NUTRIENT COMPOSITION AND CONSUMER ACCEPTABILITY OF SOYBEAN-SWEET POTATO BASED COMPLEMENTARY FOOD ENRICHED WITH LONGHORN GRASSHOPPER (*RUSPOLIA DIFFERENS)*

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(Food Science and Nutrition)

JOMO KENYATTA UNIVERSITY OF

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2017

Nutrient Composition and Consumer Acceptability of Soybean-Sweet Potato Based Complementary Food Enriched with Longhorn Grasshopper (*Ruspolia differens)*

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A Thesis submitted in Partial Fulfilment for the Degree of Master of Science in Food Science and Nutrition in the Jomo Kenyatta University of Agriculture and Technology

2017

DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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DEDICATION

To my adorable parents Agnes and Wilfred Mmari and my beloved brothers Matayo and Martin

Thanks for your love and support.

God bless you to excel higher!

ACKNOWLEDGEMENT

My deepest thanks should goes to my almighty God who gave me life and grace to be what I am today. Glory to his holy name.

Special gratitude and appreciation goes to my supervisors, Dr. John. N. Kinyuru, Dr. Judith Okoth and Prof. H.S Laswai who believed in me and not only spent their valuable time, tirelessly and wisely guiding and advising during research and writing but also became an encouraging family to me; God will reward your good work.

Technicians Mr.S. Mwanyika and Malogo (Food Sciencelaboratory), Mr. Mohammed (Soil Science laboratory), Mr. David (JKUAT Food Science laboratory) and Dr Mongi (sensory and consumer science expert) I owe you gratitude for guiding me through that long laboratory work and data analysis. I extend my special thanks to the Department of Food Science, Nutrition and Consumer Science at Sokoine University of Agriculture, Tanzania for allowing me to use their facility.

I humbly appreciate the funding support of iAGRI through RUFORUM for funding my two years MSc studies. Deserving no less gratitude are the panelists who gave much of their time and support.

Special thanks to my dearest friends Julius Joram, Dr. Joeline Ezekiel, Mary Marcel, Ezekiel Temitope, Dr. Iraseny Swai and Angela Aluko; with them tough times became bearable. My lovely parents, the rest of the family and relatives; your encouragement and prayers during the whole time of this study are unpayable.

Special thanks to Bukoba natives including Mr. Karugaba Desdery and Mr. Perfect Zangina, Mafiga and Sabasaba clinic officers. I appreciate all those who helped me in one way or another throughout the period of my study. I will never fail to remember them.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS

AOAC	Association of Official Analytical Chemists
CFU	Colony Forming Units
FAO	Food and Agricultural Organization
GAM	Global Acute Malnutrition
HPLC	High Performance Liquid Chromatogram
IAGRI	Innovative Agricultural Research Initiative
ICIPE	International Centre of Insect Physiology and Ecology
OFSP	Orange Fleshed Sweet Potatoes
RDA	Recommended Daily Allowance
SPSS	Statistical Package for Social Sciences
TFNC	Tanzania Food and Nutrition Centre
THDS	Tanzania Health and Demographic Survey
PCA	Principle Component Analysis
RUFORUM	Regional Universities Forum for Capacity building in Agriculture
UNICEF	United Nations International Children's Emergency Fund

ABSTRACT

Traditional complementary foods in most sub-Saharan African countries are deficient in protein, essential minerals and vitamins resulting to sub-optimal growth and increased premature deaths among children below five years of age. This calls for action to develop home based enrichment of traditional complementary foods through advances in available low cost animal protein like edible insects. Longhorn grasshopper (*Ruspolia differens*) commonly known as *senene* in Tanzania is among most consumed edible insects by societies around Lake Victoria crescent. This study was aimed at developing a nutritious, shelf stable and acceptable complementary food from soybean, sweet potatoes and longhorn grasshoppers. Ethnographic study with 51 respondents who were *Haya* natives was conducted, to understand indigenous technologies on processing methods, preservation, shelf-life, nutritional knowledge and traditions towards *senene* consumption among the *Haya* tribe in Kagera region of Tanzania. *Senene*-based complementary flour product was formulated from germinated, dried, roasted soybeans flour mixed with toasted *senene* and sweet potatoes flour at different ratios. The ratios focused on meeting the RDA for the age group of 6-23 months. The formulations were: Complementary Flour 1(CF1) with 25% *senene*: 35% soybeans: 40% sweet potato, Complementary Flour 2 (CF2) with 20% *senene*: 40% soybeans: 40% sweet potato and Complementary Flour 3 (CF3) with 15% *senene*: 35% soybeans: 50% sweet potato. Proximate composition, minerals (calcium, iron and zinc), vitamin A, phytic acid (PA) analyses and microbial analysis were done using standard methods. Consumer acceptability and shelf life studies were also carried out on formulated flours and respective porridges. Data analysis was done using SPSS for interviews and R Commander Software for chemical, microbial and sensory data. The origin of *senene* remained an unsolved puzzle among most of respondents. Five varieties of *senene* were identified with harvesting for household consumption being done through wild collection. Traditionally made traps were used for commercial harvesting. Deep frying was the most preferred processing method while smoking was the most preferred

preservation method, with shelf-life of up to 12 months. Traditions and taboos associated with *senene* consumption were identified, most of which favoured men while leaving out women and children. Chemical analysis showed significant 24 fold reduction of phytic acid after 72 h germination of soybeans ($p<0.05$). All three formulations had nutrients and energy levels superior to commonly used flour from the market and contained ideal composition, meeting Codex standards and above World Health Organisation (WHO) recommendations for complementary foods($p<0.05$). Toasted *senene* had the highest retinol content of 390 µg /100g while fresh sweet potatoes had the highest βcarotene content of 182Retinol Activity Equivalent (RAE) ($p<0.05$). Microbial counts were significantly higher for fresh *senene* with 6.5log cfu/g. Processed *senene* and flour samples were free from *E. coli* and *Salmonella* spp. contamination as required by Codex and East African standards (EAS). CF1 was most liked flour with significantly highest score of 4.4 out of 5 on hedonic scale. Formulated products did not pose strange sensory attributes ($p<0.05$). Quantitative Descriptive Analysis (QDA) showed thatCF1 had higher intensity scores in aroma, colour and hands feel while CF3 in whiteness and appearance. Principle Component Analysis (PCA) showed variation between products to be mainly explained by aroma, hand feel and colour on one side and attributes appearance and whiteness on the other side along PC1. Partial Least Square Regression (PLRS)showed that both mothers and students preferred CF1 for its colour, hands feel and aroma also CF2 and CF3 for their whiteness and appearance. All flours were shelf stable for five months. Indigenous technologies for harvesting, processing and preserving *senene* exist and maybe improved to fit current food processing standards hence promote commercialization of the edible insect for food and nutrition security. Exploitation of *senene* as a source of nutrients for complementary food formulation will be useful for the resource poor farmers.

Keywords; *Senene*, Edible insects, Tanzania, Food, Technology, Nutrients, Culture

CHAPTER ONE

INTRODUCTION

1.1 Background

Access to appropriate quality and quantity of foods are essential components of optimal nutrition for infants and young children (Dewey, 2013). In Tanzania, stunting is reported to affect 34% of children under five years of age, with 11.5 % severely stunted (TFNC, 2014; THDS, 2016). This is high rate according to World Health Organisation (WHO) classification of stunting rates (WHO, 2002). According to UNICEF (2009), Tanzania ranks third last on stunting in sub-Saharan Africa, after Ethiopia and the Democratic Republic of Congo in which about one third of children aged 6-59 months are iron deficient, 58 percent are anemic and 24% are vitamin A deficient (THDS, 2016; UNICEF, 2009).

As it is with most Sub-Saharan African countries, complementary foods in Tanzania are grain-based, of low nutritional quality and given in insufficient amounts (Anigo *et al.,* 2010). Commercial complementary foods are normally expensive and not easily accessible in rural settings (Muhimbula and Issa-zacharia, 2010). Widely distributed and accessible are complementary porridge flours, which are normally made up of mixed grains like maize, sorghum, millet and wheat. Some are enriched with soybean flour and groundnuts. Improving availability of adequate complementary foods include the use of simple technologies that can be applied at home or community level; like specific enrichment of home-prepared complementary foods with traditional nutrient dense foods (Kinyuru *et al.,* 2012).

Insects have been eaten for centuries in many parts of the world, particularly in the tropics (Defoliart, 2000). In this way, insects' benefits maybe forgotten thus neglected in ongoing food security programmes (Arnold Van Huis, 2013).

Recent studies on edible insects have reported adequate amounts of energy and protein in most insects, meeting the amino acid requirements for humans (Rumpold & Schl, 2013). Edible insects are also reported to be high in unsaturated fatty acids, and essential micronutrients (Kinyuru *et al.,* 2012; 2015). Furthermore, studies confirm that insects can be utilized in processing of affordable and safe complementary foods with adequate nutrient density (Belluco *et al.*, 2013; Kelemu, Niassy *et al.,* 2015; Skau *et al.*, 2015).

Longhorn grasshopper (*Ruspolia differens*) belongs to the order Orthoptera. It is anedible insect along Lake Victoria region commonly known as *senene* in local Haya language. In northwest Tanzania longhorn grasshoppers are mainly harvested during the rainy season. They are customarily processed then stored to be used as a snack until the next season. The culture of *senene* eating was indigenous to the *Haya* tribe found in Lake Victoria Zone of Tanzania, where it stood as important delicacy. Reports show that 100g of *senene* flour is capable of providing the Required Daily Allowance (RDA) for protein, zinc, vitamin A and iron to children under 5 years of age (Kinyuru, 2010).This delicacy is also consumed in different regions of Tanzania including Mwanza, Mbeya, Morogoro and Manyara. In these regions, these longhorn grasshoppers have been consumed by all age groups as toasted or deep fried refreshing snack.

Soybean products have been proven to be good substitutes for animal products as they offer a "complete" protein profile (Lokuruka, 2010), containing almost all the essential amino acids (except methionine) and a range of water-soluble and fat soluble vitamins (Paul *et al.,* 2008). Reasonable amounts of soybeans are grown in different parts of Tanzania including Iringa, Mbeya, Arusha, Kilimanjaro, Morogoro and Kagera. Dried soybeans have a stable shelf life of months to years under normal food warehouse storage conditions.

Soybean flour is among the products increasingly consumed in Tanzania in complementary feeding, and has been reported to be good source of protein, lipid and other essential nutrients (Mosha *et al.,* 2000). They have been processed into flour at the

household level. However, the home flour is challenged with presence of antinutrients like phytates and beany flavour resulting from poor processing conditions. Germination of soybean is reported to significantly reduce levels of antinutrients in soybeans hence improve bioavailability of minerals(Vernaza *et al.,* 2012). Therefore, soybean will be germinated to enhance bioavailability of essential nutrients.

