PHYSICO-CHEMICAL, NUTRITIONAL, MICROBIAL AND ORGANOLEPTIC PROPERTIES OF JAM AND JUICE PROCESSED FROM SHEA FRUIT PULP

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DECLARATION

I hereby declare that this thesis is my original work and it has never been submitted to any other University for any academic award.

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DEDICATION

This thesis is dedicated to my parents; Mr. & Mrs. Pamba Namwoyo for their support to my education.

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LIST OF ABBREVIATIONS /ACRONYMS

CMC Carboxymethylcellulose

FSFP Formulated Shea Fruit Pulp

IFTS Indigenous Fruit Trees

SFP Shea Fruit Pulp

SFP Shea Fruit Pulp

T.C.T Total Condensed Tannins

TFC Total Flavonoids Content

TPC Total Phenolics Content

UNBS Uganda National Bureau of Standards

ABSTRACT

This study aimed at evaluating the nutritional composition of Shea fruit pulps and developing the prototypes for processing juices and jams from the Shea fruit pulp (SFP). Different formulations of Shea fruit pulp juices and jams with varying ingredients were processed and sensory evaluation was carried out using a 9-point hedonic scale to determine acceptability. The sensory analysis focused on the taste, texture, flavor, colour, and general acceptability of the juices and jams. Juices with formulations of 25% were not significantly different ($P<0.05$) in general acceptability from juices with formulations of 50% SFP. Both juices were highly acceptable and in close range with the reference mango juice. Juices of 10% formulations were least accepted. All the formulated jams were generally acceptable. There was no significant difference ($P<0.05$) in the general acceptability of jams of 48 %, 78 % and the reference mango jam. Jam of 38% was the least accepted. There was a significant difference ($P<0.05$) between FSFP juices and the mango juice in regards to the carbohydrates, calorific values, proteins, vitamin C, sodium, magnesium and calcium composition. There were no significant differences ($P<0.05$) in composition of sodium, iron and calcium of 48 % and 78 % SFP jams and these values were in close range with the control (48%). Generally higher values of nutrients were concentrated in FSFP jams than in the FSFP juices. From these results, it shows that formulated Shea fruit jam and juice are nutritious and palatable as compared to the mango reference control and should be processed on a large market.

Key words: Shea fruit pulps, Shea fruit pulp juice, Shea fruit pulp jam.

CHAPTER ONE
GENERAL INTRODUCTION

1.1 Background to the study

Regional inequality in terms of household income, income generating activities in Uganda has long been and remains pronounced. Disparity between the North and Central region in particular attract a lot of interest. Northern Uganda has been one of the poorest for several decades: living standards, literacy levels, health and nutritional status were all extremely low and well below the national average (UNDP, 2015). The people here are majorly subsistence farmers who depend on rain-fed agriculture for the production of food crops. The bulk of crop yield is used to meet household food needs and the remaining is sold at markets as a source of income (Omujal, 2009). Therefore, cropping and the resultant calorie intake and source of income are seasonal and highly dependable on the amount of rain received. As a result, both government and non-governmental organizations have focused their attention in search for more dependable, natural resources that are indigenous to the area to help increase food security. These resources could be developed to generate a higher, more secure form of income to reduce poverty in the region. One such abundant natural resource in northern Uganda is indigenous fruit trees (IFTs) such as the Shea butter tree (*Vitellaria paradoxa*). During drought periods indigenous food plants provide food and income to rural households (Eriksen & Mutimba, 1998).

Shea fruits have multiple uses and highly valued at local level, national and international markets, making it one of the ideal indigenous fruit trees to research and invest in. Shea butter tree is a member of the family *Sapotacae* and is divided into two subspecies: *nilotica* and *paradoxa*. The ranges of the two subspecies are mutually exclusive, although they have been found within 175 km of one another (Hall *et al*,1996). The subspecies *nilotica* was more located in Sudan and Uganda with some small occurrence in Ethiopia and DRC Congo, while subspecies *paradoxa* was mainly found in west Africa; Mali, Senegal, Burkina Faso and Nigeria (Hall *et al*., 1996). Shea fruits resemble small avocado fruits with a flavourable pulp when ripe. The fruit is green when mature and changes to a more yellowish colour when fully ripe and is about 5 – 8cm long and 3 – 4cm wide (Karin, 2004). Each fruit has a highly nutritious fleshy exterior (pulp) with a pear-like taste when ripe and is 1–3 oval to slightly round, reddish/brown seed referred to as the

„Shea nut"(Teklehaimanot, 2004). It is a savanna species known locally in Lango sub-region as Yao (Agea et al., 2007).

Shea fruit trees generally produce 15 – 30 kg of fruits per tree and the fruits weigh approximately 10 – 57g (El Amin, 1990). Shea tree is known to offer a wide array of local uses within and beyond the Shea parkland regions. The French explorer Roger Caillie who trekked across Africa in 1830 described the traditional uses of Shea and particularly Shea butter which was used by the local people as a remedy against aches, sores and wounds as reported by (Hall *et al*., 1996). From Caillie"s simple report, it is clear that the traditional uses of Shea tree resources have not changed much since 1830. Shea butter for instance was the main edible oil for the people who live in the Shea parklands, being the most important source of fatty acids and glycerol in their diets (Saul et al.,2003). Despite being increasingly replaced by commercially produced lotions in many communities, Shea butter was traditionally used as a skin and hair moisturizer and for protection against the sun (Ezema & Ogujiofor, 1992). Traditionally, Shea butter was also rubbed on pregnant women during childbirth, newborn babies and adolescents because of its soothing properties. It"s also reported that shea fruit were collected, pulps manually removed from the kernel, sun dried and pounded. The resultant powder was again mixed with fresh mashed shea fruit pulp and moulded in the form of pancakes (locally known as *Poki* in Acholi), sun dried and stored in airtight plastic bags or tins and then consumedas snacks (Oryema *et al*.,2013).

Shea fruit trees also offer a number of non-Shea butter uses that come from the actual wood of the tree, the flowers, fruits, nuts, foliage and the bark. The wood of Shea tree can be used as a high quality firewood and to make sturdy tools (Boffa, 2000), and an infusion made from the bark is used to help extract splinters. Stripping the tree of its bark however clearly has detrimental effects and can lead to the weakening of and possible death of the tree, therefore the wood and bark should only ideally be got from carefully selected trees that are of little or no value for the shea fruit and nut production (CRIG, 2002). Aside from being highly nutritious, Shea fruit pulp is traditionally taken for its laxative properties (Soladoye, *et al*., 1989).

However, the exploitation of the fruit pulp for production of vinegar, juice, jam or jelly as well as alcoholic beverages such as wine, gin or brandy have largely not been explored. As such the commercial potential of Shea fruit pulp has not been adequately exploited.

Maranz *et al*., (2004) found that Shea fruits are very nutritious and contain a rich source of carbohydrates, proteins, calcium and magnesium. Pearson (1976) also found that Shea fruits pulp contain ascorbic acid (196mg/100g), iron (2mg/100g) and calcium (36.4 mg/100g). According to CRIG (2002), Shea fruit pulp contains 41.2 g of carbohydrates, 0.7–1.3 % proteins, and 196 mg/100g vitamin C. Research carried out on the chemical and mineral composition of Shea fruit pulps collected from different parts of Uganda such as Acholi, Lango,Teso and West Nile sub regions proximate analysis showed that the Shea fruit pulps‟ crude fat, crude fiber, crude protein, total carbohydrate, vitamin C and caloric value contents ranged between 1.5 – 3.5%, 10 – 15%; 3.1– 4.2%, 61– 64%,
85.59 – 124.86 mg/100g and 248– 256 Kcal/100g, respectively (Omujal, 2009). The mineral composition of the Shea fruit pulp consisted of calcium 35.18–95.58 mg/100g, potassium 42.04 – 63.55 mg/100g, magnesium 18.14– 24.21 mg/100g, sodium 7.07– 18.12 mg/100gm and iron 3.41– 3.76 mg/100g (Omujal, 2009). This shows that Shea fruit pulps are very nutritious and more research should be done on processing the pulp. This study therefore seeks to produce jam and juice from the pulps of Shea fruits.

1.2 Problem statement

Shea fruits are very nutritious with important sources of carbohydrate (9.35%), ash (4.67%), (proteins (4.62%), calcium (4.21mg g^{-1}), magnesium (1.11 mg g^{-1}), potassium (21.72 mg g^{-1}) , iron (0.42 mg g $^{-1}$) and phosphorus (0.95 mg g $^{-1}$), and from the kernel, fatty acids ; stearic (31.2%) and oleic (56.5%)(Mbaiguinam *et al.*, 2007). Shea fruits provide substantial income to the economy of the rural populace as an article of informal trade and from the sell of shea butter both locally and internationally (Moore, 1993). However, the Shea tree resources are currently facing the risk of becoming extinct as farmlands and urbanization is gradually decreasing their availability (Okiror, 2012). Also since fruit trees tend to crop in flushes and the fruits are usually difficult to store fresh, it leads to gluts in the local markets with people literally giving them away to avoid carrying them back home (Omujal, 2009). As a result, several losses are incurred by farmers through spoilage and or selling them at low costs without any profit. Therefore, minimizing losses can occur through value addition such as development of value added products like jam and juice which are available throughout the year. Once the fruits are accessible throughout the year, nutrients will be consumed continuously and this may lead to better nutritional status of the shea parkland population. Increased economic activities may increase household income generation and farmers may plant more trees

and thus decrease the risk of extinction. Unfortunately, there is little documentation on the physico-chemical, phytochemical, nutritional and microbial, and sensory characteristics of Shea fruit pulp, formulated juices and jams. This research aims at providing that information which may further be used by the local community, researchers, entrepreneurs, development partners, farmers to develop appropriate programmes for improving income, malnutrition and food security among the Shea parkland zones and the rural populace in general.

1.3 Objectives

1.3.1 Overall objectives

The overall objective of this study was to determine the potential of using Ugandan Shea fruit pulp to produce nutritious, safe and acceptable value added juice and jam.

1.3.2 Specific objectives

i. To determine the physico-chemical and nutritional composition of shea fruit pulps.
ii. To develop the process for the production of jams and juices from shea fruit pulps.
iii. To determine the physico-chemical and nutritional composition of juices and jams produced from shea fruit pulp.
iv. To determine the sensory acceptability of juices and jams produced from shea pulp.
v. To determine the microbiological safety of juices and jams produced from shea pulp.

1.4 Hypothesis

i. There are no significant differences in the physico-chemical and nutritional composition of Shea fruit pulps compared to the reference mango pulps.
ii. There are no significant differences in the process for the production of jams and juices from shea fruit pulps compared to those from the reference pulp.
iii. There are no significant differences in the physical chemical and nutritional composition of formulated Shea fruit juices and jams compared to reference mango juice and jam.
iv. There are no significant differences in the sensory acceptability of Shea fruit juices and jams as compared to reference mango juice and jam.
v. Shea fruit pulps produce jams and juices of good quality and microbiologically safe for human consumption like mango pulps.

1.5 Justification and Significance of the study

Shea fruits pulps are composed of vital nutrients which play a big role in supporting rural communities (Okullo, Hall, & Obua, 2004). Shea fruits are normally consumed in the dry season when other fruits and foods crops are out of season (Omujal, 2009). This presents the opportunity for alleviating hunger among resource-limited communities living in Shea parklands faced with food insecurity and malnutrition (Oryema *et al.*, 2013. The shea fruits however have a short shelf life leading to huge losses incurred by the farmers as a result of spoilage (Okiror *et al*., 2012). Most farmers in the shea parklands produce shea butter from the shea fruits and ignore the shea pulp (Omujal, 2009). Development of value added products such as jams and juices should minimize losses and increase consumption of these shea fruits in northern Uganda with possible outcome of averting food insecurity and malnutrition which is common in this region of Uganda. It is also likely to stimulate demand and encourage domestication and farming of shea fruit trees in a long run. Availability of these fruit trees further help minimize dependency on the marketed exotic fruits, which are always expensive and hardly affordable by the rural poor (Oryema *et al.*,2013). The study therefore focuses on formulating Shea fruit jam and juices with good sensory characteristics which can be appreciated by the people. The study will also generate data on the physical chemical, phyto chemical, nutritional, mineral and microbial properties of the formulated Shea fruit juices and jams. Furthermore, the findings from this research are a benchmark for further research on quality, Shelf life, commercialization; value addition of other products that have been lacking in Uganda. The information collected shall be useful to the rural farmers, researchers, commercialization and development partners. Apart from the above, the information could be used to improve marketing and further utilization of shea fruit products.

1.6 Theoretical Framework

This study was designed based on the theoretical framework which would assess the nutritional and chemical composition of shea fruit pulp and the formulated shea fruit pulp products such as jam and juice from the Shea zones of Uganda (Figure 1.1).

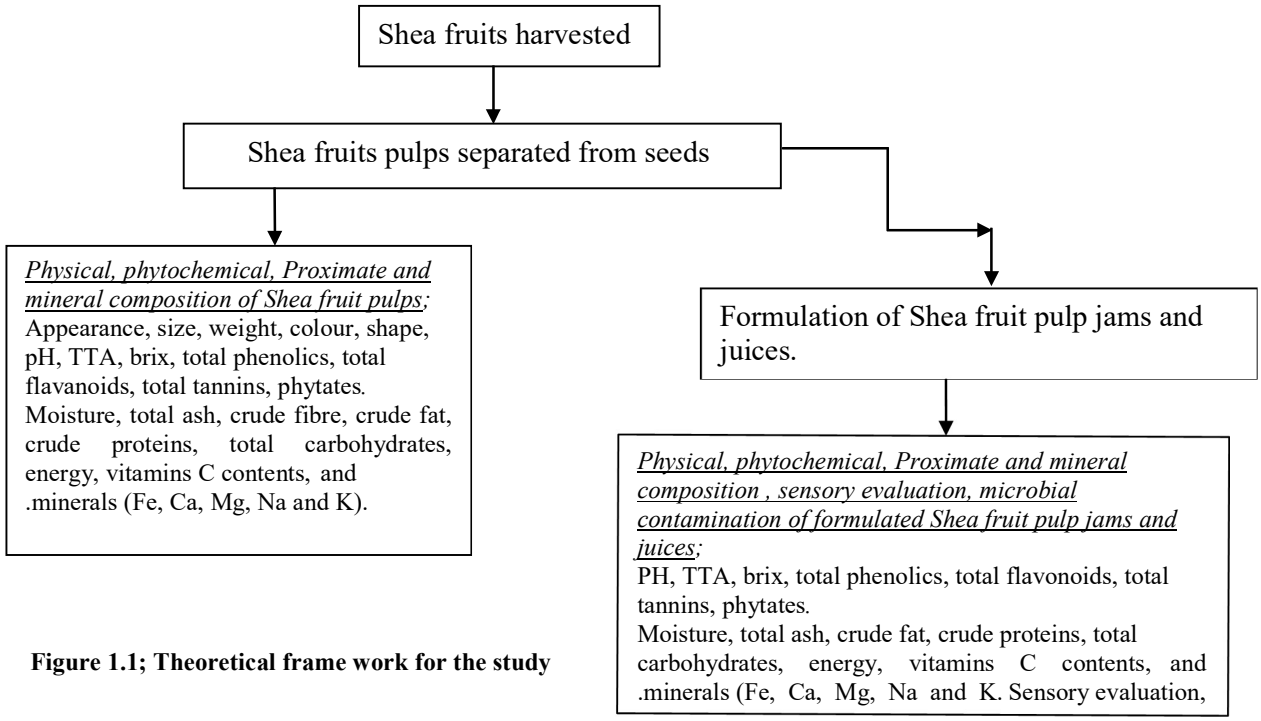


Figure 1.1; Theoretical frame work for the study

1.7 Scope and Structure of the Dissertation

This study assessed the Phyto-chemical, nutritional and mineral composition of Shea fruit pulps in Otuke district in Uganda. The study also involved the formulations of different Shea fruit pulp jams and juices. It also assessed the phytochemical, nutritional, mineral, sensory evaluation, and microbial analysis of the formulated Shea fruit pulp jams and juices.

