, thus solar drying could be used as an alternative to hot air oven drying and other sophisticated drying methods which may be expensive and inaccessible to the low resource setting. One major drawback of solar drying though, is the inability to control the environmental conditions which may sometimes lead to spoilage of samples, hence tremendous loss of food material. Therefore, dried form of cashew apples could be regarded as a nutritious product and that could be processed in a large scale and sold to wide range market segment for both income, nutrition and food security. This will ultimately reduce the post-harvest losses of cashew apples encountered at the moment.

5.2 Recommendations

Considering the availability and nutritional potential of cashew apples in Tanzania, it is recommended that tremendous efforts needs to be invested in order to efficiently exploit the potential of cashew apples. Farmers should be given education and training on the importance of cashew apples and various quality processing technologies in order to increase awareness and avail this opportunity into the farmers and processors hands. Investment on small cashew apple processing plants in the production areas by the government and/or other stakeholders is of paramount to create awareness and market demand so as to improve food security, reduce post-harvest loses and improve the livelihood of the people through employment and income generation. Moreover, the research for development (R&D) and scientific communities are called upon to pay better attention to the research concerning value addition of cashew apples to increase its market value and eventually reduce the losses. Furthermore, the government should equally encourage the establishment of processing industries and fund researches related to cashew apples value addition and marketing as it happens in cashew nuts. This will enable a remarkable reduction of post-harvest losses encountered at present and in general contribute to the growth of national's economy.

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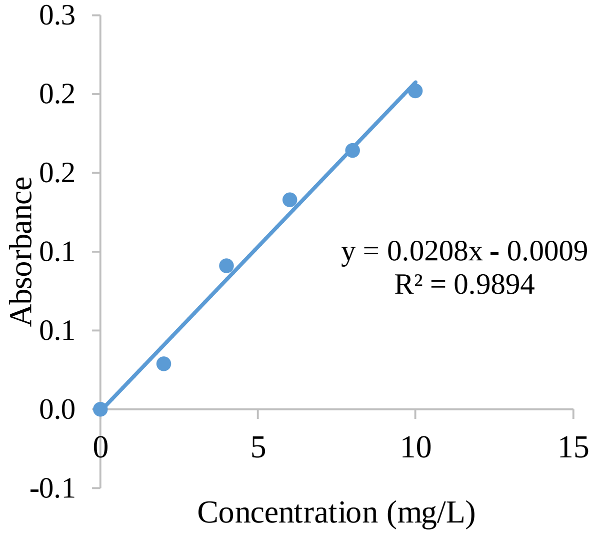
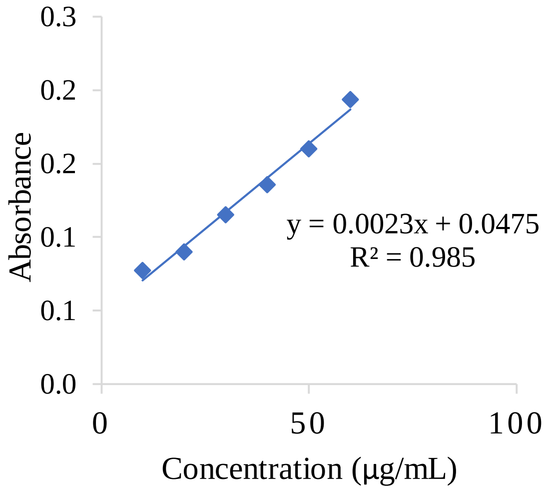
APPENDICES

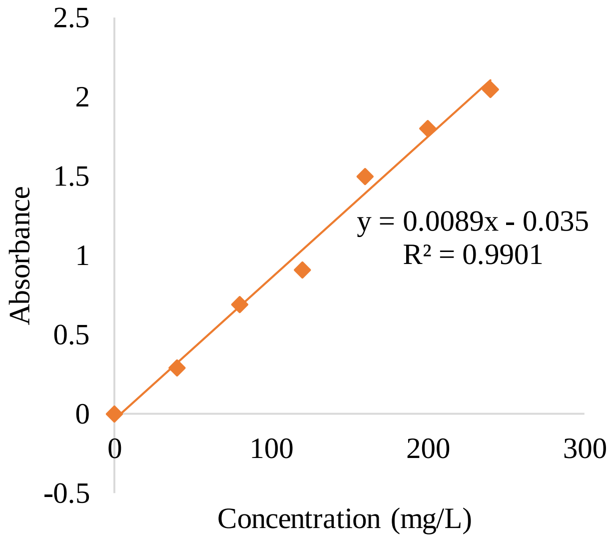
Appendix 1: Standard curves of the physiochemical parameters analysed, ascorbic acid, carotenoids, total phenolic content and total sugar content



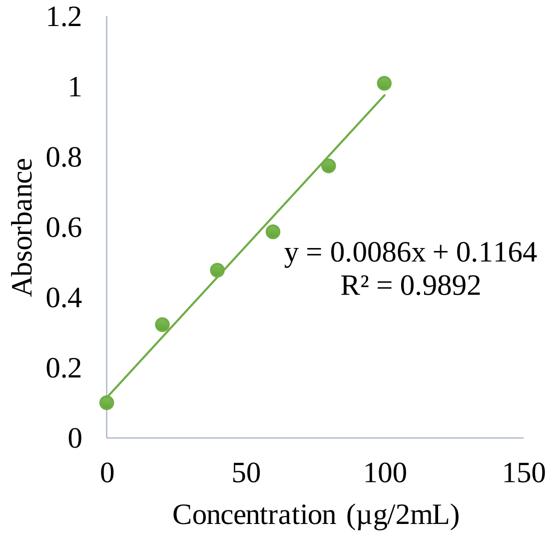
A: Calibration curve of standard ascorbic acid



B: Calibration curve of standard β-carotene



C: Calibration curve of standard Gallic acid



D: Calibration curve of standard glucose

Appendix 2: Equipment and material used during the processing of red cashew apples

A: Cashew apple collection in the field.

B: Storage of fresh cashew apples

C: Solar drier used during drying

D: Hot air oven used during drying

E: Cashew apple slices on the perforated aluminum tray inside the oven

F: Hot air oven dried cashew apple product

G: Solar dried cashew apple product