Sweet potatoes are among commonly consumed weather independent tubers, which are grown in almost all parts of Tanzania. They have been used in different African communities as part of complementary foods for their fine sensory attributes (Amagloh, 2012). These tubers are also high in carbohydrates, and contains reasonable amounts of beta carotene (Rose & Vasanthakaalam, 2011).

Enriching complementary foods with the nutritious edible insects as longhorn grasshoppers is a way towards reducing the problem of protein energy malnutrition and micronutrient deficiency among the Tanzanian children below 5 years of age. This study will focus on development of nutritious complementary food from longhorn grasshopper's flour, sweet potatoes and soybeans.

1.2 Problem Statement

Poor quality of complementary foods is a long term problem in Tanzania. Most children are born at recommended weight, however, evidence shows that growth starts to retard after the introduction of complementary foods, during which protein, energy and micronutrient needs are high (Mosha *et al.,* 2000). THDS (2010) reports that 92% of the complementary foods used in Tanzania are porridges made from single or mixed cereal grains. Children from low wealth quintile households are the victims of these cereal porridges as most of these households cannot afford animal protein (Muhimbula *et al.,* 2011).

Protein-rich insects like *senene* have been consumed for centuries among Tanzanian societies, as a customary and refreshing snack. However, there is underutilization of *senene* in Tanzania as it has never been exploited in complementary feeding despite the reported high nutrient protein concentration. Nutritional benefits of these insects have not been tapped to be of use in fighting stunting and micronutrients deficiency. Therefore, there is an urgent need for tapping nutrients from these insects by composting them with common plant based foods to avail nutrient dense complementary foods for a promising achievement towards reduction of stunting and micronutrients of public health concern deficiency in households.

1.3 Justification

Initially, *senene* used to be a traditional snack for *Haya* tribe where they mounted a sign of respect. The tradition of entomophagy is now growing in Tanzania, with commercialization and consumption of deep fried *senene* increasing countrywide. There are few studies on *senene* from East Africa, mainly Uganda and Kenya, reporting data on trade and its nutritional potential (Agea *et al.,* 2008; Kinyuru *et al.,* 2010). Few studies from Tanzania have reported on biology and phenology of *senene.* Studies on nutritional potential in this area have not been explored in Tanzania (Matojo and Hosea, 2013). Studies on culture, beliefs and indigenous technology associated with *R. differens* are rare despite the rising acceptance and prominence of this delicacy. It is important to understand indigenous technologies, culture and beliefs associated with consumption of *R. diffrens.* This understanding is crucial for scaling up innovations as well as designing adaptation for ongoing scientific findings on entomophagy. Researching on *senene* will therefore provide information on nutritional potential of these insects to be used by the public, nutritionists and commercial food product developers. The findings will also stimulate value addition, research in entomophagy and commercialization of *senene* leading to increased household income, hence livelihood improvement.

Use of *senene* as animal nutrients' source in enriching plant source complementary foods carries the potential to introduce an animal protein and essential minerals, which has potential to reduce protein energy malnutrition (PEM) and essential micronutrients deficiency at household level. WHO recommends complementary feeding with animal source foods to fight and avoid malnutrition(WHO, 2002). However, animal based foods are not readily accessible in many parts especially to low income households, which characterize many households in developing countries.

Development of composite flour formulated from soybean, sweet potatoes and *senene* flour is expected to provide these micronutrients of public health concern to meet RDA for children. It is also projected to attract commercialization and application of *senene* in production of nutritious and affordable insect-based complementary foods. The output of this study will be useful in improving feeding practices to nutrition officers in insect consuming societies like Kagera.

1.4 Objectives

1.4.1 General objective

Todevelop and evaluate the nutrient composition, shelf life stability and consumer acceptability of composite flours from soybean and sweet potato flour enriched with *senene*.

1.4.2 Specific objectives

i. To map indigenous technologies, processing methods and traditions towards *senene* consumption at Kagera region.
ii. To analyze chemical and microbial contents of developed flours from *senene*, sweet potato and soybean.
iii. To conduct chemical and microbiological safety analysis of selected common composite flour from Morogoro market.

iv. To conduct acceptability and shelf life stability studies on developed composite flours and resulting porridges.

1.5 Hypothesis

i. Soybean-sweet potato-based flour fortified with *senene* flour has fewer nutrients and not microbiologically safer than commonly consumed composite flours for children (6-23 months) in Morogoro.

ii. Soybean germination has no effect on phytic acid reduction and acceptability of soybean flour.

iii. Soybean-sweet potato based flour enriched with *senene* is not shelf stable under normal storage conditions.

CHAPTER TWO

LITERATURE REVIEW

2.1 Entomophagy Culture

Entomophagy is the culture of eating insects common among humans and some other species including birds, reptiles and amphibians; Anthropo-entomophagy is the insect eating by humans (Ramos-elorduy, 2009). According to FAO (2012), entomophagy is considered safe as there are no reported cases of transmission of diseases or parasitoids to humans from consumption of insects.

More than 1000 species of insects edible at different stage of their life cycle have been identified worldwide (Rumpold & Schl, 2013). Some of the most popular insects eaten around the world are found in Orders Orthoptera; Crickets, Grasshoppers, e.g., *Ruspolia differens* (Kinyuru *et al.,* 2010), Locust, e.g., migratory locust,*(Locusta migratoria migratoriodes)*(Moreki, 2014), Red locust, *(Nomadacris septemfasciata)*(Okore, Avaoja, & Nwana, 2014); Hymenoptera, e.g., (*Apis mellifera)*(Kelemu *et al.,* 2015); Isoptera, e.g., *Macrotermes bellicosus*(Raubenheimer & Rothman, 2013); Lepidoptera e.g. the mopane worm-caterpillar (*Gonimbrasia belina)*(Skau *et al.,* 2015) and many others as shown in table 2-1. The culture of insect farming is not widely practiced and most edible insects are harvested from the wild. Jomo Kenyatta University of Agriculture and Technology is among institutions practicing commercial edible insect farming while some research institutes like International Centre of Insect Physiology and Ecology (ICIPE) do insect rearing in small scale for research purposes.

The main problem with anthro-entomophagy as a source of animal-based protein and energy is the fact that there is a major attitudinal barrier to the use of insects as food in Western societies (Defoliart, 1999). This barrier is primarily caused by cultural and attitudinal factors (Yen, 2009). The view of insects as dirty, disgusting and dangerous is

deeply embedded in the Western psyche as insects are still viewed as pests by majority of people, despite the increasing literature pointing to their valuable role in the diets (Huis *et al.,* 2013). However, anthropo-entomophagy is still largely practiced in some of the developed countries like Japan where the most popular edible insect is a grasshopper, *Oxyayezoensis japonica* (Lensvelt & Steenbekkers, 2015). Some cultures believe in medicinal use of insects by humans, a fact partly supported by several studies(Chakravorty *et al.,* 2011; Benno Meyer-rochow and Jharna Chakravorty, 2013;Dzerefos *et al.,* 2013; (Ayieko & Oriaro, 2008)

2.2 Economic Potential of Edible Insects

Insect commercialization has been going on for many years at different levels from local barter trade to exports. Some insects like Mopane caterpillars are exported from Africa to Europe (Chakravorty *et al.,* 2011). It is reported by FAO (2012), that annually, Belgium imports 3 tonnes and France 5 tonnes of dried mopane caterpillar. Democratic Republic of Congo (DRC) are the main exporters of mopane caterpillar (Tabuna *et al.,* 2004). Insects' commercialization in most developing countries is locally practiced and the trade is growing following insects' value addition (Agea *et al.,* 2008; Moreki, 2014). Consumers buy processed and unprocessed insects at village markets, retail supermarkets and stations and from street vendors. Insects are also consumed in restaurants, depending on the extent to which anthropo-entomophagy is recognized in a given region (Megido et al., 2014). In southern Zimbabwe, mopane caterpillars are sold at rural and urban markets (FAO, 2012). In Thailand, both fresh and cooked edible insects are sold at local markets, wholesale supermarkets and minimarts; available either precooked or uncooked in frozen packages in supermarkets (Hanboonsong *et al.,* 2012). They are also marketed in ready-to-eat and microwaveable packages (Belluco *et al.,* 2013).

Active marketing of the fried grubs is reported to take place along major roads and markets in Edo and Delta States of Nigeria (Okore *et al.,* 2014). Siulapwa *et al.* (2014),

reports caterpillars as main economic activity to many Zambian traders who sustain their families including taking their children to school from this source of income. In Uganda, grasshopper's trade is dominated by men and characterized by wholesalers who buy grasshoppers from collectors and in turn sell to retailers, who subsequently sell to consumers along the roadside or highway vehicle-stopping points in Kampala (Agea *et al.,* 2008). In Tanzania, commercialization of *senene* is prominent in Lake Victoria regions of Mwanza, Geita and Kagera, where fresh *senene* collectors sell to retailers who eventually sell to producers who roast them and pack in small packages of 0.5 to 5kg. Roasted *senene* is traded in other regions across the country where it is found in different stores, groceries and some supermarkets.

2.3 Consumption of Longhorn Grasshoppers (*Senene*)

Longhorn grasshopper (*Ruspolia differens*) belongs to the order Orthoptera and is common edible insects along Lake Victoria regions and Zambia. They are referred to in different local names within the societies where they are consumed. The common local names include *Senesene* in Kenya (Kinyuru *et al.,* 2010), *Nsenene* in Uganda, *Senene* in Tanzania (Bailey & Mccrae, 1978) and *Nshokonono* in Zambia (Siulapwa *et al.,* 2014). From northwest Tanzania, they are mainly harvested during the rainy seasons. Some are eaten raw but the common preparation method is deep frying and toasting (with or without wings) and stored for use as snack until next season. The culture of eating *senene*was indigenous to the *Haya* tribe found in Lake Zone of Tanzania where it mounted a symbol of respect to the person it is served to. This culture has now spread throughout the country where *senene* is widely consumed by different tribes and ethnic groups.

2.4 Nutrition Value of Edible Insects

2.4.1 Protein Contents

Insects are reported to contain more protein, fats and carbohydrates than the equivalent of beef or fish and higher value of energy than soybeans, maize, beef, fish, lentils and other beans (Belluco *et al.,* 2013). Protein from *senene* is animal protein with high bioavailability and good ratios of amino acids compared to that of plant protein (Kinyuru *et al.,* 2010). Crude protein levels of different species of order Orthoptera are shown in Table 1. Crude protein level in longhorn grasshopper is reported to be 44% (Kinyuru *et al.,* 2010; Rumpold & Schl, 2013; Siulapwa *et al.,* 2014) with good ratios of essential amino acids; 4.98, 3.72, 3.16, 2.65, 1.98, 2.61 mg/100g of arginine, lysine, leucine, histidine, isoleucine and phenylalanine, respectively (Siulapwa *et al.,* 2014).