This dissertation is structured into six chapters as follows. Chapters 1 to 3 are for introduction, literature review and materials and methods for the whole study. Chapters 4, 5 and 6 are for Results, Discussion, Conclusion and recommendations. This is then followed by References respectively.

CHAPTER TWO

LITERATURE REVIEW

2.1 General

The world today faces urgent food and nutritional crisis. Shah & Strong (1999) estimate as many as 840 million people face chronic or perpetual hunger; 19,000 of the 40,000 infants and children die of malnutrition (World Health, 1999). The quest for food is a universal imperative which supports a diversity of life on earth; and its insufficiency and shortage threaten viability of life. This prompts humanity to conserve and sustainably utilize a spectrum of resources such as domesticated crops, wild food plants, indigenous fruits and under-utilized species (Mawula, 2009). Indigenous fruit trees (IFTs) refer to the trees bearing fruits that are not highly researched and generally ignored by commercial sector, little research has been carried out on these species and information documented about their basic biology, growing habits, management practices, processing and utilization is scant and scattered (Hughes & Haq, 2002).

In Uganda, Indigenous trees are found in many parts of the country and many have not been utilized. Shea fruit trees are some of the examples of indigenous fruits found in northern region where climatic conditions are harsh, characterized by high temperatures and variable rainfall. These conditions favor Shea trees to flourish and may not favor other exotic food crops leading to a decrease in productivity and as a result causing vulnerability of the farmers. The food situation in northern region has brought to the fore the value of domesticating and commercialization of Indigenous fruits as an alternative option. This is quite relevant at present due to overwhelming evidence that Indigenous fruits can contribute to increased food security, nutritional health, household cash income, farm diversity and environmental resilience (Akinnifesi *et al.*, 2006; Okia, 2013). Several studies indicate that edible fruits harvested from indigenous fruits trees provide vitamins and essential mineral for the proper maintenance of human health (Packham, 1993).

2.2 Nutritional properties of indigenous fruits

Nutrient is defined as a substance obtained from food and used in the body to promote growth, maintenance, and repair of body tissues, or simply as a substance that provides nourishment (USDA, 2004). Broadly speaking, nutrients are classified into two groups, namely macronutrients (also called energy producing nutrients or energy-yielding



(A) Shea fruits



(B) Shea fruit pulp removal



(C) Shea fruit pulp



(D) Shea fruit pulp Jam



(E) Shea fruit pulp Juices



(F) Shea fruit nuts (seeds)

Figure 1.2; Pictures showing the shea fruit, shea fruit pulp, jam, juice and seeds.

nutrients) and micronutrients (which are characterized by their essentiality for human health and the low quantities in which they need to be ingested) (Villarino *et al.*, 2003). Energy-producing nutrients include carbohydrates, fats, and proteins. Micronutrients often refer to vitamins and minerals. Phytochemical, also called bioactive compounds are substances present in foods in low levels that may have a role in health maintenance in humans.

Fruits have proved to be essential for a balanced diet. This is believed to be mainly due to their content of vitamins, fibers, and phytochemical, the latter being responsible in part for the antioxidant properties of fruits and foods of fruit origin. Manufacturing processes are changing the nutritional properties of some foods (USDA, 2004). For instance, partial hydrogenation of vegetable oil results in the formation of *trans*-fatty acids, and heat treatment of protein solutions in an alkali environment results in the formation of lysine alanine. Both of these have been shown to have detrimental health effects. On the other hand, some nutrients and bioactive compounds that are naturally present in fruits may undergo transformations during food processing that neither decrease their nutritional value nor bioactive value but may increase it by favoring their absorption and metabolism in the human body (USDA, 2004). In general, vitamins, minerals, water, and fibers are considered to be the main nutrients contributed by fruits to a balanced diet, and thus special attention should be addressed to this group of nutrients (Villarino, Garcia-Linares, Garcia-Fernandez, & Garcia-Arias, 2003).

Indigenous fruits have over the years been reported as rich sources of mineral elements much needed by our bodies. Minerals can be classified as either macro or micro. The macro minerals for instance consists of calcium (Ca), sodium (Na), potassium (K) and magnesium (Mg) while micro mineral includes amongst others iron (Fe), zinc (Zn), selenium (Se) and copper (Cu). A study conducted in Ghana for instance, reports the Shea fruit pulp to be rich in Ca (36mg/100g), Mg (26mg/100g) and Fe (1-3g/100g) (CRIG, 2002; FAO, 2007). On contrary Maranz *et al.,* (2003) reports that the most abundant mineral in shea fruit is potassium with the values as high as 1300 mg/100g in West African countries and 400 mg/100g in Uganda. The mineral compositions of most indigenous fruits across Africa have been said to vary by environmental conditions (Hegarty, 1988).

According to Hegarty (1988), Na and K are very important in water balance and normal functioning of the nerves, muscles and absorption of glucose and glycogen while Calcium plays a very important function in bones, nervous system, stimulates some hormonal secretions, and activates some enzymes and blood coagulation. Magnesium on the other hand can assist enzymes involved in the synthesis and breakdown of carbohydrates, fats, proteins and synthesis of DNA and RNA while iron is a constituent of hemoglobin, myoglobin and a number of many enzymes (Yusuf *et al.*, 2007).

2.3 Phytochemical and anti-nutritional properties of fruits

2.3.1 Phyto chemical properties

Phytochemical are a large group of plant-derived compounds hypothesized to be responsible for much of the disease protection conferred from diets high in fruits and fruit products (Arts & Hollman, 2005). Hundreds of phytochemical compounds (e.g. total phenolics, flavonoids, tannins, and phytates) with several different biological functions have been identified in plant-based foods. Therefore, consuming a variety of plant-based foods helps to ensure that individuals receive the optimum benefits from the fruits and vegetables consumed (Steven Maranz *et al.*, 2004).

Consumption of natural bio active compounds such as polyphenols, carotenoids and vitamins C offer protective effects against degenerative diseases including cardiovascular diseases and cancer (Kaur & Kapoor, 2001). Phenolic compounds have been attributed to their antioxidant activity which is a fundamental property in life (Balasundram *et al.*, 2006).

Antioxidants are very important in the inhibition of oxidative stresses (Zlotogorski *et al*., 2013). Oxidative stresses in humans and animals often lead to oxidative modification of cells and tissues which is associated with degenerative diseases acquired through atherosclerosis and carcinogenesis (Taigman, *et al.*, 2014).

Due to the lack of food composition data and a true understanding of the absorption and metabolism of phytochemical compounds, the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes and Its Panel on Dietary Antioxidants and Related Compounds of the Food and Nutrition Board at the Institute of Medicine chose not to create a Dietary Reference Intake (DRI) for these compounds (Instititute of

medicine, 1998).Therefore, recommended intakes for phytochemical does not currently exist.

2.3.2 Anti-nutritional properties of fruits

2.3.2.1 Phytates

Phytates are the principal storage form of phosphorus and are particularly abundant in cereals, legumes and fruits (Reddy e*t al*., 1989). These chelate divalent cations such as calcium, magnesium, zinc and iron, thereby also reducing their bioavailability (Sandberg, 2002). These are the mobilizing secondary metabolic compounds which are thought to function as reserve nutrients (Reddy *et al*., 1978) . The phytic acid serves as an important reserve of phosphate generated by the action of phytase during seed germination and growth into fruits and varies depending on different climates, soils. As the phytate cannot be absorbed and humans have a limited ability to hydrolyze this molecule, an adverse effect of the phytic acid on the bioavailability of minerals is predicted (Pawar & Ingle, 1988).

In many plant species, ninety percent of phytic acid is localized in the aleurone layer and only 10% in the embryo. There are many factors, such as genetics, environmental fluctuations, location, irrigation conditions, type of soils; year and fertilizer application that can affect the phytic acid content and availability in fruits. Phytic acid has long been considered as an anti-nutrient because of its strong ability to complex multi-charged metal ions, especially Zn (II), Ca (II) and Fe (III) (Harland & Oberleas, 1987). In consequence, the consumption of great quantities of food containing high phytic acid levels could produce a deficit in the absorption of some dietary minerals (Reddy & Pierson, 1994).

2.3.2.2 Tannins

Oligomers of flavan-3-ols and flavan-3,4-diols, called condensed tannins, occur widely in fruits, cereals and legumes (Haard & Chism, 1996). Tannins are aromatic compounds which interact with salivary proteins and glycol proteins in the mouth and render the tissues astringent to taste (Howes, 1953). The tannins are said to protect plant against dehydration, rotting, damage by animals and pathogens. When they are polymerized, insoluble protective barrier is formed which prevents microbial attack (Stumpf & Conn, 1981). They can therefore be applied to wounds as protective coating. Tannin-protein complexes can cause inactivation of digestive enzymes and reduce protein digestibility by interaction of protein substrate with ionizable iron (Kadam, Salunkhe, & Chavan, 1990).

This is possible by tannins forming protein tannin complexes through multiple hydrogen binding between their hydroxyl groups and carboxyl groups of protein peptide bonds of proteolytic enzymes in the gastrointestinal tract. The presence of tannins in food can therefore lower feed efficiency, depress growth, decrease iron absorption, damage the mucosal lining of the gastrointestinal tract, alter excretion of cations, and increase excretion of proteins and essential amino acids (Reddy & Pierson, 1994). Boiling, soaking and cooking can reduce the tannin content of fruits and fruit products like juices and jam (Farag, 2001).

2.4 Physico-chemical properties of fruits.

The physical chemical properties of fruits includes external and internal features of the fruit shape, length and width, fruit weight, pulp percentage per fruit, number of seeds per fruit, peel percentage, seed weight, titratable acidity, pH, total soluble solids, and TSS/acid ratio. These attributes act as decisive factors for accomplishment of market demands which are looking for high quality fruits which will produce high quality products like jams and juices. The sour taste of fruits is responsible for its acidity. There are many studies that indicate the chemical characteristics of fruits. For instance, the cornelian cherry fruits pH, total acidity, total soluble solids and TSS/acid ratio were found to range from 2.50 - 2.88, 1.852 - 2.348 g/ml, 13.6% - 24.1%, 6.371 - 12.61, respectively (Demir & Kalyoncu, 2003). The pH, total titratable acidity and Brix of passion fruit ranged from 2.45-2.77, 82-85%, 13.5-17.4 (^{o}Brix), respectively (Jiménez *et al*., 2011). De Almeida *et al*. (2017) established that passion fruit and orange juice commercialized in Brazil had a pH of 3.36 and 4.44 respectively.

2.5 Microbial properties of fruits, jams and juices

Post-harvest processing methods include diverse range of physical and chemical treatments to enhance the shelf life of fresh produce. The minimally processed fresh-cut fruits remain in a raw fresh state without freezing or thermal processing, or addition of preservatives or food additives, and may be eaten raw or conveniently cooked and consumed. These minimally processed fruits are washed, diced, peeled, trimmed, and packed, which lead to the removal of fruit‟s natural cuticle, letting easy access by outer true or opportunistic normal micro flora to the internal disrupted tissues abrassed during processing.

Gorny & Kader (1996) observed that pear slices cut with a freshly sharpened knife retained visual quality longer than the fruits cut with a dull hand-slicer. Rinsing of fresh produce with contaminated water or reusing processed water adds *E. coli*, *Enterobacter*, *Shigella*, *Salmonella* sp., *Vibrio chloreae*, *Cryptosporidium parvum*, *Giardia lamblia*, *Cyclosporacayentanensis*, *Toxiplasmagondii* and other causative agents of food borne illnesses in humans. This further increases the microbial load of the fresh produce that undergo further processing including addition of undesirable pathogens from the crop.

Fruits processed as fruit concentrates, jellies, jams, preserves, and syrups have reduced water activity (*a*w) achieved by sufficient sugar addition and heating at 60 – 82^0C, that kills most of xero-tolerant fungi as well as restrains the growth of bacteria. Thus, the normal microflora of such diligently processed fruit products may include highly osmophilic yeasts and certain endospore-forming *Clostridium*, *Bacillus* sp. that withstand canning procedures (Splittstoesser, 1991). Similar flora may appear for processed and pasteurized fruit juices and nectars that loose most vegetative bacteria, yeasts, and molds while retaining heat resistant ascospores or sclerotia producing paecilomyce ssp,and penicillum sp (Splittstoesser, 1991). Recently, Walls & Chuyate (2000) reported the occurrence of *Alicyclobacillus acido terrestris*, an endospore-forming bacteria in pasteurized orange and apple juices.

2.6 Organoleptic properties of fruits, jams and juices

For today"s consumers, the primary consideration for selecting and eating a food commodity is the product"s palatability or eating quality, and other quality parameters, such as nutrition and wholesomeness are secondary (Meiselman *et al.,*1999). In order for players in the food and beverage industry, to have a market edge/success, they should ensure that the quality of food is appealing and appetizing or more specifically that the eating quality attributes of; aroma, taste, aftertaste, tactual properties and appearance is acceptable to the consumer so that they crave for more.