2.4.2 Lipid Contents

Insects' fat play an important role in the course of its evolution, where it can serve as a support, reproduction, metamorphosis and other energy sources (Van Huis *et al.,* 2015). Fat is very rich in insects' biomass which is accounted for about 26.77 % on average dried insect (Belluco *et al.,* 2013). Rumpold & Schl (2013), reports most insects to have higher levels of fat at pupa and larvae stages. Insects such as *R. phoenicis* have fat contents of up to 66% at pupa stage.

Unsaturated fatty acids are abundant in insect fat; and the ratio of monounsaturated and polyunsaturated fatty acids is close to the fatty acids ratio of human standards. In longhorn grasshoppers crude fat content is reported to be about 48% (Kinyuru et *al.,* 2010; Siulapwa *et al.,* 2014). Some studies report 67% fat with palmitoleic acid (28%), linoleic acid (46%) and 16% of αlinolenic acid (Arnold van Huis *et al*., 2013).

2.4.3 Vitamins and minerals

Food and Agriculture Organisation (2012) report stated that caterpillars of many species are rich in potassium, calcium, magnesium, zinc and iron as well as B-vitamins. Nadeau *et al.* (2015) reported that in some ethnic groups, insects provide 5 – 10 % of annual protein intake as well as fats, calories, vitamins and minerals. Riboflavin is reported to range from 0.11 to 8.9 mg per 100g (Belluco *et al.,* 2013; Kelemu *et al.,* 2015; Kinyuru *et al.,* 2010; Rumpold & Schl, 2013). Low levels of retinol and β-carotene have been detected in most insects, values ranging from 32 to 48 µg per 100 g and 6.8 to 8.2 µg per 100 g of dry matter for retinol and β-carotene, respectively (Skau *et al.,* 2015). The vitamin E content is relatively high in ground and freeze-dried silkworm powder reported to be 9.65 mg per 100 g. Kinyuru *et al.* (2010) reported high levels of vitamin A (2.12 mg/g) and vitamin E (2.01 mg/g) in longhorn grasshopper from Siaya district in Kenya. Water soluble vitamins were also found to be in satisfactory amounts of folate (0.99 mg/100g), riboflavin (1.3 mg/100g), niacin (2.36 mg/10g) and vitamin C (0.44 mg/100g).

Longhorn grasshoppers are undeniably rich sources of such minerals as iron (16.6 mg/100g), zinc (17.3 mg/100g), potassium (370 mg/100g), magnesium (33.9 mg/100g), phosphorus (140.9 mg/100g), sodium (358.7 mg/100g) and manganese (5.3 mg/100g), copper (0.6 mg/100g) as reported by Kinyuru *et al.* (2010). Also 9mg/100g calcium and 0.5mg/100g lead has been reported in dried *senene* (Siulapwa *et al.* 2014). Unlike plant mineral sources which have less bioavailability of minerals as iron, zinc and phosphorus, due to presence of anti-nutrients, minerals from insects are expected to be more bioavailable due to absence or low levels of such anti-nutrients.

2.4.4 Crude fibre

Insects are reported to contain significant amounts of fibre as shown in Table 2-1. The most common form of fibre in insects is chitin, an insoluble fibre derived from the exoskeleton. (Muzzarelli *et al.,* 2012), estimated the chitin content of fresh insect species raised commercially as food for insectivores and found up to 49.8 mg per kg (fresh). Matojo & Njau (2010), reports 11.6 to 137.2 mg per kg (dry matter) of chitin, which is much like the polysaccharide cellulose found in plants, largely believed to be indigestible by humans and associated with defense against parasitic infections and some allergic conditions (Yen, 2009; Seyfarth *at al*., 2008). Crude fibre in longhorn grasshopper is reported to range between 4.9 to 8.4% (Kinyuru *et al.,* 2010; Siulapwa *et al.,* 2014).

2.5 Use of Insects in Complementary Feeding

It has been proposed that edible insects could make a significant contribution to global food security in the future (Van Huis, 2013). Insects are thought to be more sustainable source of protein compared to conventional livestock. Insects convert feed to edible food more efficiently than chickens, pigs and cattle, while producing fewer greenhouse gas emissions and requiring less land and water (Ramos-elorduy, 2009). To fight and avoid micronutrients deficiency and stunting WHO recommends complementary feeding with animal source foods (WHO, 2002). However, animal based foods are not readily accessible to low income households, which characterize many households in developing countries. Insect-based foods are reported to be shelf stable to more than 6 months of storage under normal room conditions (Bauserman *et al*., 2015). Studies confirm storage stability with neither pathogenic microorganisms nor aflatoxins (Lensvelt & Steenbekkers, 2015; Skau *et al.,* 2015). Peroxide values of insect-based foods are also reported to be below limits after 6 months of storage.

In a study conducted in DRC, complementary porridge made from caterpillars and other available cereals' flour was high in energy and all essential micronutrients. Moreover no adverse reactions were reported among the children who consumed more than 75% of the served porridge (Nadeau et al., 2015;Skau et al., 2014, 2015;Kinyuru et al., 2015)

Table 2-1: Nutrition composition of commonly consumed insects of the order Orthoptera

Edible insects (Based on dry matter) Content)	Protein [%]	Fat [%]	Fiber [%]	NFE [%]	Ash [%]	Energy [Kcal/100 g]	Origin
Orthoptera (crickets, grasshoppers, locusts)	61.32	13.41	9.55	12.98	3.85	426.25	
Achetadomesticus (adults)	64.38	22.80	19.10	5.10			USA; reared
Achetadomesticus (adults)	66.56	22.08	22.08	2.60	3.57	455.19	USA; reared
Achetadomesticus (adults)	70.75	18.55	16.35	5.03			USA; reared
Achetadomesticus (juvenile)	55.00	9.80	16.40	9.10			USA; reared
Achetadomesticus (nymphs)	67.25	14.41	15.72	3.93	4.80	414.41	USA; reared
Achetadomesticus (nymphs)	70.56	17.74	14.92	4.84			USA; reared
Achetadomestica	64.10	24.00	6.20	2.12	3.55		Mexico; wild
Acridaexaltata	64.46	7.07	7.73	3.64	4.98	495.00	India; wild
Arphiafallax		71.30	6.52	11.58	8.11	2.41	
*Brachytrupesmembranaceus*Drury (adults)	35.06	53.05	6.30	2.33	3.25		Nigeria; wild
Brachytrupesportentosus	48.69	20.60	11.61	9.74	9.36		Thailand; wild
*Brachytrupes*spp.	6.25	3.24	1.01	85.30	1.82		Nigeria; wild
*Brachytrupes*sp.	61.20	18.70	7.42	7.60	5.05		Mexico; wild
*Boopedon*af *flaviventris*	75.95	8.43	10.35	2.32	2.95		Mexico; wild
Boopedonflaviventris	59.30	11.00	10.10	16.59	2.98		Mexico; wild
Conocepalustriops	71.00						Mexico; wild
Cytacanthacrisaeruginosus unicolor	12.10	3.50	1.50	60.50	2.10		Nigeria; wild
Encoptolophusherbaceus	57.60	11.80	11.02	17.22	2.87		Mexico; wild
Hieroglyphusbanian	63.61	7.15	7.16	4.81	4.86	566.00	India; wild
Idiarthronsubquadratum	65.20	8.17	11.10	4.42	3.79		Mexico; wild
Melanoplusmexicanus	77.13	4.22	12.17	4.04	2.44		Mexico; wild
Melanoplusmexicanus	58.90	11.00	10.01	16.50	3.94		Mexico; wild
*Melanoplus*sp.	62.93	376.00					Mexico; wild
Melanoplusfemurrubru(nymphs, adults)	77.00	4.20	12.10	4.08	2.59	361.46	Mexico; wild
Oxyafuscovittata	63.96	6.49	7.51	7.51	5.01	465.00	India; wild
*Romalea*sp.	75.30	12.30	9.73	0.19	4.25		Mexico; wild
Romaleacolorata	72.70	16.30	6.33	0.00	4.64		Mexico; wild
Ruspolia differens(brown)	44.30	46.20	4.90	2.60			Kenya; wild
Ruspolia differens(green)	43.10	48.20	3.90	2.80			Kenya; wild

Source; Rumpold and Schl (2013).

2.6 Nutrition Situation for children in Tanzania

The global strategy for infant and young child feeding states that, infants should be exclusively breastfed for the first six months of life to achieve optimal growth, development and health, and thereafter, receive nutritionally adequate and safe complementary foods while breastfeeding continues for up to two years or beyond (WHO, 2002). According to Lutter and Rivera (2003), adoption of recommended breastfeeding and complementary feeding practices and access to the appropriate quality and quantity of foods are essential components of optimal nutrition for infants and young children.

In Tanzania, 59% of infants receive exclusive breastfeeding for six months, while 90% of 6-8 months and 97% of 9-11 months children receive timely complementary food. However, only 8% of these children receive the complementary food meeting the criteria for a minimum acceptable diet (THDS, 2016). Chronic malnutrition (stunting) among children 0-59 months of age is therefore reported to be 34% (THDS 2016). This is a high rate according to WHO classification. According to TFNC (2014), severe stunting affects 11.5 % of children countrywide, this level of chronic malnutrition is considered "very high". Dodoma, Ruvuma, Rukwa, Kigoma, Katavi and Geita regions are reported to exceed the 40% threshold. Three regions exceeding 50% threshold are Iringa (51.3%), Njombe (51.5%) and Kagera (51.9%). In Zanzibar, stunting rates are ranging from 20.6% in Town West to 30.4% in Unguja North.

Global Acute Malnutrition (GAM) is reported to affect 3.8% of children aged 0 -59 months and this is considered "acceptable" in all regions except for Dodoma with 5.2%. On the other hand 0.9% of these children are suffering from Severe Acute Malnutrition (TDHS, 2010). For Zanzibar, wasting rates are ranging from 6.3 to 7.5%, where GAM is reported to be 7.2% (TDHS, 2010). Vitamin A supplementation is also alarming as each year 28.0% of the children in Tanzania mainland do not receive vitamin A supplement (TFNC, 2014).

Iron deficiency anemia is another important nutritional problem in Tanzania and is estimated to affect 58% of the children below 5 years old. This is attributed to low bioavailability of dietary iron from plant sources (Mosha *et al.,* 2000). About 70.6% of children aged 12-59 months in Tanzania mainland receive deworming in the 6 months' time interval. Hand washing is reported to be good as more than 95% regions soap is used for hand washing mainly before eating and after visiting the toilets (TDHS, 2014).