Thus if we accept that food quality is that "which the consumer likes best" and that the grades of quality are understood more by the degree of desirable attributes and absence of undesirable characteristics which are primarily detected by the consumer"s sensory organs, then a good method of deciding quality of a food is through sensory evaluation. Sensory evaluation has been defined as a scientific discipline used to evoke, measure,

analyse and interpret those responses to products as perceived through the senses of sight, smell, touch, taste and hearing (Sidel & Stone, 1993).

Sensory analysis can be considered to be an interdisciplinary science that uses human panelists sensory perception related to thresholds of determination of attributes, the variance in individual sensory response experimental design to measure the sensory characteristics and the acceptability of food products, as well as many other materials. Since there is no one instrument that can replicate or replace the human psychological and emotional response, the sensory evaluation component of any food study is essential and the importance of good experimental design cannot be overemphasized in sensory experiments (Lawless & Klein, 1989; Meiselman *et al.,*1999).

For all sensory assessment methods, humans are the measuring instrument. In order for a sensory assessment to provide reliable and valid results, the sensory panel must be treated as a scientific instrument; that is, members of the panel must be screened, calibrated and validated (Meiselman *et al.,*1999).

CHAPTER THREE

MATERIALS AND METHODS

3.0 Materials

Study area

Shea fruits were collected from Otuke district. Otuke district was chosen because it is a Ruforum project district and has got well established, reliable shea fruit belt whose community highly depends on shea fruit products for both food uses and other benefits. Otuke district is made up of five sub counties namely; Adwari, Ogor, Okwang, Olilim and Orum as shown in figure 3.4 below.

Shea fruits

A hundred kilograms of shea fruits were collected using stratified random sampling method. Each of the sub country represented a strata of the whole of Otuke district. This ensured that all areas of the study are well represented. Twenty kilograms of shea fruits were collected from each sub county (strata) to make a total of 100 kgs by simple random sampling. Ripe fallen fruits were collected from the ground underneath the mother trees. Ripe fruits fall due to wind disturbance. The fruits were mixed up randomly. Undamaged ripe fruits with no symptoms of visible discoloration, shriveled, spoilage and infections were selected. The remaining good quality fruits were stored in cooler boxes for eight hours as they were transported to the freezers in the laboratories at the School of Food Technology, Nutrition and Bioengineering, Makerere University. Analysis commenced after 24 hours.



Shows Otuke district where the Shea fruits were collected.

Figure 3.4 Showing Otuke district where Shea fruits were collected.

Mango fruits

Ten kilograms of fresh and fully ripened mangoes (Florigon) were obtained from Nakasero local market in Kampala. Simple random sampling method was used while buying the mangoes from the vendors. The mangoes were packed in sisal bags to allow air circulation within the sisal bag. The sisal bags were then loaded onto a refrigerated truck and brought to the laboratory where they were cleaned and sorted for any quality defects. The good quality mangoes were then stored in a refrigerator at 8°C prior to processing and laboratory analyses.

Other production ingredients

White Sugar (kenya), Acidulants such as citric acid (Norbright investment CO Limited) and ascorbic acids (Shanghai Huaxuan Chemicals CO Limited) ,thickeners such as Carboxylmethylcellulose (CMC)(CPKelcoApS, Denmark), Pectin (type LM-106 AS- YA, CPKelcoApS, Denmark), Preservatives such as sodium meta bisulphate (Shanghai Huaxuan Chemicals Co Limited, Potassium Sorbate (Shanghai Huaxuan Chemicals Co

Limited) and sodium benzoate (Shanghai Huaxuan Chemicals Co Limited) were all purchased from DESBROS(U) Limited, Kampala, Uganda.

Methodology

3.1 Preparation of Shea fruit pulps (SFPs) and mango pulp

Shea fruits were thawed and washed thoroughly in clean running water to remove dirt, reduce microbial load and other extraneous materials including plant debris. The hard skin was manually removed to expose the inside fruit pulp which was separated from the nut. The pulps were blended using a blender (Royal Philips, model HR 2167/40, Amsterdam, The Netherlands). Two hundred mls of distilled water were added to ease blending of the pulp by improving viscosity.

The mangoes were washed with clean running water, peeled with a stainless steel knife and then sliced into smaller pieces to release the seeds. They were then blended using a blender (Royal Philips, model HR 2167/40, Amsterdam, The Netherlands) to produce the fruit pulps. All the pulps were stored in the refrigerator below 8^{o}C to await further processing.

3.2 Developing Formulations

3.2.1 Formulation of Shea fruit pulp juices

Three formulations of Shea fruit pulp juices were made according to FAO guidelines (FAO, 1997) with variations in pulp concentrations .UNBS standards for fruit juices states that a natural fruit juice should at least have or contain 10 % natural fruit. So feasibility studies were carried out and several formulations were developed and the best three different formulations which were used in this study. Different proportions of 10%, 25% and 50% of Shea fruit pulp were used to develop the formulations. For the formulated Shea first pulp (FSFP) juice (25% pulp), 200g of pulp were mixed with
522.08 g of boiled water and filtered using a sterile cheese cloth to remove the residues and fibers. The mixture was heated to 60 ^{0}C before 0.32g of carboxymelthylcellulose (previously blended with water) was added to the mixture while stirring. Then 76.8g of white refined sugar were added to the mixture bringing the ^{o}Brix to 12^{o}. White refined sugar was used because its pure white, odourless and thus does not add colour or odour to the products and doesn‟t have foreign particles. Then 0.28g of citric acid was added to the mixture to lower the pH. This was followed by addition of 0.04g Ascorbic acid to maintain the colour of the juice by minimizing oxidation. 0.08g sodium meta-bisulphite

was added as antioxidant and antimicrobial agent, 0.28g of potassium sorbate and 0.12g of sodium benzoate were then added to the mixture as preservatives and pasteurized to 85 ^{0}C for 5 minutes. The resultant formulated juice was cooled to 60 ^{0}C before being poured into clean plastic bottles previously rinsed in 0.2% Sodium meta-bisulphate solution. The bottles were allowed to cool to room temperature (25^{0}C) and stored in a cool dry place. For the 10% FSFP Juice, 50% FSFP Juice and reference mango juice (25% mango pulp), the same procedures were followed but with different percentages of Shea pulps and distilled water as presented in Table 3.1.

Table 3.1: Different formulations of Shea fruit juices

Ingredients (%)	10% FSFP juice	25% FSFP juice	50 % FSFP juice	25% Mango fruit pulp
Shea Fruit pulp	10.0	25.0	50	25
Boiled water	79.86	63.83	40.61	65.83
C.M.C	0.04	0.05	0.06	0.05
White Sugar	10.0	11	9.2	11
Citric Acid	0.035	0.038	0.04	0.038
Potassium Sorbate	0.035	0.038	0.04	0.038
Sodium metabisulphite	0.01	0.015	0.02	0.015
Sodium benzoate	0.015	0.018	0.02	0.018
Ascorbic acid	0.005	0.008	0.01	0.008

3.2.2 Formulation of Shea fruit pulp jams

Different formulations of Shea jams were developed according to FAO guidelines (FAO, 1997; Dietz, 1997). UNBS standards for fruit jams for low sugar jam states that a natural fruit jam should at least have or contain 32 - 35^o final total solids (^{o}brix). So feasibility studies were carried out and several formulations were developed and the best three different formulations were used in this study. Three different percentage were used to develop the jam formulations namely 38%, 48% and 78% (Shea fruit pulp). For FSFP Jam of ratio 48% pulp; 250 g of pulp were mixed with 250 g of sugar in a stainless steel saucepan and brought to heat, 10.42 g pectin (previously mixed with some sugar) were added and mixed thoroughly. Preservatives 2.6 g of potassium sorbate and 2.6 g sodium

benzoate were added and the mixture boiled for 5 minutes. To ensure that the jam had set, wrinkles and spreadability tests were conducted following the procedure laid-down by (Dietz,1997). The processed jam was hot filled into sterilized glass jars leaving a headspace, sealed, tilted to sterilize head space and left to cool over night to gel at ambient temperature (25–32^{0}C).

For the other formulations, percentages of 38 % and 78 % the same procedures were followed but with different percentages of Shea fruit pulp to sugar ratios. Reference mango (Florigon) samples were processed into jam with ratio (48%). The formulated jam samples were stored overnight in the fridge at 4^{o}C and analyzed in the microbiology and chemistry laboratories. The ingredients used in the jam formulations were presented in Table 3.2 and the procedure presented in Figure 3.3 as shown below.

Table 3.2: Different formulations of Shea fruit pulp jams

Ingredients (g)	38:58 FSFP Jam (38 %)	48:48 FSFP Jam (48 %)	78:18 FSFP Jam (78 %)	48:48 Mango Jam (48 %)
Shea Pulp	38.00	48.00	78.00	48.00
White Sugar	57.70	48.00	17.60	48.00
Pectin	02.15	02.00	02.20	02.00
Citric Acid	01.05	01.00	01.10	01.00
Potassium Sorbate	00.55	00.50	00.55	00.50
Sodium Benzoate	00.55	00.50	00.55	00.50

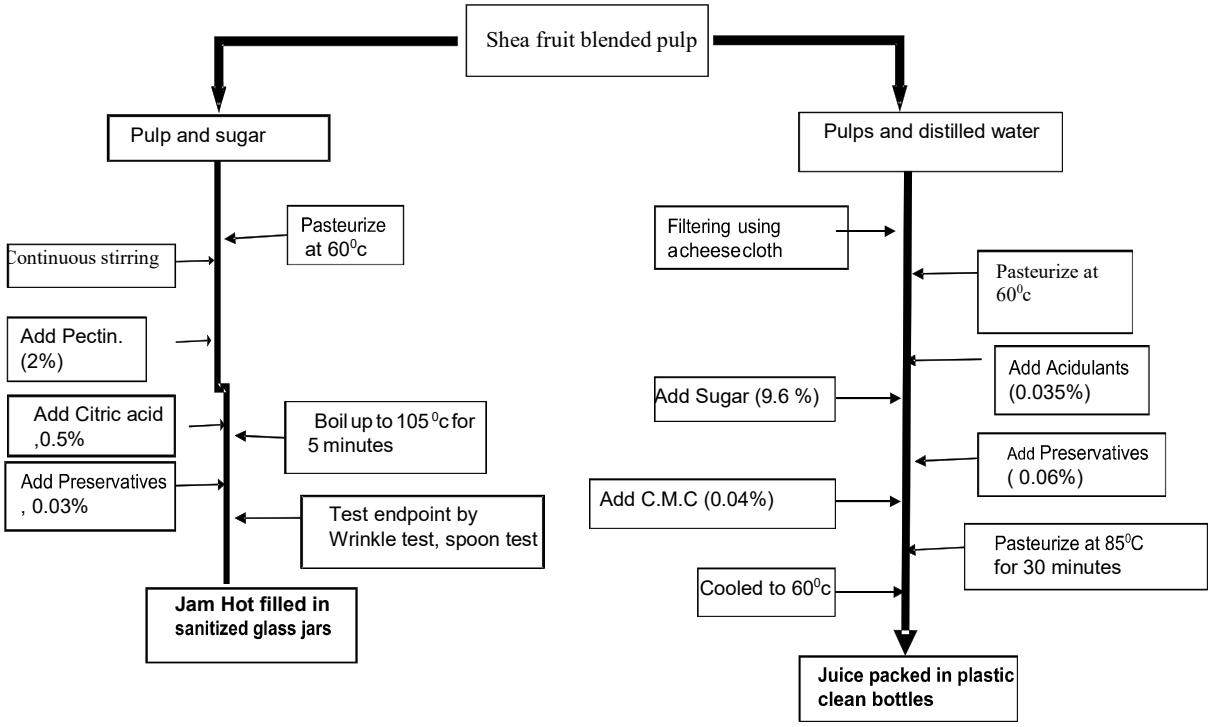


Figure 3.4: Flowchart for processing of juice and jam from Shea fruit pulp fruits.

3.3 Physico-chemical analysis

3.3.1 Shea Fruit Shape, Size, pulp, seed and skin percentage

Shea fruits were sorted for quality defects and approximately 200 Shea fruits were analyzed using method described by Maranz et al.(2003). Shea fruits were observed to identify the shape of the fruits. The length and width of Shea fruits were measured using a Vernier caliper (Mitutoyo Corporation, Japan). The Shea fruits were then weighed on a precision balance (Mettle-toledo, Switzerland). The skin/outer covers were then separated from the fruits and fruits were weighed again to calculate skin percentage. The seeds were then removed from the fruits to calculate seed and pulp percentages.

3.3.2 PH

The pHs of the Shea fruit pulps, FSFP jams and FSFP juices and their references were determined by using a pH meter (Mettler-Toledo GmbH, schwerzenbach, Switzerland) according to AOAC official method 943.02 (1995). The pH meter was first calibrated using standard buffer of pH 4.0 and 7.0. Twenty five mls of the each of the samples were transferred into a beaker and the PH probe inserted in the beaker. Sufficient

time was allowed for stabilization before readings were taken. For each sample, three readings were taken.

3.3.3 Determination of Titratable Acidity

Titratable acidity of the Shea fruit pulps, FSFP jams and FSFP juices and their references were determined according to AOAC (1999). Thirty grams of each sample were weighed accurately into beakers and distilled water was added to form a solution. The solution was then transferred into a 250ml volumetric flask and topped up to the mark with distilled water. The solution was then filtered and 30mls of the filtrate were titrated with 0.1N sodium hydroxide solution using phenolphthalein as the indicator to the appearance of a distinct pink colour. The samples were carried out in three replicates. The acidity as anhydrous citric acid was expressed using a formular as:

$$\text{Acidity as anhydrous citric acid} = \frac{\text{Titre value} \times \text{Normality of alkali} \times 64 \times \text{volume made up} \times 100}{\text{Ml of filtrate} \times \text{weight of sample} \times 1000}$$

3.3.4 Determination of Total Soluble Solids

The total soluble solids (^{O}Brix) of the Shea fruit pulps, FSFP jams and FSFP juices and their references were carried out using a hand held sugar refractometer (Model; RBX0080 Trans Instruments Ltd, Petro center, Singapore). The prism of the refractometer was cleaned and a drop of each of the samples were placed on the prism and closed. The sugar content percentage (soluble sugar) of each sample was read in triplicates from the scale of the refractometer at 20^{o}C when held close to the eye using AOAC (1999) method 981.12.