Nutrition status of school children is dire as most of them are suffering from almost all forms of malnutrition with anemia and protein energy malnutrition taking lead by 40% (TFNC, 2014). According to TFNC (2014), short term hunger is the main reason for poor school attendance and school dropouts, in her survey it shows that 50-75% of pupils go to school without taking breakfast.

2.7 Key Factors and Dietary Practices Leading to Poor Nutritional Status among Children

The problem of under nutrition is traced from early days of a child life and prevails as a result of inadequate breastfeeding and poor complementary feeding (Paul *et al.,* 2008). Lack of maternal education is among the determinant factors of a child's nutritional status other factors being poverty, mothers' education and literacy.

A number of studies report a significant association between low maternal literacy and poor nutrition status of young children, aged 3–23 months old. It has further been observed that the introduction of complementary foods for infants at an appropriate age (6 months) improved when mothers were educated (UNICEF, 2009 and 2015). Poverty among mothers is another contributor to poor nutrition status among children. Furthermore, animal protein and heme iron sources are expensive for low income households to afford. Most therefore rely on plant sources, which are known for less bioavailability (Muhimbula & Issa-zacharia, 2010).

Mothers from medium and high-income groups are reported to introduce complementary foods to children at early age compared to those in lower income groups. Among 90% of children from 6 to 8 months who are reported to have had a timely introduction of complementary food only 24.5% received foods from 4 or more food groups and 20% received a minimum acceptable diet (TFNC, 2014).

2.8 Challenges with Dominant Complementary Foods

In most Sub Saharan African countries, dominant complementary foods are porridges based on local staple foods including cereals and root crops (Dewey, 2013). Commercially formulated complementary foods are often of high cost thus inaccessible to low-income households (Muhimbula & Issa-zacharia, 2010). Tanzania is dependent on cereal and roots based traditional weaning foods from maize, sorghum, millet, rice, cassava, potatoes and yams, which are known for their high bulkiness and concentrations of fiber and inhibitors which reduce their nutritional benefits (Mamiro *et al.,* 2004; Mosha *et al.,* 2000).

While assessing complementary feeding patterns among children aged 3 to 23 months in Kilosa district of Morogoro region, Mamiro *et al.* (2004), reported plain maize porridge, finger millet, rice and peanut composite flour porridge as main complementary foods given to children in the district. Majority of locally formulated complementary foods, as well as some commercial complementary foods in Tanzania markets does not meet the quality attributes especially in terms of energy and micronutrient density as per Tanzania Bureau of Standard (TBS, 1984) standard number TZS 180:2014.

Studies report low fat, iron, calcium, zinc and phosphorus levels with high crude fibre, carbohydrate and magnesium in most complementary foods (Pee & Bloem, 2009). According to Onoja *et al.* (2014), calcium, iron and zinc are the most common deficient micronutrients in the home made weaning foods. Mosha *et al.* (2000), reports

concentrations of iron (Fe) lower than 10.87 mg/100 g in most Tanzanian complementary foods.

2.9 Uses and Nutrition Value of Soybeans

Soybean (*Glycine max.)* is a protein rich legume with the highest amino acid score and closest to the standard set by the Food and Agriculture Organization and World Health Organization (WHO). For thousands of years, soybean has been a staple of the Asian diet, but over recent decades, consumption is quickly growing worldwide (Lokuruka, 2010).

Varieties of fermented and unfermented products are in different markets and are used in many households worldwide. Unfermented soybean products include soy sprouts, immature green soybeans, roasted soy beans, soy flour, soy milk and tofu while fermented soybean products include miso, tempeh, tofu, and soy sauce (Abiose *et al.,* 2015; Anigo *et al.,* 2010; Arueya *et al.,* 2001). Common used soy product is soy flour and soy drink from roasted soy beans. Consumption of soy milk is also gaining popularity in different parts of the Tanzania (Laswai *et al.,* 2009).

Crude protein content of soybean is reported to be up to 38% with satisfactory ratio of essential amino acids which are necessary for human nutrition (Lokuruka, 2010). Sulphur containing amino acids are the limiting amino acids with a chemical score of 47, compared to 100 for an ideal protein (Karasulu, 2001; Quinhone *et al.,* 2015; Shin *et al.,* 2013).

Lysine content is very high and that makes soybean an excellent complement for cereals that are deficient in lysine but excellent sources of sulphur containing amino acids (Lokuruka, 2010). Soybean is thus reported to be the most nutritional legume with nearly double the amount of methionine and cysteine.

Soybean has a unique carbohydrate profile which is different from other beans;it is low in high molecular weight carbohydrates and has a total carbohydrate content of about 30% (Arueya & Osundahunsi, 2015). Among these soluble carbohydrates; sucrose, fructose, and saccharose, represents 10-12% and starch 1% (El-shemy, 2011). It also contains indigestible carbohydrates like raffinose and stachyose that are tri and tetrasaccharide fermentable by the gut micro flora. Soybean also contains 18% insoluble fibers, been a mixture of cellulosic and non-cellulosic structural components (cellulose, hemicellulose and pectin substances) Muzzarelli *et al.* (2012).

Lipids (crude oil) content of soybeans is approximately 20% with triglycerides representing about 96 %, phospholipids (2%), unsaponifiable lipids (1.6 %) mainly tocopherols (vitamin E) and 0.5 % free fatty acids (Karasulu, 2001). Soybean is also high in mono and polyunsaturated fatty acids with 80% of its total fatty acids in the form of linoleic acid essential for lowering blood cholesterol levels. Furthermore, soybean is among plant sources with few amounts of a noble essential fatty acid, alpha-linolenic acid and omega-3 fatty acid that are reported to have independent coronary benefits (Bau *et al.,* 2000; Karasulu, 2001). Mineral content of soybean is reported to be about 5%, its major constituents been calcium, potassium and magnesium (Quinhone *et al.,* 2015). Studies of soy in children and adolescents have shown that soy eases constipation, combats diarrhea (Shu *et al.,* 2001), lowers serum cholesterol (Ballmer-Weber *et al.,*2007) and may even decrease risk of breast cancer later in life in girl children (Shu *et al.,* 2001).

2.10 Challenges Associated with Soybean Flour Consumption

As it is with other plant based protein foods, the beauty of soybean protein is challenged by anti- nutrients mainly trypsin inhibitors and hemaglutinins (lectins) as well as carbohydrate–binding proteins, which reduce the bioavailability of noble nutrients (Lynch *et al.,* 1985). Soybeans contain two types of trypsin inhibitors, which are reported to be abundant anti-nutritional proteins in soybean seeds and are characterized as a food allergen in humans (Quirce *et al.,* 2002; Ballmer-Weber *et al.,* 2007). Different processing methods as cooking, soaking in sodium bicarbonate and citric acid solution have been reported to reduce these nutrients at greater extent (Laswai *et al.,* 2009). Laswai *et al.* (2009), reported beany flavour as another challenge associated with soybean consumption, found mainly in unfermented soybean products like soy milk. Lipoxygenase is a technologically most important enzyme found in soybean believed to catalyze oxidation of the polyunsaturated fatty acid by molecular oxygen, leading to the development of rancidity and beany flavours (Kulwa *et al.,* 2015). Development of this beany flavour is believed to occur during the initial grinding step as enzyme reaction environment is created. Fermentation of soybeans with *Rhizopus oligosporous* (culture used in *tempe* production) for about 36 hours is reported to reduce reasonable amount of anti-nutrients thus improving protein availability. However, most Tanzanian communities have not been able to easily adopt and make use of this technology.

Phytic acid is found mainly in plant seeds, where it functions as a reserve material for phosphorus. Soy meal is reported to contain about 1.5% phytic acid. It is known for forming insoluble salts with different metal ions as can sequester several metals by chelate formation (Vaintraub & Lapteva, 1988). There is strong experimental evidence that phytates may decrease zinc availability in animals and in humans. Phytic acid is also reported to strongly decrease iron bioavailability from potential iron plant foods (Vaintraub & Lapteva, 1988; Shin *et al.,* 2013). Phytic acid is hydrolyzed during germination, when the phytase activity increases very rapidly (Mostafa *et al.,* 1987).

This forms a base for processing methods involving germination for phytate level reductions. Recent animal-based trials, reports a remarkable increase in protein efficiency ratio, biological values and true digestibility above 60% for germinated soy bean products.

2.11 The Use of Soybeans in Complementary Feeding

Soybean has been widely used in complementary foods in different parts of the world because of its availability, accessibility and good nutritional profile. It has been reported that Asian mothers prefer the use of *tofu* during weaning for its availability, soft consistency and high palatability (Chapman and Associates, 2004). Soy-based infant formulas (SBIs) are reported to have been used from beginning of the 20th century for infants with eczema and later became a commercial product available for any infant who had allergy or intolerance to cow's milk formula or breast milk (Arueya & Osundahunsi, 2015).

Soybean is among commonly used ingredients in enriching African traditional complementary foods (Anigo *et al.,* 2010). Different methods of preparation ranging from soaking, dehulling to fermentation have been employed in making African complementary foods like gruels and porridge flours (Arueya & Osundahunsi, 2015; Bau *et al.,* 2000; Kim *et al.,* 2013; Shin *et al.,* 2013). Soybean composite crackers have also been developed as energy dense healthy snack for school children (Mosha *et al.,* 2010).

Evidence suggests that soy-based complementary foods have played a reputable role in reducing protein energy malnutrition among African children (Muhimbula *et al.,* 2011; Onoja *et al.,* 2014; Paul *et al.,* 2008; Pee & Bloem, 2009). Soy-based composite flours are available in many local markets (commonly known as *unga wa lishe* in Swahili). Soy flour is normally mixed with such cereals as sorghum, finger millet, maize and wheat to make composite flour for porridge. Soy milk is also increasingly gaining popularity as

replacement of cow milk with added nutritional benefits despite of the challenged acceptability caused by bean flavor (Laswai *et al.,* 2009). Commercially available soymilk, homemade soymilk, and soybeans have been shown to decrease the severity and duration of diarrhea while stimulating weight gain in Nigerian children with diarrhea and malnutrition (Anigo *et al.,* 2010). Shelf life of soy based complementary foods has been reported to vary from 3 to 9months depending on the moisture levels and packaging material; storage in laminated sachets was shown to have most stable shelf life of up to 9 months with no change in both nutritional and sensory attributes (Abiose *et al.,* 2015).