3.4 Phyto- chemical analysis

3.4.1 Sample preparation

Phenolics compounds were extracted using method described by (Makkar, 2005) with slight modification.0nehundred mg of Shea fruit pulps, FSFP jams and FSFP juices and their references control were extracted using 5mls of (50% methanol: 50mls of water solution (v/v)) and placed in the falcon tubes. The falcon tubes containing the mixture were suspended in ultrasonic water (bransonic series, M.2800-E; Branson Ultrasonics, Co, Danbury, CT, USA) and subjected to ultrasonic treatment for approximately 20 minutes at room temperature to allow extraction to take place. The extracts were then cooled at 4^{o}C in a freezer for 10 minutes and there after centrifuged at 3000g for 10

minutes using a centrifuge (Fischer scientific 225, fisher scientific co, st Louis, MO, USA). The supernatant was removed from the mixture and collected into a separate tube and stored at 4^{o}c. The remaining mixtures were further re-extracted under the conditions previously described to ensure efficient extraction. The two supernatants were poured in an airtight container and stored in a freezer at 4^{o}C to be used in the determination of total phenolics content (TPC), total flavonoids content (TFC), and total condensed tannins (T.C.T).

3.4.2 Determination of Total Phenolic Content

The total phenolics content of Shea were determined using the folin-ciacalteu colorimetric method as described by Makkar (2005) with some modifications. A hundred µL of the diluted sample extract (1:10 of the pulp to water (v/v)) of Shea fruit pulps,FSFP jams and FSFP juices and their references were pippeted into a test tube covered with aluminum foil and topped up to 0.5mL with double distilled water. Then 0.25mL of folin-ciocaltec reagent (1N) was added followed by 1.25ml of sodium carbonate (20% w/v) and the mixture homogenized using a vortex.

The mixture was then incubated at room temperature for 40 minutes to allow for colour development. Colour Absorbance was measured at 725nm (Genezys 10-uv-spectrophotometer, thermo Electron Corporation, Madison WI, USA) against methanol as the blank. Gallic acid was used as a standard for plotting a calibration curve with varying concentrations (0.02-0.125mg/mL). The total phenolics contents were determined and expressed as milligram gallic acid equivalent (GAE/100ml) of the Shea fruit pulp extract.

3.4.4 Quantification of total carotenoids

Total carotenoids of Shea fruit pulps, FSFP jams and FSFP juices and their references were determined according to the method of Rodriguez-Amaya and Kimura (2004). Briefly, 2 Ml of each of the samples was extracted by mixing with 50 mL cold acetone in the dark. The acetone was then removed through the slow addition of 250 mL double distilled water to prevent the formation of emulsions. The aqueous phase was discarded and this procedure was repeated four times until there was no residual acetone. The extract was then transferred through a funnel into a 50 mL volumetric flask containing glass wool with15 g of anhydrous sodium sulfate. The final volume was adjusted with petroleum ether. Absorbance was measured at 450 nm (Genesys 10- UV

spectrophotometer, Thermo Electron Corporation, Madison, WI) against petroleum ether as a blank. The total carotenoid content was calculated using the following formula:

$$\text{Total carotenoids content } (\mu g/mL) = \frac{\text{Absorbance} \times \text{Total volume of extract} \times 10^4}{\text{Absorption coefficient of beta carotene (2592)} \times \text{sample volume (mL)}}$$

3.4.5 Determination of Total Flavonoids Content

Total flavonoid content (TFC) was determined using the Muanda *et al* method of (2011). In brief, 0.5ml of catechin standard solution and sample fruit pulp extract and the reference were mixed with 2mlsdeionised water and 0.15ml of sodium nitrite (5%w/v). After 5minutes, 0.15ml of 10% Aluminum chloride was added followed by the addition of 1ml of molar sodium hydroxide after another 6 minutes. Finally distilled water was used to adjust the total volume to 5ml and absorbance was read at 510 nm (Genesys 10-uv spectrophotometer, Thermo Electron Corporation, Madison WI, USA). A standard calibration curve was plotted using different concentrations of catechin (0.002-0.125 mg/ml). The total flavonoids content values were expressed in milligrams catechin equivalents per 100ml of Shea fruit pulp or FSFP jams and juices (mgCE/100ml).

3.4.6 Determination of Vitamin C

Vitamin C was determined by titration with 2, 6-dichlorophenolindophenol (Pearson, 1990).The extract solution was prepared by mixing 15g of phosphoric acid with 40ml of acetic acid, 100ml of water and then made to 500ml with water. The ascorbic acid standard solution was prepared by dissolving 100 mg L-ascorbic acid in 100 ml of water while the indophenol solution was prepared by dissolving 50mg of 2,6dichlorophenolindophenol(DCPIP) in 450ml of water containing 42mg sodium bicarbonate which was later diluted to 500ml, filtered and kept in brown reagent bottle. The standard vitamin C solution (2ml) was pipetted into a 50ml conical flask containing 5ml of extracted solution and titrated with DCPIP solution until the pink colour that persisted for about 6 seconds was obtained. The concentration of Vitamin C was then calculated in 1ml DCPIP solution. The fruit pulp sample, FSFP jam and FSFP juices (1gm) were each blended with 100ml of extracted solution and filtered in porous filter paper. The fruit extract solution (10ml) were then pipetted into 100ml conical flask and titrated with DCPIP until the pink colour persisted for 6 seconds. The vitamin C results were expressed as mg / 100g.

3.5 Anti-nutrient determination

3.5.1 *Determination of Total Condensed Tannins*

Total condensed tannins were determined using the method described by Sun, *et al*.,1998), with slight modifications. Briefly 1.5ml of vanillin solution (4%) was added to 50μLof v/v in the diluted Shea fruit pulp with ratio of (1:10 of Shea fruit pulp to water) in a test tube. Immediately, 0.75mls of concentrated HCL was added and the mixture vortexed. The mixture was incubated at room temperature for 10 minutes to allow for colour development. Absorbance was read at 500nm (Genesys 10-uv spectrophotometer, Thermo Electron Corporation, Madison WI, USA) with water as a blank. A standard curve was developed using catechin standards of varying concentration (0.02 to 0.06mg/ml).The total condensed tannins values were expressed as mg catechin equivalent/100ml of the Shea fruit pulp.

3.5.2. Determination of Phytates

Phytate contents were determined using the method described by Reddy and love (1999).The method of Ola and Oboh (2000) was adopted for determination of phytates.

3.6 Proximate Composition analysis

Proximate analysis was carried out on the Shea fruit pulp, to determine parameters such as moisture content, crude protein, crude fat, crude fiber, vitamin C, carbohydrate content and calorific value. Mineral composition analyzes included: calcium, potassium, sodium, magnesium, zinc, iron and phosphorus.

3.6.1 Moisture Content

The moisture content of the Shea fruit pulps,FSFP jams and FSFP juices and their reference samples were determined by loss in weight on drying at 140^{o}C according to (AOAC, 1999. NO 934.01).Dried moisture dishes were weighed and 5 grams of each of the samples were put in the pre weighed moisture dishes and transferred to an electric oven for 5 hours set at 140^{o}C. When the drying was complete, the dishes were carefully removed using a pair of tongs and put in the desiccator to cool. The dishes with the samples were weighed and the percentage moisture content calculated as follows,

$$\% \text{ Percentage moisture} = \frac{\text{Weight of wet sample} - \text{weight of dry sample}}{\text{Weight of wet sample}} \times 100$$

3.6.2 Determination of Total Protein Content

The quantification of total protein in the Shea fruit pulps, FSFP jams and FSFP juices and their reference samples were performed by determining total nitrogen using Kjeldahl method. A conversion factor of 6.25 was used according to AOAC (1999). About 5g of each sample were weighed and transferred in to a 250ml digesting tube; 12ml of concentrated sulphuric acid was added to each digesting tube followed by one tablet of Kjeldahl catalyst.

The tubes were placed on the digesting unit and heated at 420 ^{0}C and allowed to run for 1hr until the digestion tube content became colorless, power was switched off and digestion unit cooled to about 40^{o}C. After cooling the digest, 50ml of distilled water was added to it and the mixture loaded on to the distillation unit of the Kjeltec Auto Analyzer. Fifty ml of 40% sodium hydroxide was added into the digesting tube and the liberated nitrogenous compound (ammonia) distilled in 25ml of boric acid solution. The distillate was titrated against 0.1N Hydrochloric acid to determine the ammonia absorbed by boric acid (until the color turns pink). Blank samples were also titrated. The total crude protein was determined by calculating the amount of nitrogen obtained and multiplying with a factor (6.25).

$$\text{Total nitrogen } \% = \frac{V_2 - V_1 M_{HCL}}{W} \times 0.014 \times 100$$

% Protein = Total Nitrogen *k; V_2 = Volume (ml) of the hydrochloric acid solution required for the test portion; V_1 = Volume (ml) of the hydrochloric acid solution required for the blank test; M_{HCL}= Molarity of hydrochloric acid; W = Weight (g) of the test portion; K= 6.25 (correction factor for Shea fruit); 14 = Atomic mass of nitrogen.

3.6.3 Determination of Crude Fat

Crude fat content was determined using the method described by AOAC (1999); Method 920.85. Extraction of the crude fat was done on a soxhlet extracting machine using petroleum ether (40-60 boiling points) as the extractant. About 2g of dry Shea fruit pulps,FSFP jams and FSFP juices and their references samples were weighed in to a clean thimble, stuffed with cotton wool and covered tightly with the thimble cover. Fat beakers of 50ml were weighed and 30ml of petroleum ether were measured in to each beaker.

The thimble and the fat beakers were loaded on to the soxhlet machine (HT 1043 extraction unit, Tecator, Hoganas, Sweden) and boiled at 100^0C for 1 hour and 20 minutes until the petroleum ether was evaporated and the fat extracted into the beaker. The beaker and its content were placed in the oven to dry for 1hr to ensure that the petroleum ether evaporates from the beaker. The weight gained by the beaker was used to calculate the fat content;

$$\text{Crude fat \%} = \frac{W_3 - W_2}{W_1} \times 100$$

Where W_1 = Weight (g) of sample; W_2 = Weight (g) of empty beaker; W_3 = Weight (g) of beaker and fat.

3.6.4 Determination of Crude Fibre

The dietary fibre was determined using the method described by Pearson (1981). Total dietary fibre solution was prepared. Approximately 1gm of each of the samples of Shea fruit pulps, FSFP jams and FSFP juices and their references wereweighed in to a 600 ml beaker; 100 ml of the total dietary fibre solution was added to it. The mixture was boiled under reflux for an hour on the (Labconco fibre analyser, Kansas City, Missouri, 64132). The beaker was removed, left to cool for 2 minutes and the content filtered through a cheese cloth- polyester material on Buchner funnel connected to a vacuum pump through a glass fibre. The residues were washed with distilled water four times to free it of any acid. The filtrates were discarded while the residues were transferred into pre weighed nickel crucibles. The crucibles with the insoluble materials were transferred into a Gallenkamp hot box oven with a fan and dried at 100^0C for 1hour to a constant weight. The crucible with the content was removed from the oven, cooled in the desiccator and weighed. The crude fibre was reported as;

$$\textbf{Dietary fibre } \% = W_2/W_1 \times 100;$$

Where W_2 = Weight (g) of the fibre;

W_1 = Weight (g) of the sample.

3.6.5 Determination of Total Ash

The Shea fruit pulp samples were ignited to oxidize all organic materials without flaming according to the method of AOAC (1999). The inorganic residue that does not volatilize

at that temperature will be considered as ash. About 5 grams of each of the samples were weighed into a dry pre weighed porcelain crucibles. The samples in the crucible were then carbonized using hot plate in a fume hood. The carbonized samples were then transferred in to a muffle to ash at a temperature of 550^{o}C for 5 hrs. The ash content was reported as the loss in weight which occurred from complete oxidation of the sample.

$$\text{Ash } \% = W_2/W_1 \times 100;$$

Where W_1 = Weight (g) of sample, W_2 = Weight (g) of Ash.

3.6.7 Determination of Carbohydrates

Total carbohydrates of Shea fruit pulps,FSFP jams and FSFP juices and their references were determined by difference using the method in AOAC (1997):

Total carbohydrates = [100- (Moisture content- Crude lipids- Crude proteins)].

3.6.8 Determination of Calorific Values

Total calories of Shea fruit pulps, FSFP jams and FSFP juices and their references were determined by difference using method in AOAC (1997).

3.6.9 Minerals Analysis

Five grams of each of the different samples of Shea fruit pulps, FSFP jams and FSFP juices and their references were weighed and placed in a crucible and ignited at 550^{o}C for five hours. The muffle furnace was turned off and crucibles transferred to desiccators for cooling. The ash was then dissolved in 20ml of 1:1 68% Nitric acid to water solution and the solution was warmed so as to dissolve any un-dissolved particles.

The solution was then filtered through an acid washed filter paper to a 100 mL volumetric flask. The solution was then diluted to volume with potassium chloride solution and transferred the solution to the sample Vials. Standard solutions of different minerals earlier prepared in the concentrations of 0.1, 0.5, 1.00, 2.00 and 5.00 ppm were used in the calibration. The samples were then analyzed with Atomic Absorption Spectrophotometer (Analysit-400, PerkinElmer). The mineral content was calculated using calculation sheet for the specific minerals such as Iron, Magnesium, Zinc, calcium and phosphorus, while metals (Na and K) were determined by flame photometric method (AOAC, 1990).

3.7 Microbial analysis

All the FSFP juices and jams including references were analyzed for fungal, yeast and bacterial contamination in the microbiology laboratories of Uganda Industrial Research Institute, Kampala Uganda. All the samples were stored overnight at 4^{o}C in a fridge and immediately analyzed for Total plate count, *Coliforms, Ecoli*, yeasts and moulds to ascertain whether pasteurization was effective and that the products are safe to be consumed by the public. In order to determine how long the products can stand safe for consumption on the shelf, they were again analyzed for microbiology after four weeks (one month) for microbial analysis.