2.12 Soybean Germination Effects

Soybean germination has been used in the production of functional foods mainly in such products as soy sprouts, which have gained popularity over decades now as a functional food owing to their high nutritional value(Vernaza *et al*.,2012). The use of germination process in soybean flour making has not been widely reported. Studies on effect of soybean germination report reduction in phytic acid levels up to 46–65 % as a result of phytase enzyme production, leading to increased bioavailability of iron, zinc and calcium by 25–36 % (Bau *et al.,* 2000; Huang *et al*., 2014; Kim *et al.,* 2013; Lynch *et al.,* 1985). Total fatty acid content and trypsin inhibitor activity are reported to decrease below 32% in 6 days of germination (Wang *et al.,* 2015). Sensory evaluation of germinated regular soybean is reported to show highest scores for colour, taste, and overall acceptability against soybean seeds (Shin *et al.,* 2013). In another study, lipase and α-galactosidase activities are reported to increase with reduced lipoxygenase activities after less than 72 hours of germination (Karasulu, 2001). Decrease in lipoxygenase activity is expected to improve the substantial odour and flavour scores of germinated soybean flour. In rat bioassay, one-day germination of soybeans is reported to induce a significant increase of daily body weight gain, daily protein intake and protein efficiency ratio (PER) of seed meal (Huang *et al.,* 2014).

2.13 Uses and Nutritional Value of Sweet Potato

Sweet potato (*Ipomoea batatas* L) is a root tuber crop, which has been long used as staple food crop in most parts of the world. It is less sensitive to drought, tolerant to heavy rains, needs low inputs, and grows in a wide range of ecological zones with simple cooking methods (Rose and Vasanthakaalam, 2011). The plant is of food and economic potential as both leaves and roots are important and reliable foods to the consuming societies. These cream-yellowish roots have a sweet appealing flavour with soft mouth fill thus usually preferred as breakfast snack in many societies. In Tanzania, they are commonly grown in the backyard garden or along the river valleys mainly for the local market and household consumption (Laswai, 2011). The most consumed part is the root. Consumption of leaves as a vegetable is also a common practice to most African countries including some regions of Tanzania mainland. Leaves are reported to contain high potassium-sodium ratio among other nutrients (Laswai *et al.,* 2011). Sun drying is a common traditional processing method for both sweet potato roots and leaves.

Orange fleshed sweet potato (OFSP) is another cultivar of sweet potato, which has gained nutritional popularity in bio fortification programs as cheap and reliable source of pro-vitamin A. The use of orange-fleshed (β-carotene-rich) sweet potatoes has become effective entry point for improving vitamin A and caloric intake in sub-Saharan Africa since are widely grown under women's control (Rose & Vasanthakaalam, 2011). Pro-vitamin A content in home cooked OFSP is reported to exceed that in commercial products for babies in both raw and cooked forms (Amagloh, 2012). However, long boiling and frying of OFSP is generally expected to decrease total beta carotene contents.

2.14 The Utilization of Sweet Potatoes in Complementary Feeding

Sweet potato-based complementary food formulated using both household and industrial level processing methods like fermentation, blanching, sun drying, milling, blending, freeze drying and drum drying has been reported (Amagloh, 2012; Laswai, 2011). Sweet potato-based complementary foods are reported to meet the stipulated energy values specified in the Codex Standards though deficient in protein and essential minerals (Lutter & Rivera, 2003).

For complementary food formulations, sweet potato has been blended with such staple foods as sorghum, finger millet, maize, soybeans and cowpeas (Muhimbula *et al.,* 2011). In some Tanzanian societies, it is blended with meat soup and/or immature beans and vegetables for child feeding. Sweet potato-based infant foods are shown to contain measurable levels of pro vitamin A in form of β-carotene, also high in sugars like maltose, sucrose free glucose and fructose contributing to higher viscosities, solubility and high consumer acceptance (Amagloh, 2012). Furthermore, sweet potato-based formulations have significant advantage of use in complementary food due to the low level of phytic acid.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Design

The study followed ethnographic survey design on its objective number one. The rest of the study followed experimental design whereby raw materials for composite flour formulation were randomly collected and processed to flour. Nutrient composition for targeted micronutrients of public health concern and microbial safety analyses was carried out on flours where the samples were replicated three times for analysis. The composite flour was formulated from sweet potato flour, soybean flour and *senene* as shown in figure 3-2. The composite flour samples were then randomly assigned to participants during acceptability tests. The methodology overview is shown in Fig. 3-1.

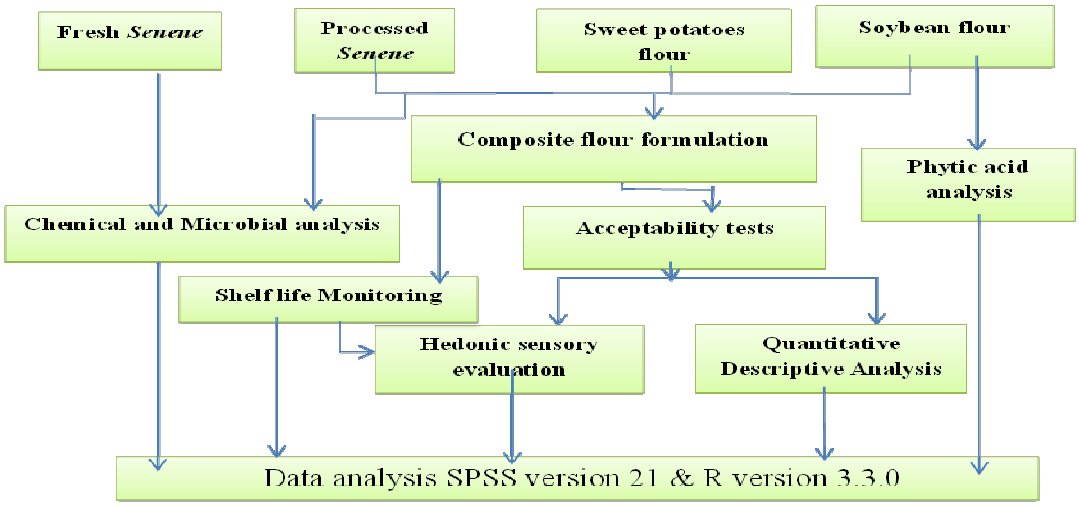

Figure 3.1: Methodology overview

3.2 Study Area

The study was carried out in Kagera and Morogoro regions of Tanzania. Kagera is found in the northwestern corner of Tanzania, lying between 1°00' and 2°45'S of the Equator and 32°40' E of Greenwich. The capital town of Kagera is Bukoba, which is about 1,500 km from Dar es Salaam by road. Kagera region shares borders with Uganda to the north, Rwanda and Burundi to the west and Lake Victoria to the east. Main economic activities carried out in this area include farming, fishing, livestock keeping and mining (URT, 2015). The natives of Kagera are mainly the *Haya* tribe to whom *senene* is an esteemed delicacy. This hilly terrain region with thick tropical vegetation including forests and wide-open grasslands, experiences two rain seasons. The long rainy season is from March to May and short rainy season from October to December. The region is also among the three regions reported to have stunting rates above 50% (TFNC 2014: URT 2015). The survey part focused on Muleba and Kagera urban districts, where *senene* harvesting and enterprise is endemic, while laboratory analyses and consumer acceptability studies were carried out in Morogoro region where Sokoine University of Agriculture food laboratory and food scientist students to be used as semi-trained and trained panelists were available. Sensory evaluation for mothers was also done in Morogoro region as it the region is close to the laboratory where analyses were done. Morogoro region has similar geographical ethnographic characteristics with the regions where *senene* was obtained from.

3.3 Survey and Interviews

A total of 51 randomly selected adults of *Haya* ethnic group were interviewed from Muleba and Kagera urban districts of Kagera region. Purposive sampling with the help of village elders was done to identify a population of 100 *Haya* natives with *senene* knowledge from which 51 respondents from both Muleba and Bukoba districts were randomly selected. The sample size was obtained using Fischer's formula (Fischer,1991): $n=(z^2xpxq/d^2$ where z(standard normal deviate corresponding to 95%

confidence interval=1.96,p(proportional of indicator measured)=0.5,q(1-p)=0.5,d(degree of desired precision=0.15 which equals n(desired minimum sample size) =43 respondents. Among these were 10 key informants mainly elders of *Haya* tribe and *senene* collectors who were selected using purposive sampling due to their distinct knowledge of local culture and *senene*. In this, former interviewees were asked to pinpoint respected village elders and experienced *senene* collectors. *Senene* collectors who were found at the collection points during the night hours were also interviewed. Key informants interviews were mainly for confirmation and clarification of some beliefs and indigenous technologies outlined by interviewees. Information was collected through face to face interviews using questionnaires administered in local Swahili language(Appendix 3). The questionnaire covered questions regarding demographics, cultures, harvesting, indigenous technologies in processing and preservation. The questionnaire started with a brief awareness creating sentence about nutrition status of residents of Kagera region. The study was of ethnography nature with interviews focused on perceptions, beliefs and traditions towards *senene* consumption, storage and shelf-life. *Senene* prices and nutrition knowledge among *senene* consumers were also collected using the questionnaires. Observations of harvesting, cooking and traditional processing of *senene* was done by the researcher in the homestead, farms and wild fields for two weeks and recorded. To document some of the traditional practices, photos of the insects, traditional traps and *senene* markets were taken. Photos were taken using camera and a video was taken where necessary. Samples of *senene* were collected from the fields and markets for identification and inventorying.

3.4 Sample Collection for Product Development

Wild collection at dawn and trapping of fresh longhorn grasshoppers (*senene*) during the night took place in Bukoba and Muleba districts of Kagera region. Fresh samples were packed in polythene bags, preserved in a -20°C freezer then transported in iced cool box to Sokoine University of Agriculture (SUA) within 72 h after harvest, Morogoro for

chemical and microbial analysis. Toasting of the remaining *senene* was done in Bukoba before transporting them to SUA for nutrients analysis and product development. Dried soybean (Semeki variety, harvested October 2015) was obtained from Turiani district in Morogoro whereas local variety of fresh sweet potatoes were obtained from Morogoro central market and carried in polyethylene bags to SUA food laboratory for preparation and analysis.

3.5 Sample Preparation for Product Development

3.5.1 *Senene* preparation

Senene were sorted to remove contaminants like soils, grasses and accompanying insects before removal of wings and appendages (Fig.3-2). Toasting on a hot frying pan was done for 10 minutes, the way Bukoba natives prepare *senene* for normal snacks. Toasted *senene* were winnowed to remove appendages and wings residuals. Toasted clean *senene* were co-milled using a laboratory grinder (Pigeon mixer grinder, special model manufactured by Pigeon Appliances Pvt Ltd, India) with sweet potato and soybean flour during the mixing of flours to form complementary flour. Toasted *senene* were stored in coloured plastic containers and frozen (-4◦C) for composite flour formulation.