3.7.1 Total plate count

Total bacterial counts were done according to AOAC (1995). FSFP juices, jams and reference sample homogenates were prepared in sterile diluents in ratios of 1:10. For each homogenate, 1 ml was aseptically diluted through several tubes containing 9ml sterile diluents. Approximately 1 ml of diluents of each tube were spread plated on to plate count agar (PCA) and incubated for 48 hrs at 35^{o}C. Plates with less than 300 colonies were counted and the rest autoclaved. The number of bacterial colonies was expressed as colony forming units per gram (CFU/g) of the formulated Shea fruit sample using the formula from International Dairy Federation method (IDF, 1996) as follows:

$$\text{Log } C=\Sigma C / V ((n_i + (0.1 n_2)) d.$$

Where:

C= Count CFU/g

ΣC = Total number of colonies counted on all the dishes from successive dilutions.

n_i= Number of plates from initial dilution from where counts were made

n_2= Number of plates from second dilution from where counting was done

d= Dilution factor corresponding to first dilution.

3.7.2 Total Coliforms and E.Coli.

Total *Coliforms* and *E.coli* were analyzed according to the method by harrigan and McCance (1996). Violet red bile was used to determine the *Coliforms* organisms. Different formulated Shea fruit juices and reference samples were analysed for *Coliforms*

and *Coliform* counts were carried out on Red Bile Agar (Oxoid, Hampshire, England) incubated at 37±1ºC for 48 hours. Confirmation of the presence of *Coliform* was carried out in 2% Brilliant Green Bile Broth (Oxoid, Hampshire, England) with inverted Durham tubes incubated at 45ºC. Evolution of gas and production of acid were considered as positive results.

3.7. 3 Yeasts and moulds count

The yeasts and moulds analysis were carried out using potato dextrose agar (PDA) AOAC (1995). The different FSFP juices and jams and reference samples homogenates were prepared in sterile dilutes in ratios of 1:10. 1ml of each homogenate was then aseptically diluted in series up to a dilution of 10^{-3}. The diluents were then pour plated in triplicates. Incubation of the plates was done at 25ºC for 72 hrs. The number of yeast and moulds were expressed as colony forming units per gram (CFU/g) using the formula used in TPC determination.

3. 8 Consumer sensory evaluation of the FSFP juices and the jams

A semi trained 50 member panel (33 women and 17 men),drawn from the Uganda Industrial Research Institutes‟ community, Nakawa, Kampala including students of food science and technology on industrial training , The recommended minimum number of panelists for assessing sensory acceptability of a product is 50 since a big number best represents the population (Hough, Krishnapur, Peres, & Virág, 2006). They evaluated the sensory characteristics (colour, appearance, taste, consistency, wholesomeness, sweetness and flavour) of the various formulated juices and jams processed to determine Shea suitability for jam and juice processed. They used a 9-point hedonic scale ranging from least preferred (1) to most preferred (9) (Watts, Ylimaki, Jeffery, & Elias, 1989). During product testing, panel members washed their mouths in between evaluations.

Each assessor was asked to taste three randomly coded samples of each formulated juice and jam including the references and score each product for preference on a nine point scale. All samples were presented to the panelists at room temperature under normal lighting conditions in transparent plastic glass.

3.9 Statistical Analysis

All experiments were conducted in triplicates and all the data collected from physico chemical, mineral, phytochemical analysis and microbial analyses were assessed using Analysis of Variance (ANOVA) with Statistical Analysis Software (Genstat, 14thEdition). Duncan,,s Multiple Range Test (DMRT) was applied to assess the differences between the means (Duncan, 1955) and significance defined at $p<0.05$ (Steel *et al*., 1997). The mean values were displayed with standard deviation (SD) of the means.

CHAPTER FOUR

RESULTS

4.1 Physico – Chemical, Nutritional Composition of Shea Fruit Pulps

Shea fruits were mainly ovoid, elliptical in shape and looked like small avocado fruits, with sizes ranging from very small (12g) to relatively big (50g) with an average weight of 30.93g. Length and width ranged between 3 – 5cm long and 2.5 – 4cm wide with an average of 3.7cm and 3.8cm respectively. The Shea fruit pulp weighed between 8.0 g and 30 g averaging 16.25 g with pulp percentage of approximately 52.55 (%). The Shea nuts (seed) were hard and had distinctive colour of red brown to dark brown. Their weight ranged between 10 – 25 g averaging 14.82 g with seed percentage of 48.25%. Shea fruits have a very small skin whose weight ranged from 2 – 6 g. The fruits had high Brix of 22.6^{o}, a high pH of 6.2 and total titratable acidity of 1.6% (Table 4.3). They have low titratable acidity and high soluble solids and thus have a great potential for consumption as fresh fruit, and also particularly important in fruit processing, reducing the addition of cane sugar and artificial acid components. The crude ash, crude fiber, crude fat, crude protein, carbohydrates and calorific value of Shea fruit pulp are presented in table 4.3. The fruit pulps contained high levels of total phenolics amounting to 9.82mg/100g, total flavonoids amounting to 16.39 mg/100g, and carotenoids of 0.35mg/100g. It also had anti -nutrients such as phytates of 120mg/100 and no tannins concentration (Table 4.3). Shea fruit pulps were found to be rich in moisture content (70.3g/100g DW), carbohydrates (21.8g/100g DW), crude fibre (11.2 g/100g DW) and calorific value (457.7 kJ/100g).

Table 4.3: Physico–chemical, phytochemical and Nutritional composition of Shea fruit pulps

Parameters	Concentration (g/100g) fruit pulp
Proximate	
Moisture Content	70.30 ±1.23
Ash	3.50 ±0.90
Crude protein	3.60 ±1.60
crude Fiber	11.2 ±1.17
Crude Fat	0.70 ±2.80
Carbohydrates	21.80 ±1.26
Calorific value	**kj/100g**
	457.7±1.20
Minerals	**(mg/100g)**
Potassium	
Sodium	1093.4±3.20
Iron	3.10 ±0.92
Calcium	6.10 ±4.39
Magnesium	55.0 ±2.50
Phosphorus	8.20 ±1.77
Zinc	0.10 ±3.20
	0.40 ±1.88
Phytochemical	
Total Phenolics	9.82 ± 4.50
Total Flavonoids	16.39± 3.88
Carotenoids	0.35 ± 1.56
vitamin C	3.60 ±2.45
Anti-Nutrient	
	120.00±0.2
Phytates	0.0 ± 0.0
Tannins	
	(%)
Physical-Chemical Composition	
	22.60 ± 0.92
Brix	6.20 ± 0.63
pH	1.60 ± 1.30
Total Titratable Acidity	
	(g/100g)
Physical properties	
	30.93 ±9.25
Shea fruit weight	3.70 ±0.78
Shea fruit length	3.80 ±1.00
Shea fruit width	16.25 ±5.13
Shea fruit pulp weight	14.84 ±4.00
Shea fruit nut weight	

4.2 Physico – chemical composition of Formulated Shea fruit pulp Jam and Juices

4.2.1 Formulated Shea Fruit Pulp Juices

The pH values of the formulated Shea fruit juices ranged from 4.1 – 4.4 and can be compared to 4.5 of the reference mango juice (Table 4.4). The total soluble solids (^{0}Brix) of the formulated Shea fruit pulp juices were within range (12.2^0– 14^0) with that of the reference mango juice (13^0). There were no significant differences ($P<0.05$) in titratable acidity values of 50% Shea fruit pulp juice and that of the reference product (0.2). Titratable acidity was lowest in 10% formulated Shea fruit juice (0.069%).

4.2.2 Formulated Shea Fruit Pulp Jams

The titratable acidity of all the formulated Shea fruit pulp jam ranged from 0.23 – 0.31and these were well within range with the reference jam (0.33). There was no significant differences ($P<0.05$) in titratable acidity values of 48 % SFP jam and 78 % jam formulations. The Brix value was lowest in jam from the FSFP jam of 78% (35.5^0) and highest in FSFP jam of ratio of 48% (68.5^0). The pHs of the formulated jams ranged between 3.3 – 3.4 and all were within range to the reference mango jam (3.37) (Table 4.4).

4.2 Nutritional composition of formulated Shea fruit pulp juices and jams

The means of the proximate composition (crude ash, moisture, protein, carbohydrates and calories) of the juices from different formulations of Shea fruit pulps are presented in Table 4.5. The ash content ranged from 0.2 – 0.34% in all the FSFP juices. Highest ash content (0.34%) was observed in 50% FSFP juice and lowest ash content (0.2%) was observed in both 10% and 25% FSFP juice. However the reference juice has slightly higher values with 1.2%. The highest values of crude protein were recorded in 50% FSFP juice (0.36%), followed by 25% juice (0.16%) and lowest in 10% FSFP (0.1%). The crude protein content of the juices were within range with the reference (0.2%). There were significant variations ($P>0.05$) in the carbohydrates and caloric values of FSFP juices and references. The carbohydrates and calorific values of all the formulated Shea fruit pulp juices were higher than that for the reference. The carbohydrate and calorific values were recorded highest in 50% FSFP juice with values of 75.5% and 1290 kj/100g respectively and lowest in reference juice (9.2% and 159.0 kj/100g).

The Proximate composition values for the formulated jams are presented in Table 4.6. The values for the crude ash and crude protein contents for all the FSFP jam were significant higher ($P<0.05$) than that of reference jam. There were no significant differences ($P<0.05$) in the crude ash and crude protein of jam with 78% and 48% SFP but significantly different from jams of 38% SFP. Carbohydrate contents and calorific values were significantly ($P<0.05$) different across all the FSFP jam and reference. Highest values of carbohydrates and calories were observed in jam ratios of 38% and least values in jam of 78% SFP.

4.3 Mineral composition of formulated Shea fruit pulp jam and juice

Mineral compositions across all the formulated Shea fruit pulp (FSFP) juice are presented in table 4.5. All the FSFP juices exhibited high potassium levels with the highest being registered in 50% FSFP juice (869mg/100g) and lowest in 10% FSFP juice (709.6mg/100g). Sodium levels were relatively high in all the FSFP juices with highest values being recorded in 50% FSFP juice (14.5mg/100g) and lowest in 10% FSFP juice (9.1mg/100g). The reference juice however had significantly higher sodium levels (21.2mg/100g). Calcium levels were significantly different ($P<0.05$) across the formulated Shea juices. Highest values were observed in 50% FSFP juice with 30.0 mg/100g and the least were observed in 10% with 10.41mg/100g. Magnesium levels in all the formulated juices were significantly different with highest values being recorded in mango juice (35.3 mg/100g). The iron levels across all FSFP juices were generally low with similar amounts in FSFP juice of 25% and 50% (3.2mg/100g) and lowest levels being observed in mango juice (0.9mg/100g). All the FSFP juices and reference contained traceable levels of Zinc ranging from 0.2 – 0.4mg/100g.

Potassium was the richest macro mineral found in all the FSFP jams and the reference jam and were significantly difference ($P<0.05$) across all the FSFP jams. Highest levels of potassium were registered in FSFP jam of 78% (1200mg/100g) and lowest in FSFP jam of 48 % (1144mg/100g). Sodium levels were equally high in all the FSFP jams ranging from 39.9 – 45.8mg/100g and were comparable to those recorded in the mango jam (47.13mg/100g). There was no significant difference ($P<0.05$) in calcium levels across the FSFP jam of 78 % and 38 % (32.2mg/100g). They were within range with values recorded in reference jam (34.1mg/100g). Magnesium levels were recorded highest in mango jam (37.8mg/100g) and were significantly different from all the FSFP jams with values ranging from 6.4 – 6.75mg/100g. Iron levels were generally low across all the jams

ranging from 2.6 – 3.3 mg/100g. Zinc levels were equally low among all the FSFP jam and the reference jam with values ranging from 0.37– 0.5 mg/100g.

Table 4.4: Physico-chemical characteristics of formulated Shea juices and jam and the reference product (mango juice/jam)

Shea fruit pulp (%)	pH	Titratable acidity (%)	Total soluble solids ^{o}Brix
Juice			
FSFP juice ;10	4.40 ± 0.30^{b}	0.09 ± 0.02^{c}	12.20 ± 0.20^{c}
FSFP juice ; 25	4.28 ± 0.10^{c}	0.12 ± 0.03^{b}	12.50 ± 1.00^{c}
FSFP juice ;50	4.10 ± 0.10^{d}	0.20 ± 0.10^{a}	14.00 ± 1.10^{a}
Mango juice;25%	4.50 ± 0.20^{a}	0.20 ± 0.04^{a}	13.10 ± 0.80^{b}
Jam			
38%	3.30 ± 0.30^{b}	0.31 ± 0.07^{a}	68.20 ± 1.40^{b}
	3.40 ± 0.10^{b}	0.23 ± 0.05^{b}	68.50 ± 0.40^{a}
48%			
	3.40 ± 0.50^{a}	0.23 ± 0.08^{b}	35.50 ± 3.40^{d}
78%			
M ; 48%	3.37 ± 0.20^{a}	0.33 ± 0.06^{a}	67.00 ± 8.70^{c}

Mean scores in the same column followed by the same superscript letter are not significantly different from each other (P>0.05).

Table 4.5: Nutritional composition for the formulated Shea fruit pulp juice and the reference product (mango juice)

Shea pulp %	MC %	Ash %	Protein %	CH, %	CV KJ/100g	K mg/100g	Na mg/100g	Fe mg/100g	Ca mg/100 g	Mg mg/100g	Zn mg/100g
10	86.50±4.50^{ab}	0.20±0.10^{c}	0.10 ± 0.60^{d}	13.10±2.02^{c}	224.4±1.20^{c}	709.60±5.50^{d}	09.17±1.93^{d}	2.30 ±0.39^{b}	10.40 ±1.75^{d}	04.30 ±0.62^{d}	0.30±0.14^{c}
25	84.80 ±0.30^{b}	0.20±0.01^{c}	0.16 ± 0.08^{c}	14.80±1.20^{b}	254.2±2.60^{b}	848.20±4.20^{b}	10.80 ±2.18^{c}	3.30 ±0.26^{a}	14.20 ±1.90^{c}	05.47±1.22^{c}	0.32±0.19^{b}
50	24.30±0.80^{d}	0.34±0.10^{b}	0.36 ± 0.14^{a}	75.50± 2.40^{a}	1290.0 ±9.00^{a}	869.00±8.70^{a}	14.50±1.50^{b}	3.20 ±0.94^{a}	30.00 ± 3.29^{a}	06.3±0.95^{b}	0.35±0.18^{b}
M;25%	89.30±2.40^{a}	1.20±.0.1^{a}	0.20 ± 0.00^{b}	9.20±1.60^{c}	159.0±1.10^{c}	811.00±1.50^{c}	21.20±1.90^{a}	0.90 ±0.36^{c}	20.00 ±0.95^{b}	35.3±3.38^{a}	0.42± 0.28^{a}

Mean scores in the same column followed by the same superscript letter are not significantly different from each other (P>0.05). MC = Moisture Content, CH=Carbohydrates, CV = Calorific Value, M=Mango.