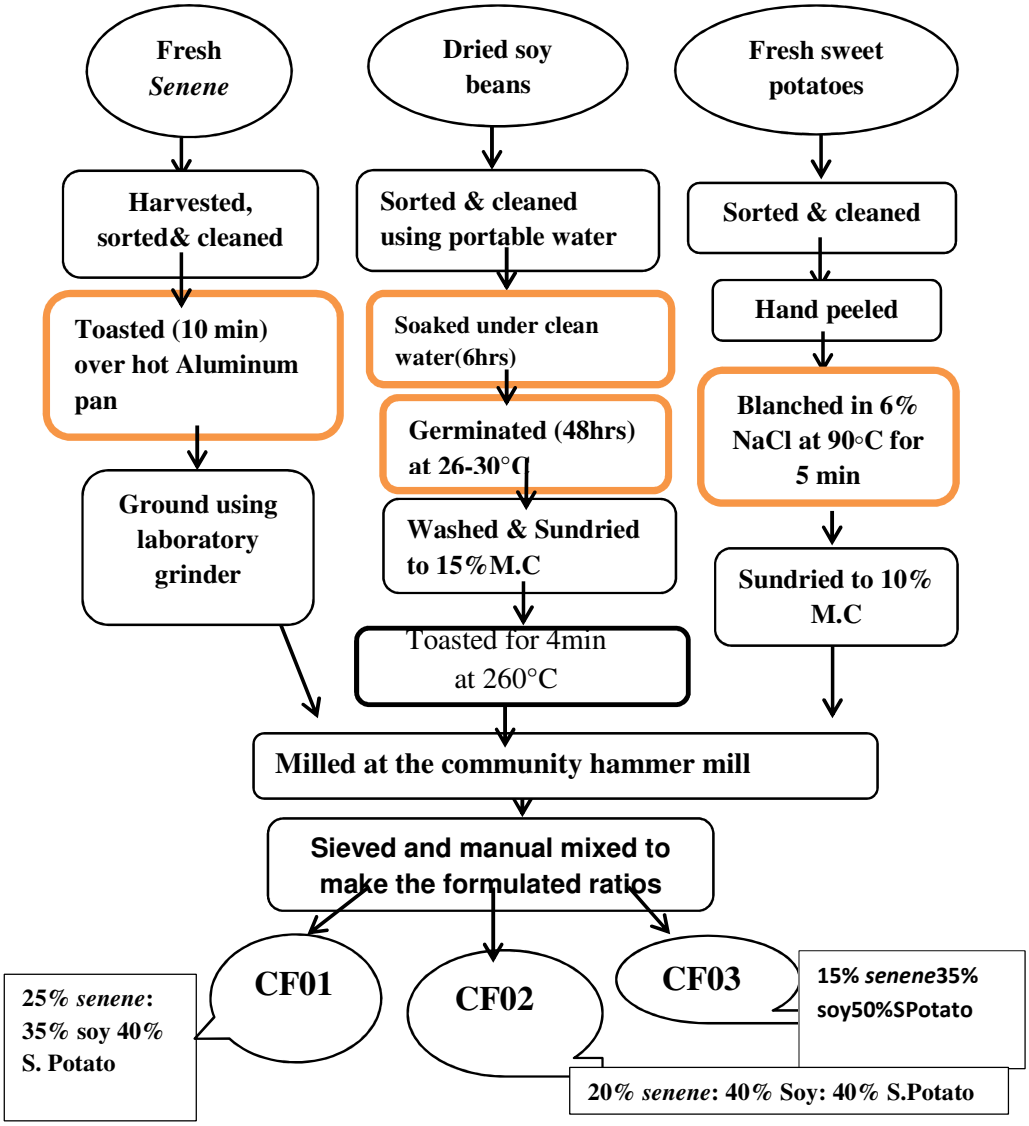

Figure 3.2: Flow diagrams for *senene*, soybean, sweet potato and complimentary flour preparation

3.5.2 Soybean flour preparation

Dried soybeans (Semeki variety) were sorted to remove contaminants and broken beans then washed to remove dust. The clean soybeans were soaked for 6 h based on the literature (Karasulu 2001: Wang *et al.,* 2015).Soaked soybeans were germinated in locally made basket germination chambers (Fig. 3.3) for 72 h under average ambient temperature of 30°C during the afternoon and 26°C during the night for periodic phytic acid quantification (protocol page 37). After the periodic phytic acid analysis results, the 48th hour of germination was agreed as soybean germination time for product development. Germination process was repeated and the 48 h germinated soybeans were dehulled, washed and solar dried to about 15% moisture content (protocol page 34) then toasted at 260°C for four minutes to improve sensory attributes, digestibility and keeping qualities (Fig 3.2). Toasted soy beans were milled at Mafiga village community hammer mill number 75.

Figure 3.3: Soybean germination using baskets, muslin cloth and black-dark cloth

3.5.3 Sweet potato flour preparation

Fresh sweet potatoes (cream-yellow local variety) were sorted and cleaned to remove soil debris. They were then hand peeled, washed, equally sliced then dipped in 6% Sodium Chloride (NaCl) boiling water for 5 min, sun dried to 5% moisture content and milled at Mafiga village community hammer mill number 75 (Fig. 3.2).

3.5.4 Composite flour formulation

Complementary flours 1, 2 and 3 (CF 01, CF 02 and CF 03) were developed using Nutri-survey data collection software-The linear programming module, Microsoft Excel 2010 and WHO guide for complementary feeding of year 2002. Nutrisurvey has been used previously in optimizing nutrients for complementary feeding (Briend *et al.,*2003).Three different ratios of soybean flour, sweet potato flour and *senene*were formulated based on the criteria of obtaining balanced ratios meeting the RDA for 6-24 months children group. Amount of *senene* in CFs decreased from 25% to 15% as follows; CF1 had 25% *senene*: 35% soybean flour: 40% sweet potato flour, CF2 had 20% *senene*: 40% soybean flour: 40% sweet potato flour and CF3 had 15% *senene*: 35% soybean flour: 50% sweet potato flour (Table 3.1). The three CFs were sieved in 1mm sieve to obtain fine flour ready for porridge preparation and shelf-life monitoring.

Table 3.1 Complementary flour formulation ratios

Formulation	**Composition**		
	Senene	**Soybean flour**	**Sweet potato flour**
CF 01	25	35	40
CF 02	20	40	40
CF 03	15	35	50

3.5.5 Porridge Sample Preparations

Two hundred grams of three complementary flours (CF1, CF2 and CF3) and one control flour bought from the market (made of maize, finger millet, soybean and groundnuts) were each made to a thick gruel, which was added to 1000 ml of boiling water in a cooking pan. Control flour bought from the market was named CF4. The mixture was continually stirred for about 20 minutes then 25 g of sugar added to it and allowed to boil just before serving.

3.6 Acceptability Tests for Formulated Flours and Porridges

3.6.1 Sensory evaluation

Sensory evaluation of flour and porridge samples was conducted at SUA main campus. The panel consisted of 57 untrained mothers of children aged 6 months to 5 years selected randomly from Mafiga and Sabasaba clinic and 32 semi trained panelists selected among SUA food science students. A 5 point hedonic scale was used, where; 5-like extremely and 1-dislike extremely and 3;neither like nor dislike as described by Lawless & Heymann, (2010). Porridge samples were served at 27±2°C. Panelists were required to fill sensory evaluation forms (Appendix 3&4) as per instructions. The scores were coded, compiled and analyzed statistically. Mothers were used to taste the product intended for children because difference testing and descriptive analysis are best left to adults who have similar perceptions to those of children, and yet greater cognitive abilities, as required to carry out difference testing, scaling and descriptive analysis (Guinard, 2011).

3.6.2 Qualitative descriptive analysis (QDA)

QDA was used in this study to understand detailed qualitative and quantitative description of the sensory attributes perceived in the developed flours. QDA is a useful and highly informative class of sensory tests, which tries to answer the question of what

is the nature and magnitude of difference between products. QDA was conducted in the research laboratory at SUA using a trained sensory panel of 10 assessors, aged 21-31 years according to method described in Lawless and Heyman (2010). The assessors were selected based on willingness, basic knowledge on sensory evaluation and health condition then taken through training according to ISO Standard (1993). In a pre-testing session the assessors were trained in developing sensory descriptors and the definition of the sensory attributes (Table 3.2). Assessors developed a test vocabulary describing differences between samples, then agreed upon total number of attributes on; whiteness, colour hue, appearance, hand-feel and aroma for flours and thickness, sweetness, mouth-feel and oiliness for porridge. The assessors were subjected to duplicate pre-testing of the samples just after the training before the actual testing to measure their reproducibility and efficiency. A nine point line scale developed during training showing low intensity (value 1) to the highest intensity (value 9) was used (Appendix 5&6). Panel check software was used to generate turker and p*MSE correlation loadings plots for assessing panel performance. All samples were coded in 3-digit random numbers and each panelist served in a randomized order. Clean drinking water was provided for mouth rinsing.

Table 3.2: Attributes, definition, references and anchors developed in quantitative descriptive analysis panel training

Attribute	Definition	Reference	Anchor
Colour	Colour intensity; greyness and whiteness	White paper	Low to high
	Colour hue	Brownish material	Low to high
Hands feel	Texture, softness at hand, particle size of flours	Purely fine flour	Less particles to more particles
Mouth feel	Mouth texture of the porridge, softness in the mouth	Filtered fruit juice	Low to high
Aroma	Aromatic	Roasted nuts	Less aromatic to very aromatic
Appearance	Porridge, food look, appealing		Less appealing to very appealing
Thickness	Porridge viscosity	Specific brand Mango Juice	Less viscous to very viscous
Oiliness	Presence of visible oil on porridge surface	Shiny porridge surface	Less oily to very oily
Sweetness	Sweetness intensity	Sweetness of brown sugar	Less sweet to very sweet

Source: QDA panel

3.7 Selection of Commonly Used Flour

A market survey using questions on most liked and most sold flour was conducted. All 14 groceries selling composite flours in Morogoro central market were identified in order to select commonly used composite flour (*unga wa lishe*). This was analyzed for proximate composition, vitamin A, zinc, calcium and iron contents then rated against developed formulations.

3.8 Shelf Life stability

Shelf life stability of formulated composite flours was monitored for six months. Free fatty acids (FFA), peroxide value (PV), microbial quality and moisture content (MC) were monitored in three weeks interval for 15 weeks. Acceptability through sensory evaluation using a five point hedonic scale was also monitored by 20 randomly selected semi-trained panelists maintained throughout the shelf-life period.

3.9 Chemical Analysis

3.9.1 Proximate analysis

Proximate composition (moisture, protein, fat, ash, fibre and carbohydrates) for soybean flour, sweet potato flour, selected market flour and *senene* (fresh, toasted and deep fried), were determined by the methods of AOAC (1995).

Moisture content was determined according to standard oven drying method at 110°C overnight. Crude protein was determined using block digestion and steam distillation (Kjeltec TM 8200 Auto distillation unit 2012). Crude fat content was determined by solvent extraction method using SoxtecTM2055 while ash content was determined by sample heating in a muffle furnace at 550°C for 4 hours. Crude fibre was determined using dilute acid and alkali hydrolysis using Fibertec 2010 while carbohydrate content was determined by difference (100-.(%moisture+ %protein+ %fat +% ash + %fibre).