Table 4.6: Nutritional composition of formulated Shea fruit pulp jam and the reference product (mango jam)

Pulp to sugar ratio	MC %	Ash %	Protein %	CH %	CV KJ/100g	K mg/100g	Na mg/100g	Fe mg/100g	Ca mg/100g	Mg mg/100g	Zn, mg/100g
38:%	23.60 ±2.70^{d}	0.50 ±0.17^{b}	0.80 ±0.25^{b}	74.90 ±15.60^{a}	1289.10 ±43.0^{a}	1156.00 ±17.00^{c}	39.88±5.70^{c}	3.00 ±0.57^{ab}	32.20 ±5.40^{ab}	6.70± 1.13^{b}	0.39±0.14^{b}
48%	30.20 ± 3.40^{c}	0.65±0.14^{a}	0.90 ±0.16^{a}	68.40 ±8.50^{b}	1176.40 ±17.0^{b}	1144.20 ±14.20^{d}	45.43±7.50^{ab}	3.00 ± 0.80^{ab}	30.30 ±3.35^{b}	6.40 ±1.72^{c}	0.37±0.13 ^{b}
M; 48%	48.60 ±8.55^{b}	0.30 ±0.12^{c}	0.60 ±0.11^{c}	51.00 ± 5.72^{c}	877.80 ± 9.8^{c}	1162.30 ±16.50^{b}	47.13 ±6.50^{a}	2.60 ±0.92^{b}	34.10 ±4.40^{a}	37.80±5.40^{a}	0.50 ±0.11^{a}
78 %	56.80 ±5.70^{a}	0.70 ± 0.20^{a}	0.90 ±0.33^{a}	40.80 ±0.51^{d}	709.10 ± 3.30^{d}	1200.20 ±17.90^{a}	45.80±8.30^{ab}	3.30 ±1.50^{a}	32.30± 2.90^{ab}	6.75± 1.16^{b}	0.49±0.12^{a}

Mean scores in the same column followed by the same superscript letter are not significantly different from each other (P>0.05). CH = Carbohydrate, CV = Calorific value, MC = Moisture content, M=mango.

4.4 Phyto-chemical characteristics

4.4.1 Formulated Shea fruit juices

The total phenolics in the Shea fruit juices were generally high ranging from 9.2 mg/100g in 10% FSFP juice to 36.57 mg/100g in 50% FSFP juice (Table 4.7). There were no significant difference ($P<0.05$) in values of total phenolics in FSFP juice of 25% (20.6mg/100g) and that of the reference juice (20.73 mg/100g) but significantly different with 10% FSFP juice. There were low levels of total carotenoids in the formulated juices and ranged from 0.01mg/100g - 0.06mg/100g with the reference having 0.02mg/100g. There were significant differences ($P<0.05$) in the total flavonoids of all the FSFP juices and reference juice. Data reveal that the highest values of total flavonoids were recorded in 50% FSFP juice (184.2mg/100g) and lowest values in 10% FSFP juice (13.18mg/100g). Vitamin C values were significantly different ($P>0.05$) across the different FSFP juices and reference. Highest levels of vitamin C were observed in 25% FSFP juice (13.5 %), followed by 50% FSFP juice (8.2%) and least in 10% FSFP juice (4.3%).The reference juice however, had very high levels of vitamin C (24.4%) compared to the Shea juice formulations.

4.4.2 Formulated Shea fruit jam

FSFP jams had generally higher values of photochemical as compared to the formulated Shea juices (Table 4.7). There were a significant difference ($P<0.05$) in the total phenolics recorded in all the FSFP jams. Highest values of phenolics were recorded with 98.31mg/100g in FSFP jam of ratio 78:18 and lowest in FSFP jam of ratio 38% with (56.21mg/100g) though higher than the reference jam (44.7 mg/100g).The flavonoids values in the FSFP jams were generally high ranging from 466.56 - 521.34mg/100g with the reference having lowest value (379.7mg/100g). The total carotenoids values were generally low across the FSFP jams ranging from 0.06 to 0.1645mg/100g. There were no significant difference ($P<0.05$) in vitamin C of FSFP jam with ratios of 78 % and 38 % . Highest values of vitamin C were observed in reference jam (24.6 mg/100ml) and the least values were observed in ratio FSFP jam of 48 % (3.6 mg/100ml).

4.5 Anti-nutrient Composition

The phytates concentrations were very high ranging from 141.4 to 163.5mg/100g and were significantly different across the different formulated juices. Mango juice had the highest concentration of phytates (300.6mg/100g). FSFP jams recorded a very high concentration of phytates ranging from 715.1 to 725.8mg/100g. The reference mango jam had higher concentration of 1364.3mg/100g.

Tannins concentration was negligible in the FSFP juices. Tannins concentration was negligible in the FSFP jams.

Table 4.7.1 Phyto-chemical characteristics of formulated Shea juices and jam and the reference Product (mango)

FSFP Samples	Carotenoids mg/100g	Phenolics mg/100g	Flavonoids mg/100g	Vitamin C mg/100ml
Shea Juices				
10%	0.01 ±0.00^{b}	09.20±2.18^{c}	13.18 ±3.10^{d}	4.30 ± 2.30^{d}
25%	0.06 ±0.02^{a}	20.73±6.44^{b}	95.88 ±8.60^{b}	13.50 ±1.6^{c}
50%	0.08 ±0.01^{a}	36.57±4.81^{a}	184.19 ±13.76^{a}	18.20 ±0.60^{b}
M,25%	0.02 ±0.00^{b}	20.56±6.40^{b}	54.36 ±7.96^{c}	24.4 ±1.80^{a}
Shea jams				
38%	0.06 ±0.01^{b}	56.21 ± 5.80^{c}	521.34 ± 04.94^{a}	12 ± 2.09^{b}
M,48%	0.16 ±0.08^{a}	44.69 ± 8.40^{d}	379.70 ±10.90^{d}	24.6 ± 1.80^{a}
48%	0.06 ±0.01^{b}	62.02 ± 6.90^{b}	466.58 ± 28.14^{c}	3.6 ± 0.80^{c}
78%	0.09 ±0.01^{b}	98.31 ± 6.80^{a}	477.49 ± 16.90^{b}	11.6 ±2.90^{b}

Mean scores in the same column followed by the same superscript letter are not significantly different from each other (P>0.05).M, mango reference sample

Table 4.7.2 Anti-nutritional characteristics of formulated Shea fruit juices and jam and the reference Product

FSFP Samples	Phytates mg/100g	Tannins mg/100g
Shea Jams		
M,48%	1364.30±27.00[a]	32.0±2.0
48%	715.10 ±9.50[c]	0.0
38 %	725.85±10.70[b]	0.0
78%	724.20 ±12.3[b]	0.0
Shea Juices		
10%	163.47±9.10[b]	0.0
25%	149.70±12.20[c]	0.0
50%	141.38±8.80[d]	0.0
M,25%	300.61±16.50[a]	18.0 ±1.5

Mean scores in the same column followed by the same superscript letter are not significantly different from each other (P>0.05).

4.6 Microbial properties

4.6.1 Microbial properties of the formulated Shea fruit pulp juices

The total plate counts of the juices ranged from 40 cfu/g to 163 cfu/g and these were below the maximum acceptable range of 1000 cfu/g by UNBS standards for microbiology. The values of the total Coliforms ranged between 0 - 2.7cfu/g. All the formulated Shea fruits juices were within the safe consumption range since they were all below the Coliforms maximum limit of 10 cfu/g. No *Escherichia* coli (E. coli) were detected in all the FSFP juices and the reference sample. The yeasts and moulds ranged between 2.7cfu/g - 8cfu/g but they were all below the maximum acceptable limits of 30cfu/g (Table 4.10).

Samples of FSFP juice kept at room temperature for one month showed that an increase in microbial load with some values going out of specifications like the 10% FSFP juice

which showed TPC, having colonies which are way out of specifications. Generally the microbial load increased tremendously in all the formulated shea fruit juices.

4.6.2 Microbial properties of formulated Shea fruit pulp jams

The microbial analysis carried out on the FSFP jam and the reference mango jam showed low concentrations of Coliforms, yeasts and moulds (Table 4.10). All the values were within the limits acceptable by Uganda National Bureau of Standards (UNBS) and therefore the jams can be good for consumption.

It was observed that there was an increase in microbial load in all the FSFP jams and reference with some values exceeding the specifications of UNBS standards meaning they were not safe for consumption. Generally, the microbial load increased tremendously in all the formulated shea fruit jams.

Table 4.10: Microbial Properties of Formulated Shea Fruit Juices, Jam and references immediately after processing.

Sample	**TPC** **(spec** 1000cfu/g)	**Coliforms** **(spec** 10cfu/g)	**Yeasts&Moulds** **(spec** 30cfu/g)	**E .Coli** **(spec 0)**
Jams				
38%	30.0 ±5.0^{c}	0.0 ±0.0^{c}	1.0± 0.0^{c}	0.0
M, 48 %	123.0 ±25.0^{a}	2.0 ±1.0^{a}	9.0± 1.6^{a}	0.0
48 %	57.0 ±15.0^{b}	0.0 ±0.0^{b}	4.0 ± 1.0^{b}	0.0
78 %	13.0 ±2.8^{d}	0.0 ±0.0^{c}	0.0 ± 0.0^{d}	0.0
Juices				
10%	163.0 ± 56^{a}	3.0 ± 0.2^{a}	8.0 ± 2.0^{a}	0.0
25%	93.0 ± 25^{b}	2.0 ± 0.1^{b}	2.0 ± 0.5^{d}	0.0
50%	40.0 ±10^{d}	0.0 ± 0.00^{d}	3.0 ± 0.5^{c}	0.0
M, 25%	57.0 ± 20^{c}	1.0 ± 0.0^{c}	5.0 ± 1.0^{b}	0.0

Mean scores in the same column followed by the same superscript letter are not significantly different from each other (P>0.05). M - Mangoes

Table 4.11: Microbial properties of formulated Shea fruit juices and jam after one month (At room temp).

% Ratio	TPC (spec 1000cfu/g	Coliforms (10cfu/g	Yeasts& moulds (30cfu/g)	E .Coli (spec 0)
Jams				
38 %	1043.0 ±50^{b}	3.0 ±1.0^{c}	11.0 ±2.0^{b}	0.0
M, 48 %	1250.0 ±70^{a}	7.0 ±1.0^{a}	20.0 ±4.0^{a}	0.0
48 %	667.0 ±152^{c}	0.0 ±0.0^{d}	8.0 ±1.0^{d}	0.0
78 %	667.0 ±58^{c}	5.0 ±1.0^{b}	10.0 ±2.0^{c}	0.0
Juices				
10 %	1217.0 ±175^{a}	5.0 ±2.0^{c}	38.0 ±7.0^{a}	0.0
25 %	837.0 ±56.0^{c}	6.0 ±2.0^{b}	19.0 ±3.0^{b}	0.0
50 %	833.0 ±75.0^{c}	7.0 ±1.0^{a}	18.0 ±2.0^{c}	0.0
M, 25 %	927.0 ±73.0^{b}	5.0 ±2.0^{c}	18.0 ±6^{c}	0.0

Mean scores in the same column followed by the same superscript letter are not significantly different from each other (P>0.05)

4.7 Sensory evaluation

4.7.1 Sensory evaluation of formulated Shea fruit juices

The flavor and the appearances of the FSFP juices of 10% and 25% were not significantly different (P >0.05) from that of the reference mango juice but significantly different from FSFP juice of 50% pulp (Table 4.8). There were no significant difference in the taste of FSFP juice of 25% and 50% with preferences as high as 5.8.Taste of 10% FSFP juice were least preferred with values as low as 4.85.The sweetness of the FSFP juices was significantly different (p >0.05) across the FSFP juices and ranged from 4.6 - 6.5 with higher values being observed in reference juice (6.91). The colour of the juices of both 25 and 50% were fairly acceptable with reference juice having the best preferred colour (7.85). Consistency of the FSFP juices were acceptable with values ranging from 5.3 to 5.9, however the reference had quite higher values (7.0) in reference jam. General consumer acceptability (wholesomeness) of the FSFP juices were way above the average (5) with values ranging from 5.65 - 6.5 which is in close range with mango juice (7.45) indicating that juices from Shea fruits can be consumed and acceptable like the juices from mango fruits.

4.7.2 Sensory evaluation of formulated Shea fruit jams

There were no significant differences (p >0.05) in colour, taste, and sweetness among the different FSFP jams and that of the mango jam (Table 4.9). Flavour values were highest in FSFP jam of ratio 48 % (7.0) but were equally acceptable in all the FSFP jams and reference jam. The appearance values were highest in FSFP jam of ratio 48 % and were not significantly different from the values of the reference. The least preferred appearance was in ratio 78 % (4.95). Consistency of all the FSFP and reference was generally accepted and ranged from 5.2 - 6.45 and was well within range with that of the reference (6.9). General acceptability and wholesomeness of all the formulated FSFP jams were highly preferred (6.2-7.25) and within the range of reference jam (7.15) indicating formation of FSFP jams shall be well received by the consumers.

Table 4.8: Sensory evaluation of formulated Shea fruit pulp juices

% Shea pulp	Flavour	Taste	Colour	Appearance	Consistency	Sweetness	Overall acceptability
10	6.25±1.8^{ab}	4.85±1.4^{c}	4.80 ± 1.6^{d}	6.25±1.6^{a}	5.30 ±1.2^{c}	4.60 ±1.5^{d}	5.65±1.5^{c}
25	6.75±1.6^{a}	5.80± 2.0^{b}	5.75± 2.1^{b}	6.15±1.2^{a}	5.80 ±1.9^{b}	5.95±2.4^{c}	6.50±2.7^{b}
50	5.55±1.2^{b}	5.75±1.7^{b}	5.50 ± 2.4^{c}	5.55±1.8^{b}	5.90 ±1.8^{b}	6.5±1.8^{b}	6.35±2.6^{b}
M,50	6.85±2.3^{a}	6.85±2.2^{a}	7.85± 2.3^{a}	6.75±2.0^{a}	7.05±2.0^{a}	6.91±1.6^{a}	7.45± 2.0^{a}

Results are expressed as mean ± standard deviation. Scale: 1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4=dislike slightly, 5=neither like nor dislike, 6=like slightly, 7=like moderately, 8=like very much, and 9=like extremely. Mean scores in the same column followed by the same superscript letter are not significantly different from each other (P>0.05).M= mango reference sample

Table 4.9: Sensory evaluation of formulated Shea fruit pulp jams.

Pulp to sugar % Ratio	Colour	Taste	Flavour	Appearance	Consistency	Sweetness	General acceptability
38%	7.05±2.0^{a}	6.90 ±3.5^{ab}	6.20±2.6^{d}	6.4±2.4^{b}	5.20±2.2^{b}	7.35±2.6^{ab}	6.20± 1.4^{b}
48%	6.65± 2.1^{ab}	7.20 ±2.2^{a}	7.05±1.8^{a}	6.8±3.2^{ab}	6.25±5.2^{ab}	7.60± 1.9^{a}	7.25±3.1^{a}
M,48%	7.20 ±1.4^{a}	6.95±2.7^{ab}	6.35± 1.5^{c}	7.05±4.3^{a}	6.90±2.6^{a}	7.05±1.7^{ab}	7.15± 2.5^{a}
78%	5.60 ±3.2^{b}	6.05±2.4^{b}	6.55± 2.1^{b}	4.95±2.6^{c}	6.45±3.0^{ab}	6.65±1.8^{b}	6.55±1.6^{ab}

Results are expressed as mean ± standard deviation. Scale: 1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4=dislike slightly, 5=neither like nor dislike, 6=like slightly,7=like moderately, 8=like very much, and 9=like extremely. Mean scores in the same column followed by the same superscript letter are not significantly different from each other (P>0.05). M= mango reference sample.

CHAPTER FIVE

DISCUSSION OF RESULTS

5.1.1 Physical chemical composition of pulp

Shea fruits were ovoid/spherical in appearance and their sizes range from small to big. This is in agreement with Maranz *et al.*(2003) who reported that they are elliptically shaped fruits, which begin green in colour and ripen to a more yellowish colour. The shea fruits had an average length to width of 3.7 – 3.8cm respectively. This was in range with what Maranz *et al*. (2003) reported that Shea fruits measures about 5-8 centimetres long and 3 – 4 centimetres wide. The shea nut seed were hard with distinctive colour of red brown to dark brown whose weight ranged between 10 g to 25 g averaging 14.82 g with seed percentage of 48.25%, This was comparable to what Maranz *et al*.(2003) reported that this seed measures about 2 – 4 cm in length and 1–
2.5 cm in width, has a shiny, smooth surface and comprises about 50% of the weight of the fresh fruit.

The weight of the whole fruits ranged from 19 – 48g with an average of 30.93g. These values were comparable to average weights of 17 – 33g reported by (Mbaiguinam *et al.*, 2007). Ruyssen (1957) also found that Shea fruits from West Africa weights ranged from 10 – 45g. This was also in agreement with other researchers such as Boffa *et al.,* 1996), who found out that shea fruit weight ranged between 10 – 44g. The fruit pulp percentage was 51.73 which was relatively high and close to 53 – 83% reported by (Mbaiguinam *et al*., 2007). These attributes are necessary in helping the food processor to identify which kind of machinery is required to process the fruits in bulk.

The average pH of the Shea fruit pulp was 6.2. PH is considered primarily a means of growth inhibition of existing pathogens in foods and juices. At low pH, many micro-organisms could be destroyed if held at that pH for significant time (Falguera & Ibarz, 2014).The lower the pH, the higher the acidity of the juices and jams.

The average titratable acidity of Shea fruit pulp was 1.6. The higher the titratable acidity, the lower the pH and the more acidity is the product. Acidity contributes to the development of flavour by maintaining a proper sugar - acid ratio thereby modifying the sweetness of sugar and palatability of food products, lends tartness to taste and also provides a thirst-quenching effect by encouraging saliva formation in the mouth (Omobuwajo *et al.*, 1998). Acidity also increases the efficiency of heat processing and

inhibits the growth of surviving heat resistant microorganisms (Schoenemann *et al.,* 1974). Shea fruit pulp had a brix of 26.2^0 which was relatively high implying that it contains high amount of sugars.

5.1.2 Phyto chemical composition of pulp

The total phenolics content of the Shea fruit pulp was 9.82mgGAE/100mL. The values of total phenolics content of Shea fruit pulps were higher than the total phenolics content in tomato juice (5.97mgGAE/100ml) (Owusu *et al.,* 2015), mango (6.25mgGAE/100g) (Gorinstein *et al*., 1999) and jackfruit (0.36mgGAE/100g) (Swami *et al.,*2012). This shows that Shea fruit pulp contains high levels of bioactive compounds thus increasing the nutraceutical properties on consumption of its fruits. Andabati & Muyonga (2014) reported that based on the classification of Lai & Lim (2011), samples with total phenolic content (TPC) greater than 20mgGAEgDW $^{-1}$were considered high, those with TPC 5-10mgGAEgDW^{-1}were moderate and samples with TPC less than 5mgGAEgDW-1 were considered low. Therefore, Shea fruit pulps were considered to have moderate amounts of total phenolics.

The flavonoid content of Shea fruit pulps were16.39mgCE/100g. Flavonoids of about 14.33mgCE/100g/day has been reported to reduce memory loss in elderly people (Letenneur *et al.,* 2007). So daily consumption of 100g of Shea fruit pulp is adequate to meet the flavonoid content necessary to mitigate memory loss in elderly people. Flavonoids are known to be potent antioxidants and metal chelators (Tapas, *et al.,* 2008) and are said to be beneficial to several chronic diseases such as cardiovascular diseases (Kris-Etherton *et al.*, 2002), cancer (Birt *et al.,* 2001) and inflammation (Manthey, *et al.,* 2001). Numerous studies have demonstrated that polyphenolics and flavonoids compounds are the most effective antioxidant constituents in fruits, vegetables and grains (Choi *et al.,* 2007);Dykes & Rooney, 2007a) Antioxidant activity is very important in human health mainly because of its free radical scavenging activity and protection against oxidative stress (Valdés *et al.,* 2015) and thus prevents development of diseases such as heart diseases and cancer (González-Vallinas *et al.,* 2013). The total carotenoids content of Shea fruit pulp was 0.35mg/100gRAE. The low levels of carotenoids could be attributed to processing conditions of high temperature which greatly influence the content of carotenoids in processed food products (De Moura *et al.,* 2015).

5.1.3 Anti-nutritional composition of pulp

On average phytate value of Shea fruit pulp was relatively high (120 mg/100g). The problem with high content of phytate in food is that it can bind some essential mineral nutrients in the digestive tract and can result in mineral deficiencies (Bello *et al.,* 2008). The phytate composition of the Shea fruit pulp reported in this study might pose some health hazard when compared to a phytate diet of 10 – 60 mg/g which if consumed over a long period of time that has been reported to decrease bioavailability of minerals in monogastric animals (Thompson, 1993).

The values of tannins in Shea fruit pulps were negligible rendering it a less toxic fruit to be consumed as compared with values of tannins in Bojer (*Argyreia nervosa* seeds, 1.21mg/100g (Fowomola, 2010) and those of maize (Hassan *et al.,* 2005). Tannins are aromatic compounds containing phenolics groups. Howes (1953) reported that tannins interact with the salivary proteins and the glycol proteins in the mouth and render the tissues astringent to taste. Research shows that continuous intakes of tannins include gastritis as well as irritation and edema of the intestines (Bichel & Bach, 1967). Tannins are known to bind strongly to proteins in vitro and form a compound called tannin- protein complex (T-PC). The complexes are quite resistant to degradation by digestive enzymes, thereby interfering with nitrogen balance in vivo (Feeny, 1976; Rhoades & Cates, 1976).

5.1.4 Proximate composition of Shea Fruit Pulp

Shea fruit pulps were rich in carbohydrates with values of 21.8mg/100g. Carbohydrates are very important sources of energy to the body (Anhwange *et al.*, 2004). Neuwinger (1994) also reported Shea fruit pulps as rich sources of carbohydrates such as galactose, glucose and fructose. Crude fiber was also relatively high in fruit pulp. Fibres associated with prevention of diseases such as cancer of the colon and the rectum, abdominal hernias, varicose veins, diverticular, diabetes, coronary heart diseases and obesity (Ramulu & Rao, 2003; Yusuf *et al*., 2007). The protein content of Shea fruit pulps was 3.6% which was in range of 3.0 – 4.0% reported by Omujal (2009), and 3.2 – 8.5% reported by Lockett, *et al.* (2000). Most edible fruits tend to have low levels of proteins (Hacıseferog *et al.,* 2005). Protein is indispensable part of the food for human as it‟s a major constituent of the protoplasm which forms the vital part of every living cell. Protein repair body tissue by continuous catabolism in the body and synthesis of the new proteins from the amino acids. Plasma protein regulates water balance protein involved in the regulation of acid –base balance (Lokonuzzaman, 2015). According to NAS (2005), the recommended daily allowance (RDA) for proteins is $0.8gkg^{-1}$ of body weight for adults and an increased value

of 1.1gkg^{-1} of body weight for pregnant and breast feeding women. WHO (2007) recommended a slightly higher protein value of 0.83gkg^{-1} of body weight which translates to about 33 – 66 g day^{-1} for adults and about 16.2 – 59.9 g day^{-1} for boys and girls aged between 4 –18 years. Lack of enough proteins in the body can lead to kwashiorkor especially in children, edema, muscle wasting and growth retardation (Hergaty, 1988). Therefore, encouraging consumption of Shea fruits among rural communities can be a good protein supplement in the diet.

Shea fruit pulps had low levels of crude fat (0.7%) compared to those reported (1.5–3.5g/100g) by Omujal (2009). The crude fat value was also low compared to that of most wild fruits (2.0%) (Hacıseferog *et al.,* 2005). Although the pulp contains low crude fat contents, these fats could nonetheless supplement energy requirement in the human diet (Anhwange et al., 2004). The value of vitamin C content of the pulp recorded was 3.6 mg/100ml which was very low. This value differs significantly from 86-125 mg/100greported by Omujal (2009) in Uganda and CRIG (2002) (196mg/100g) in Ghana. These variations could perhaps be as a result of edaphic factors (Wilhelmina , 2004). Vitamin C helps to lower blood pressure, anti-carcinogenic and useful in managing colds and flu (Akhilender, 2003).

Shea fruit pulps had ash content of 3.5% compared to 3.61% – 5.54% reported by Omujal (2009). Most fruits and vegetables are said to have alkaline Ash. Consumption of Shea fruits will contribute to a healthier diet by neutralizing the effect of other acidic foods. Snyder health (2003) suggests that a healthy diet should at least consist of 70– 80% basic foods and with no more than 20-30% acidifying foods to enable the body maintain a balanced pH in the blood and tissues.

5.1.5 Mineral composition of Shea Fruit Pulp

As presented in table 4.3, this study shows that Shea fruit pulps contained high levels of essential macro and micro minerals which play a big role in nutrition. Macro minerals included sodium (Na), potassium (k), magnesium (mg) and calcium (Ca) while micro

minerals included among others zinc (Zn), iron (Fe). High concentrations of potassium and calcium recorded in the study amounting to 1093.4mg/100g and 55mg/100g respectively. The potassium values were comparable to 1300mg/100g found in West Africa (Maranz *et al.*, 2004). These values, however, differ from those reported by Omujal (2009) with potassium (50 mg/100g) and calcium (90mg/100g). The amount of magnesium recorded in this study from Shea fruit pulp was 8.2 mg/100g compared to 21mg/100g reported by PROTA (2007). The Shea fruit pulp contained high values of iron (6.1 mg/100g) which is higher than 3.76mg/100g reported by Omujal (2009). sodium content of the Shea pulp was 3.1mg/100g which was lower than 18.12 mg/100g recorded by Omujal (2009). Variation in the mineral composition could be attributed to the environmental factors such as soil and climatic conditions. Similar variations in mineral composition in the Shea fruit pulp has also been reported in Mali and Burkina Faso (Maranz *et al*., 2004).

When compared with Recommended Daily Allowance (RDA) by United States National Recommended Council (1989), 100g of dry Shea fruit pulp powder contributes 8.8% of required calcium per day. From the analyses carried out, it‟s evident that Shea fruit pulps are nutritious because of multiple functions they carry out in the body. Calcium is a very important during bone formation, hormonal secretions, activation of enzymes, nervous system and blood coagulation (Agatemor & Ukhun, 2006). Magnesium is an equally important mineral which assists enzymes involved in the synthesis and breakdown of carbohydrates, proteins, fats and syntheses of DNA and RNA. Potassium is also important in the systhesis of proteins, normal functioning of the nervous system, muscles, water balance and absorption of glucose and glycogen. (Hegarty, 1988). The presence of sodium and potassium is necessary in calculating the Na/K ratio which is significant in the control of high blood pressure. This makes Shea fruits a valuable resource in the management of high blood pressure as an alternative measure for controlling high blood pressure.

5.2.0 Physico-chemical composition of formulated Shea fruit pulp juices and jam

The overall range of pH is 2.5 – 4.5 for most common processed fruit juices (Falguera & Ibarz, 2014). In this study, the pH of all the three different formulated Shea fruit pulp juices and the reference mango juice varied from 4.3 – 4.5, implying that all the different formulated juices from Shea fruit pulp are suitable for consumption. The pH range of 4.3 – 4.5 also shows that the formulated juices can be consumed but with consideration to

their acidic content (pH) in relation to their effect on the gastrointestinal tract, the stomach and the intestine (duodenum).

The jams were generally more acidic than the juices.PH of all the FSFP jams ranged from 3.40, 3.32 – 3.30 respectively compared to reference jam (3.38). These pH values were within range of pH values of 2.8 – 3.3, which is needed for optimum gel formation depending on the nature of the pectin in fruit (Desrosier, 1970; Lee, Teoh, & Yap, 1997). The most common cause of gel failure in jam is insufficient acid. Goldthwaite (1925) reported that ideal fruit jam with a good gel should: quiver, not flow, when removed from its mould; be a product with texture so tender that it cuts easily with a spoon; be a clear product that is neither syrupy, gummy, sticky nor tough.

Titratable acidity is a measure of the total acid present in a juice, and it has been shown that it is a better indicator of its erosivity than its pH (Grenby, Phillips, Desai, & Mistry, 1989). Titratable acidity for most fruit juices vary widely from about 0.08 –1.8% in 100mL of juice (Grenby *et al.*, 1989). The titratable acidity for the formulated Shea fruit juices in the current study especially the 25% and 50% Shea fruit pulp juice formulations falls in this range, implying these juices can be consumed with less erosive impact of tooth/teeth enamel.