3.9.2 Determination of acid value

A 5g of a sample warmed in a water bath at 40^0C for 45 minutes in 20 ml of 5% diethyl ether was dissolved in alcohol. The mixture was titrated against 0.1M sodium hydroxide using phenolphthalein indicator until pink colour appeared. Acid value was calculated using the formula:

$$\text{Acid value in mg NaOH/g} = \frac{(V_1\text{-}V_2) \times 0.004\text{g/ml} \times \text{Extraction vol. (ml)} \times 1000}{\text{Sample weight (g)}}$$

Where $V_1$and V_2 are initial and final titre volumes respectively

3.9.3 Determination of peroxide value

A 5g sample was warmed in water bath at 40°C for 45 minutes. The sample was then mixed with 25 ml of solvent mixture of acetic acid-chloroform 60:40(v/v) and 1g of solid potassium iodide then heated in a boiling water bath for 30 seconds. The heated contents were poured into 100 ml conical flask and titrated against standardized 0.002M sodium thiosulphate ($Na_2S_2O_3$) using starch solution as an indicator until blue black colour disappeared. Peroxide value was calculated using the formula;

$$\text{Peroxide value (meq/kg)} = \frac{(A\text{-}B) \times N \times 1000}{\text{Sample weight (g)}}$$

where; A= Volume (ml) of $Na_2S_2O_3$ used for sample

B= Volume (ml) of $Na_2S_2O_3$ used for blank

N= Normality of $Na_2S_2O_3$

3.10 Determination of Vitamin A Content

3.10.1 Retinol content

Retinol analysis was done as per Zahar and Smith (1990) method where, to a 10 ml glass stoppered centrifuge tube, about 1 g of sample (fresh, toasted and deep fried *senene*, germinated soybean flour, sweet potato flour) was added followed by 2 ml of absolute ethanol containing 0.1% (w/v) ascorbic acid and 1 ml of 50% (w/v) Potassium hydroxide (KOH). The tubes were stoppered and agitated carefully before placing them in a water bath at 80°C for 20 min. Complete digestion of fat was ensured by periodic agitation. A 2 ml sample of hexane containing 0.01% (w/v) Butylated hydroxytoluene (BHT) was added and the tubes were stoppered again for vigorous mixing using a vortex mixer for 1 min, then allowed to stand for 2 min before vortexing again for 1 min. A 1 ml sample of cold water (1°C) was added to the tubes and inverted 10 times then centrifuged at 3500 rpm for 10 min. Then, 2 ml of the upper organic layer was pipetted accurately into a tube and solvent evaporated at 40°C using a rotary evaporator. The residue was dissolved in 1 ml methanol.

For the standard solutions, the procedures were similar but with the following modifications; 1 ml of the standard solution was used and 0.1 ml peanut oil added before saponification to avoid oxidation. A 5 ml sample of the upper phase was pipetted and residue dissolved in 5 ml methanol. The absorbance was read using UV-Visible Spectrophotometer (Wegtech, CECIL 2021) at 325 nm.

Sample concentration was calculated using the following equation

$$Rc = \frac{A \times El \times 100000}{E \times S \times Et}$$

where;

Rc=Retinol concentration (mg/L)

A=Sample absorbance as read at 325 nm UV-Vis spectrophotometer

El=Elution

E=Extinction coefficient of retinol in ethanol (975)

S=Amount of sample taken for analysis

Et= Extraction volume

3.10.3 Determination of beta carotene

Beta carotene determination was done according to Rodriguez-Amaya & Kimura (2004), where about 0.5 g of each sample was weighed, extracted with 50 ml of acetone (acetone refrigerated at 40°C for 2 hours prior to use) using a homogenizer (Gaustin M3 Homogenizer 58789) placed under the fume. About 40 ml of petroleum ether were put in a separating funnel (250 – 500 ml capacity) and about 50ml acetone was added. About 200ml distilled water was added slowly along the neck without shaking to avoid emulsion formation. The two phases were then left to separate and the lower aqueous layer discarded, the sample was washed 3-4 times with distilled water (approx. 200 ml) each time to remove residual acetone, in the last phase washing was done ensuring no any amount of the upper phase was discarded. Then, the upper layer was collected into 50 ml flask using anhydrous sodium sulphate filter arrangement to remove residual water and the absorbance was determined by using a spectrophotometer.The absorbance was determined at a wavelength of 450 nm and beta carotene was calculated using the equation of the standard curve.

3.10.4 Determination of mineral content

The analysis of minerals (calcium, iron and zinc) was done according to the AOAC (1995) procedures. The mineral content was determined by the use of Unicam 919 Atomic Absorption Spectrophotometer (AAS). Test portions were dried and then ashed at 4500°C under a gradual increase (about 500°C/h) in temperature. The residue was dissolved in 0.1 N HNO_3 left to dissolve then filtered using a Whatman filter paper. The analyses were analyzed by flame procedures. The set of instrument was as per the guidelines given in the instruction manual. The absorbance of sample and standard solutions was determined.

The standard conditions for Atomic Absorption Spectrophotometer (Element wavelength flame-gases) were: zinc (Zn) 319.9 nm, iron (Fe) 248.8 nm and calcium (Ca) 422.7 nm. The Standard curve plot of absorbance against the known concentration of standard solutions (0, 0.5, 1, 2, 4, 5, 10, 20 and 40 ppm) was used to determine the concentration of minerals in samples and the results expressed as shown in the following formula.

$$(\text{Mineral content } (mg/100g) = \frac{(\text{Reading value in ppm} \times \text{dilution factor} \times 100)}{\text{Sample weight } (g)}$$

3.10.5 Determination of phytates

Phytates composition determination was done by HPLC analysis method by Camire & Clydesdale, (1982). Fifty mg of germinated soybean flour was extracted with 10 ml of 3% H_2SO_4. Contents were filtered and the filtrate transferred to a boiling water bath (BWB) for 5 min followed by addition of 3ml of $FeCl_3$ solution (6mg ferric iron per ml in 3% H_2SO_4). Contents were heated for 45 min to complete precipitation of the ferric phytate complex. Contents were centrifuged at 2500 r.p.m. for 10 min and the supernatant discarded. Precipitate was washed with 30 ml distilled water, centrifuged

and the supernatant discarded. 3 ml of 1.5N NaOH was added to the residues and the volume brought to 30ml with distilled water. Contents were heated for 30 min in a BWB to precipitate the ferric hydroxide. Cooled samples were centrifuged and the supernatant transferred into a 50ml volumetric flask. The precipitate rinsed with 10 ml distilled water, centrifuged and the supernatant added to the contents of the volumetric flask.

Then, 20 µl of the supernatant was injected into a HPLC fitted with a C-18 (5 µl) Chromosorb column at 30°C and a Refractive Index Detector (RID). The mobile phase was 0.005N sodium acetate in distilled water, flowing at 0.5µl/min. A stock solution of the standard containing 10 mg/ml of sodium phytate (Inositol hexaphosphoric acid $C_6H_6(OPO_3Na_2)_6+H_2O$ was used.

3.11 Microbial Analysis

3.11.1 Determination of total plate count

A 25g sample was aseptically weighed into sterile homogenizing container followed by addition of 225 ml sterile buffered peptone water, the mixture was homogenized for 2 min followed by three (3) serial dilutions made by mixing 1 ml of sample with 9ml of sterile peptone water. Pre-prepared sterile plate count agar (PCA) made according manufacturer specification was then used for culturing and enumerating bacterial colonies. Inoculation of the sample onto the PCA plates was done aseptically by spreading 200 µl of the sample from each dilution onto a separate sterile PCA, followed by incubation at 37°C for 24-72 hours. Plates with less than 300 colonies were counted and the rest were autoclaved. The number of bacterial colonies was expressed as colony forming units per gram (CFU/g) of the sample using the formula from International Dairy Federation method (IDF, 1996) as follows:

$$\text{Log } C=\sum x/n_1+(0.1n_2)^x d$$

where:

C= Count CFU/g

x= Total number of colonies in all plates

n_1= Number of plates from initial dilution where counts were made

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

d= Initial dilution where counting started

3.11.2 Determination of total coliforms and *Escherichia coli*

A 25g sample was aseptically weighed into sterile homogenizing container followed by addition of 225 ml sterile buffered peptone water, the mixture was homogenized for 2 min followed by three (3) serial dilutions made by mixing 1ml of sample with 9 ml of sterile peptone water. Pre-prepared sterile Tryptone, Bile salts, X-Glucuronide (TBX) agar made according manufacturer specification was then used for culturing and enumerating *E coli*. Inoculation of the sample onto the TBX agar plates was done aseptically by spreading 200 µl of the sample from each dilution onto a separate sterile TBX media, followed by incubation at 37°C for 24-72 hours. Observed cream colonies were counted for coliforms and blue for *E. coli* (AOAC, 1995).

Identification of *E. coli* 0157:H7 was done using Dynabeads©2012 Life Technologies Corporation (Invitrogen Grand Island New York). Dynabeads (50 µl) were added and used according to the manufacturers' instructions. Immunogenic separation was performed on the samples that were positive for generic *E. coli* (blue colonies). Samples were streaked on Sorbitol MacConkey with cefixine and tellurite (Neogen) followed by incubation at 37°C for 24 h. MacConkey plates were then screened for 0157:H7 suspect

(purple colonies). Suspect colonies were confirmed by using Oxoid *E .coli* 0157:H7 Latex tests.

3.11.3 Determination of *Salmonella typhi*

A 25g of sample was aseptically weighed into sterile homogenizing container and 225 ml sterile buffered peptone water added then blended for 2 min. The mixture was incubated at 37°C for 24h for pre-enrichment followed by second enrichment into pre-sterilized Rappaport Vassiliadis R10 (RPV) Broth. Then, 1 ml of pre-enriched sample was taken to 9ml of RPV followed by incubation at 37°C for 24 h, prepared Xylose Lysine Deoxycholate agar (XLD) with manufacturer specification was made to solution, sterilized, poured in petri dishes and allowed to cool at room temperature (27±2°C). Aseptic streaking of the sample from enriched RPV onto the XLD agar plates was done before aerobic incubation at 37°C for 48 hours. Characteristic black colonies of *S. typhi* were observed and enumerated (AOAC, 1995).

3.11.4 Total yeast and mold

A 25g sample was aseptically weighed into sterile homogenizing container followed by addition of 225 ml sterile buffered peptone water, the mixture was homogenized for 2 min followed by three (3) serial dilutions made by mixing 1 ml of sample with 9ml of sterile peptone water. 200 µl of the inoculum from each of the dilutions was pipetted and spread gently onto pre-prepared sterile Sabouraud Dextrose agar (SDA) plates. The inoculated plates were incubated at 24°C for five days. The plates were then examined and counted for colonies growing on the medium.