The acidity of formulated Shea juices and jam is important from a food processing standpoint, since acidity is important in determining the quality of fruit juices (Yusof & Ibrahim, 1994). For a good jam preserve titratable acidity have been reported to vary from 0.3 to 1.1%. The formulated jam from the Shea fruit pulp and the reference mango had titratable acidity (0.23 – 0.33%) falling in this range. Acids present in food not only improve its palatability but also influence their nutritive value. The acid influences brightness of colour, stability, consistency and keeping quality of the product *(*Adedeji *et al*., 2008).

^{o}Brix values of juices often give information on the sugar concentration and the composition of the juice. In the current study, the Brix values of the formulated juices including the reference mango juice ranged from 12 – 14°. USAID (2009) gives a range of Brix values of single strength fruit juices such as apple, grapefruit, guava, mango, orange, passion fruit, and pineapple juices from 9.5° – 15°. This implies that Brix of the formulated juices from Shea fruit pulp in this study falls within acceptable range for quality tastes. The °Brix value of 68.2° of the FSFP jam with ratio of 38% and 68.5°

of FSFP jam with ratio of 48% conforms to values recommended for jam (68°) to hinder microbial growth and maintain keeping quality (Aina & Adesina, 1999; Moyls *et al.,* 1962).The °Brix value of the jam is also close to 67 °Brix recorded for syrup produced from black-plum fruit (Egbekun & Akowe, 1996) and mango reference jam (67 °Brix).

5.2.1 Phyto-chemical composition of FSFP Juices and Jams

Total phenolic contents of different FSFP jams and juices ranged from 62.0 – 98.3 mgGAE/100mL and 10.7 – 40.0mgGAE/100mL respectively. Highest values were observed in 50% FSFP juice (36.6mgGAE/100mL) and 78% FSFP to sugar (98.3mgGAE/100mL). This could be attributed to the large quantities of Shea fruit pulps added in the formulations as compared to the other formulas. The values of total phenolics in FSFP juices were higher than that for the reference mango juice (20.7mgGAE/100ml) and tamarind pulp juice (24.7mgGAE/100ml)(Andabati& Muyonga, 2014). These phenolics values were also in range with other natural fresh juices made from Apricot (23.75mgGAE/100mL), pineapples (36.16 mgGAE/100mL), white grapes (37.7mgGAE/100mL), Apples (45.387mgGAE/100mL) and red grape juices (49.4mgGAE/100mL) as reported by Mahdavi *et al*. (2010).

This shows that Shea fruit pulp juice contains high levels of bioactive compounds. Natural sources of phenolic compounds and inhibitors of digestive enzymes from food sources have provided an opportunity for low-cost dietary management for cardiovascular diseases (McDougall *et al*., 2005). The flavonoid content of FSFP jam and juices ranged from 466.6 – 541.6 mgCE/100g and 13.2 – 184.2 mgCE/100g respectively. The highest values of total flavonoids in the jams were observed in FSFP jam of 38 % (521.3 mgCE/100g) and the lowest was in 48 % (466.7 mgCE/100g). Generally, all the FSFP jams had relatively high levels of total flavonoids content. FSFP juice (10 %) had the lowest values of total flavonoids with 13.1mgCE/100g and the highest in 50% FSFP juice 184.2 mgCE/100g. This large difference could be attributed to the fact that more Shea fruit pulp was added in the FSFP juice of 50%.

The total carotenoids content of FSFP jam and juices ranged from 0.0548 – 0.99 mg/100gRAE and 0.01– 0.06 mg/100gRAE respectively. There was no observed increment in total carotenoid concentrations in the different formulations in the jams and this could be attributed to poor extraction of carotenoids during analysis. This could

also be attributed to processing conditions of high temperature which greatly influence the content of carotenoids in processed food products (De Moura, Miloff, & Boy, 2015).

Then vitamin C content of the formulated Shea fruit pulp juices and jam ranged between 4.3–13.5 mg/100g and 3.6 –12 mg/100g respectively. All the formulated juices from Shea fruit pulp had significantly lower vitamin C contents compared to reference mango juice. The low value for vitamin C reported in this study contradicts with literature which opines that most fruits are good source of vitamin C (Franke *et al.,* 2008). The low contents of vitamin C in the FSFP jams could be linked to the destructive nature of jam-making process. Processing of fruits into jams have been revealed to be most damaging towards vitamin C (Uckiah, Goburdhun& Ruggoo, 2007) which explains low vitamin C content in jams in this study. Valmnente *et al.*(2014) reported that vitamin C is integralin biochemical process in human body. The variation of vitamin C content could be a result of environment factors and/or different types of laboratory analysis (Wilhelmina , 2005). Consumption of vitamin C is essential to our bodies by acting as a good antioxidant, helps to lower blood pressure, improves or boosts immunity (FAO, 2007). It‟s also anti-carcinogenic and used in treating colds and flu (Akhilender, 2003). The recommended daily allowance (RDA) for vitamin C is between 100-120 mg/100g per day and consumption of lots of Shea fruits will meet these recommended values and improve the nutritional status of the population of the Shea fruit community.

5.2.2 Anti-nutrient composition of FSFP juices and jam

The level of phytates differed significantly for all the FSFP juices and ranged between 141.4 –163.5mg/100g. Reference Mango juice had higher phytate scores of 300.2mg/100g. There were no significant differences in the values of phytates of FSFP jams (715.2 – 725.9mg/100g) but significantly different with the reference mango jam (1364.3mg/100g).When we eat the plant, phytates are hydrolyzed during digestion to myo-inositol-1,2,3,4,5,6-hexkisphosphate (IP6) and lower inositol polyphosphates including IP1 through IP5 (these are phytate degradation products) (Dykes & Rooney, 2007). Most phytate (37 – 66%) is degraded in the stomach and small intestines. Ordinarily, our bodies regulate phytate levels, adjusting uptake in the gut and excretion until body levels come into balance (Dykes & Rooney, 2007).

The absence of tannins in the Shea fruit pulps and the formulated juices and jams renders shea, a less toxic fruit to be consumed as compared to other fruits.

5.2.3 Proximate composition of FSFP juices and jams

The value for moisture content for two juice formulations, one with 10% Shea fruit pulp and the other with 25% Shea fruit pulp ranged between 84.9 – 86.3% respectively. These moisture contents are within the acceptable range of 80 – 95% for fruit and vegetable juices (Kareem & Adebowale, 2007). Other fruit juices that fall within this range are cocktail juices (90.72 – 92.78%), fresh beetroot juice (91%) and
89.31 – 92.10% for mangoes and soy-carrot-beetroot drinks (Banigo *et al.*, 2015). The high moisture content suggests that the products have a short shelf life. Therefore, processing aids such as addition of preservatives and pasteurization are highly recommended to have a longer shelf life.

A moisture level of any food material is a measure of the longevity or life span of the food. It indicates how long a food material can be stored without becoming mouldy (Fellows, 2007). On this basis, the formulated jams from Shea fruit pulp to sugar ratio of 38:58 and 48:48 with 23.6% and 30.1% moisture contents respectively were the best jams that could have longer shelf life under storage. These moisture contents were within range with moisture contents (20 – 35%) of many fruit and vegetables jams, jellies, marmalades, conserves (Pomeranz, 2013). Low moisture content indicates that the jams have a longer shelf life.

The analysis of the formulated Shea fruit pulp juices and jam shows that they were rich in carbohydrates with values ranging from of 13–75g/100g and 40 – 75g/100grespectively. The values for carbohydrate and calorie in this study were higher compared to the carbohydrate and calorie value for fresh beetroot juice reported by (Emelike, 2015).

Jam processed from Shea fruit pulp to sugar ratios of 38:58 (74.9g/100g) and 48 % (68.4g/100g) had higher carbohydrate contents than the reference mango jam (51g/100g). These values were also higher than those observed in pineapple and jackfruit jams (Eke-Ejiofor & Owuno, 2013). High carbohydrate content in the two jam formulations above can be associated with the large presence of sugar added during the jam preparation.

Jam processed from Shea fruit pulp to sugar ratio of 38 % provided the highest energy while the jam from Shea fruit pulp to sugar ratio of 78 % gave the lowest energy. The differences in the energy contents could be attributed to the different sugar ratios of the different formulations. Sugar is a great source of energy (USDA, 2011) and so as expected the jam formulation with the highest added sugar would give the highest energy.

The protein content of the formulated Shea fruit pulp juices and jam ranged between 0.1 – 0.36g/100g and 0.8 – 0.9g/100g respectively. A considerable proportion of the protein content of fruits is insoluble and consequently remains in the pomace; therefore, most fruit juices are usually very low in protein contents. In this study, protein content in Shea fruit pulp juice processed from 25% Shea fruit pulp was comparable to that of the reference mango juice. Generally, the results indicated low protein levels from the various fruit juice formulations after analysis, with the highest (0.36%) amount recorded in juice processed from 50% Shea fruit pulp. According to WHO (2004), there was inadequate protein consumption in many developing countries, such as Uganda. Therefore, encouraging consumption of Shea fruits among rural communities could be a good protein supplement in the diet especially during the dry season where other commonly available foods rich in proteins such as beans, peas and groundnuts are out of season and therefore not easily accessible.

5.2.4 Mineral Composition of FSFP juices and jams

From the analyses carried out, the result indicates that the formulated Shea fruit juices (FSFP) were rich in the mineral elements analyzed. The jams, as expected, contain much higher nutrient levels than the juices. Processing of jams results in water removal and thus concentration of food nutrients. The jams hence can be a very good source of mineral nutrients as they are of great importance thus contribute to the wellbeing of the body. All the formulated Shea fruit jams were rich in the mineral elements (k, Na, Ca, Mg, Fe and Zn) relative to the reference mango jam. Consumption of the Shea fruit pulp juices and jams could significantly contribute to the daily nutrient intake of Ca, Mg, Fe and Zn as recommended by United States‟ National Research Council (NRC) (1989).

5.3 Microbial Properties

5.3.1 Formulated Shea fruit pulp juices

Total plate counts, Coliforms, yeasts and moulds detected were minimal and within range of the maximum limits of microbial standards of juices as stipulated by UNBS standards of juice, US 818:2001. The low values of microbes and fungi detected in the formulated juices could be attributed to the fact that pasteurization of the juices was effective and the products were processed under hygienic, addition of preservatives and regulating the pH of the juices.

However, the microbial analysis made after one month showed that there was an increment in microbes of total plate counts, Coliforms, yeast and moulds of the formulated juices. This could be attributed to the fact that recontamination could have occurred after packaging the juices and this is possible if the containers were not sanitized aseptically. It could also be a result of poor sealing integrity of the juice bottles thus allowing air from the surrounding entering the bottles and providing a conducive environment for microbial growth.

5.3.2 Formulated Shea fruit pulp jams

Coliforms, E coli, yeasts and moulds results show that the formulated fruit jam were within acceptable range and below the maximum limits as stipulated in the specifications of Uganda National Bureau of Standards, US 31: 1999. The low levels of microbes in the formulated jams could be attributed to pasteurization of the jams which were effective and the products were processed under hygienic, addition of preservatives and regulating the pH of the jams. This could also be attributed to high sugar concentration in the jam which does not favour growth of microbes. This is in agreement with Pilgrim *et al*., 1991 who reported that jams and jellies depend on their high sugar concentration for microbiological stability.

Microbiological analysis after one month at shelf life of the formulated Shea fruit jam showed an increment in the microbial load. This could have occurred as a result of recontamination of the jam during packaging and/or sealing integrity which could have allowed some air to enter the jars and provide a conducive environment for microbes.

5.4 Sensory evaluation of formulated Shea fruit pulp juice and jam

Compared with reference mango juices, juice formulation from 25% and 50% Shea fruit pulp juices were the most preferred considering flavour, appearance, consistency and wholesomeness/mouth feel. The preference score for 10% Shea fruit pulp juice was a bit low due to its low score in taste (4.8) and colour (4.8). In order to improve on these scores, more shea fruit pulp was recommended to be added so as to be of acceptable colour and taste. In relation with reference mango jam, FSFP to sugar jam of 38% and 48% were the most preferred considering colour, taste, flavour, consistency, sweetness, appearance and wholesomeness. Shea fruit jam of ratio 78% Shea pulp to sugar had low score ratings on the colour (5.6) and appearance (4.9) which were not appreciated by some members on the panel.

Generally, the colour of all the jams at the start were light green but changed to dark brown during processing. However, the formulated jams maintained a sweet and delicate taste, with flavours which were very pleasant and distinguished. Food colours were recommended to be added to improve on the colour but this was not done and was left for future research work. It is interesting that the entire panel members were not familiar with Shea fruit.Sensory evaluation indicated that Shea fruit pulp juices and jams were acceptable to consumers.

5.5 Conclusions

The results from this study revealed that good quality and palatable products such as jam and juice could be made from Shea fruit pulps. Sensory evaluation tests carried out show that the products were acceptable and can compete favourably in the market with other commonly available products such as mango jam and juice.

From the nutritional point of view, the study indicated that formulated Shea fruit pulp jam and juice contain some nutrients and minerals such as carbohydrates, calories, vitamins C, proteins, calcium, magnesium and iron which are necessary for proper growth and development of mankind and thus can help mitigate malnutrition in populations in Shea parklands.

General microbiological indicators (total plate count, Coliforms, yeasts and moulds and E Coli) were carried out to ensure the products were free of faecal contamination, total Coliforms, and infectious microbes. However more research is needed to process products free from general microbial contamination.

The low levels of anti-nutrients such as tannins in the formulated jam and juices indicate that Shea fruits were good with respect to nutrient availability since low levels of anti-nutrients were shown to increase the utilization of essential nutrients by the body. Development of Shea fruit jam and juice should be encouraged where the nutrients are conserved and easily consumed by the Shea parkland community and the rest of the country.

5.6 Recommendations

African indigenous fruits are under-utilized; efforts should go towards finding more commercial uses for them.

Processing of Shea fruits and jam should be adopted by processors, small scale business men and women as well as farmers. Expanding the utilization of these crops will be an incentive for farmers to cultivate them.

Combination of shea fruit pulps with other fruits which could serve to improve sensory properties of juices and jam such as the colour, taste and consistency.

There is need to domesticate and cultivate shea fruits since most of them are still being collected largely from the wild.

Protection of phytochemicals such as carotenoids from degradation during processing is also equally important to maintain its required level in human diet through advanced and cost-effective processing methods.

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