Identification of observed colonies was done by microscopy method, where a colony portion was taken by using a sterile inoculating needle and mixed with lactophenol cotton blue stain on a clean glass slide followed by covering of the specimen using a

clean glass cover slip. Excess stain –inoculum mixture was blotted by folding the slide in between the filter paper.

The blotted slide was placed on light microscope (Batch no. 25, 0825583 of Brunel Microscopes Ltd) stage for observation and identification using the key by Naveen Kango (2010). Total magnification used for observations and identification was 1000x.

3.12 Data Analysis

All chemical tests were conducted in duplicate and the mean values ± standard deviation (SD) were reported. Mean comparison on nutrient composition for each mentioned nutrient (proximates, vitamins, minerals, anti-nutrients) as well as microbial (total plate counts, total coliforms, yeast and mould counts)in all the *senene* and flour samples was done by analysis of variance (ANOVA) and least significant difference (LSD) $P \leq 0.05$. Interview data analysis was carried out using (SPSS version 21) where descriptive (frequency, means and percentages) were computed. R commander software (version3.3.0) was applied in means comparison chemical and sensory data analysis through computation of p values.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Survey on indigenous technologies, processing methods and traditions towards *senene* consumption

4.1.1 Social-economic information of the respondents

Socio-economic characteristics of respondents involved in the study collected included age, gender, tribe and occupation. The age of the respondents ranged from 21 - 60 years old with a majority (43%) being 21-30 years of age. Fifty one percent of respondents were female. These were first hand informers as *senene* collection and processing is dominated by women. Edible insects consumption is merely cultural and differs across different ethnic groups, 90% respondents were Hayas, others being *Sukuma*, *Nyambo*, *Bunganda* and *Kerewe*. Interviewees' occupations were mainly local government officials (39%) mostly from nature and forestry department, self-employed in informal sector including *senene* traders (33%), peasants (15%) and students (13%).

4.1.2 Forms and seasonality of *senene*

The respondents identified five culturally significant forms of *senene*, each carrying meaningful and unique *Haya* name (Figs. 4.1 a-e.).

(a) *Mwanamwana* meaning beautiful woman.

(b). *Mfaume* meaning a ruler/mad man

(c). *Kishorowanda* meaning colourful bird

(d). *Katikomile* meaning dry tree

(e). *Kimbisimbisi* meaning greeny leaves

Figure 4.1: (a-e). *Senene* forms found in Kagera as identified by *Haya* ethnic group

The names are based on the appearance and behaviour of each. Purple coloured *senene* are known as *mwanamwana,* which means 'beautiful woman' in *Haya* language. This was the scarcest form of all. *Kishorowanda* is green with purple stripes. *Mfaume* is brown in colour and it was said to be the most unpredictable, fierce, biting and hard to trap. *Katikomile* means dry tree in *Haya language,* and is a brown-khaki *senene*, which is said to signify ending of *senene* season. *Kimbisimbisi* is the name given to common green *senene* meaning 'green tree leaves', abundant at peak seasons. Studies on morphology report six colour forms which are said to be genetically controlled(Bailey and Mccrae, 1978; Matojo and Njau, 2010). Some natives reported that the varieties taste different with, *mwanamwana* being the tastiest. The green form was associated with femaleness and richness of the season while brown was said to mark end of the season and was associated with maleness.

Senene swarms in two seasons in a year, April to June being the longest season. November to December is characterized by heavy rainfall hence marked with high volumes of *senene swarms*. This season reaches its peak on around 9th December; this day is also an important national holiday in Tanzania known as *Jamhuri day.*

4.1.3 Origin and availability of *senene*

When asked about the origin of *senene*, one old man aged 72 years explained that *'it is just God's plan for Kagera, I don't even understand because they just drop from heaven'*. Most natives also believe that *senene* came from heaven just like how *Manna* dropped to Israelites in bible times according to the Holy Bible in Exodus 16:1-36. It was further suggested that *senene* came from Lake Victoria; few believed that *senene* emerged from bushes and pine trees while others said they came from dense-dark clouds. According to Matojo and Yarro (2010), bushes are the breeding grounds for *R. differens*, where both swarming and non-swarming adults lay eggs in ribbons cemented together. Time lapse between oviposition and maturity is reported to take about 3 months (Bailey and Mccrae, 1978). *Senene* swarms were reported to decrease as years

went by with some key informers' suggesting that climate change has significantly affected the current volumes of *senene*.

4.1.4 Traditions, consumer perception, custom and taboos

'Senene is an icon of Kagera, God's gift from heaven for Haya' reported one retired forest officer from Bukoba Municipal Council. It is a delicacy normally reserved for men and in-laws. Majority (98%) of all respondents liked to eat *senene* for different reasons. Reasons for consumption included; respect to traditional delicious delicacy (44%), source of nutrients (41%) and tasty nature of *senene* as multipurpose sauce (15%).

Senene is a delicacy exported to *Haya* relatives living in distant places like United Kingdom or in wedding ceremonies held as far as Dar es Salaam located 1,500 km from Bukoba. '*Haya* wedding ceremony will not be perfect until guests are welcomed by a pack of this delicacy at the entrance', remarked a respondent. According to *Haya* traditions, a reception with a plate of *senene* is a symbol of respect and acceptance to that family. *Senene* remains a protected snack, not to be offered to any person but few esteemed individuals.

Eating raw *senene* was reported to be a prohibited act, whereby 92% of respondents had never eaten these raw *senene*. Eating them raw was regarded unethical by most respondents who associated it with stomachache (52%) and diarrhoea (48%). There is scientific evidence that raw insects contain high microbial counts, thus consuming them raw can bring such complications (Ssepuya *et al.,* 2010). The remaining 8% of these respondents had eaten fresh-raw *senene* out of greed though others appreciate the raw *senene.* A young male respondent said *'senene are just so delicious even when freshly raw'*.

Respondents reported that as it was with many African taboos, women and children had limitations towards s*enene* consumption. Pregnant women were prohibited from eating *senene* or else they would give birth to children with coned-head like that of *senene*. It was further believed that giving *senene* to infants and young children would make them unable to speak for the rest of their lives. This taboo is similar to that of the grasshopper clan of the *Baganda* in Uganda where women are prohibited from eating *senene* though allowed to catch and cook for their husbands (Agea *et al.,* 2008). However, key informants invalidated the taboo by clarified that the taboo was due to men's selfishness and desire to have all *senene* prepared for them. There was a widespread belief that marriages became stronger and happier during *senene* season as women proudly collected and prepared them for their husbands and in return they got rewarded with gifts such as *kitenge*, an esteemed traditional piece of cloth. *Senene* appendages, ovipositor and wings are not generally consumed and were discarded far from the main houses across the road junction, as a show off to neighbours. Some key informants explained the basis for this belief that it was to avoid the rotten smell, ants and flies from disturbing them in the house. Apart from being an important delicacy to *Haya* people, *senene* was used in preparation of snacks, chicken feed and fish and rat baits.

Although studies report protein rich arthropods, such as shellfish (mainly shrimp, lobster and crayfish) to be widely known for their ability to induce allergic reactions (Ayuso 2011), no such allergy experiences were reported by respondents caused by consumption of *senene*. Few respondents (28%) reported diarrhoea cases after consuming excessive amounts of *senene*; probably due to the high fat content or microbial contamination.

4.1.5 Collection and harvesting

The findings of the study suggested that traditionally, harvesting of fresh raw *senene* for family consumption was done through wild collection in the fields. However, nowadays it is common to harvest *senene* at homesteads under very bright light. Homestead collections were normally done by women and children of school age, early in the

morning before sun rise when they were inactive, hence easily captured. Commercialization of *senene* has triggered advancement in harvesting technology, using locally made traps (Fig 4.2a-c &4.3).

Figure 4.2: *Senene* harvesting using traditionally made trap

a). Folded iron sheets folded into a cone shape and held in position using props, b). Large buckets with a hole on the lid, c). An assembled trap ready for harvesting)

The traps were made using folded iron sheets, large buckets and three combined very bright light bulbs (400 Watts each) as shown in Fig. 4.3. The iron sheets were folded to a cone shape leading to the large bucket underneath, which collected the falling *senene* (Fig. 4.2b). During the night, smoke was set under the bright light, which confused the *senene,* hampering their flight ability. A key informant reported that "*Like a cow moving its head to the abattoir unsuspectingly, senene followed the bright light and dropped on folded iron sheets, which slid them directly to the large bucket where they could not move out"*.When the buckets were full, trapped *senene* were transferred to big sisal sacks/bags and the traps reset ready for the next harvest until the swarm stopped, usually around 5 a.m. during high seasons *Senene* collectors reported that during high

seasons, normally eight to ten sacks (one sack approximately100kg capacity) were collected on a single night swarm.

Majority of respondents reported that they obtain *senene* for their consumption from market purchase (43%) while others obtained from wild collection (31%), from setting traps (18%) and as gift from relatives (8%).

Figure 4.3: *Senene* harvesting trap during the night

4.1.6 Processing methods

From observations and responses from respondents, different processing methods have been grouped and discussed in different stages as shown in Figs. 4.4 and 4.5. Edible insects processing is a common practice in almost all areas where they are consumed

(Defoliart, 1999). Traditional processing methods are mostly similar among insect-consuming societies with slight differences between the processes. Processing is normally done for value addition to increase palatability, safety and for preservation purposes. Also, processing ensures removal/reduction of anti-nutrients such as phytates and tannins (Nwagbo, 2014). Processing methods significantly impact nutritional composition of insects (Kinyuru *et al.,* 2010).

4.1.6.1 Cleaning and washing of fresh raw senene after harvest

Cleaning was done to remove inedible body parts namely wings, appendages and ovipositor for female *senene* (Fig. 4.4).

Figure 4.4 :(a). *Senene* cleaning and sorting at BukobaTown *senene* market (b). Cleaned *senene* ready for sale

Wood ashes were used to increase friction and ease the process. Being slippery and light, antennae were often not removed as they disappeared within processing chain. At this stage, also the other insects harvested with *senene* as well as grasses and other filth materials were removed. Washing with cold water was reported to be done before further processing; though some did not wash, claiming that washing would drain out fat and make *senene* less enjoyable.

4.1.7 Boiling

Cleaned and/or washed *senene* were placed in boiling salted water with or without spices (such as onions, garlic, ginger and cardamom) then left to boil for about 15 minutes (Fig. 4.5). This was normally a stage in making smoked, toasted and deep fried s*enene.* However, boiled *senene* can be drained out or left to be eaten with its soup. The soup (liquid part without *senene*) was sometimes mixed with boiled banana and given to children by some of the natives (10%).

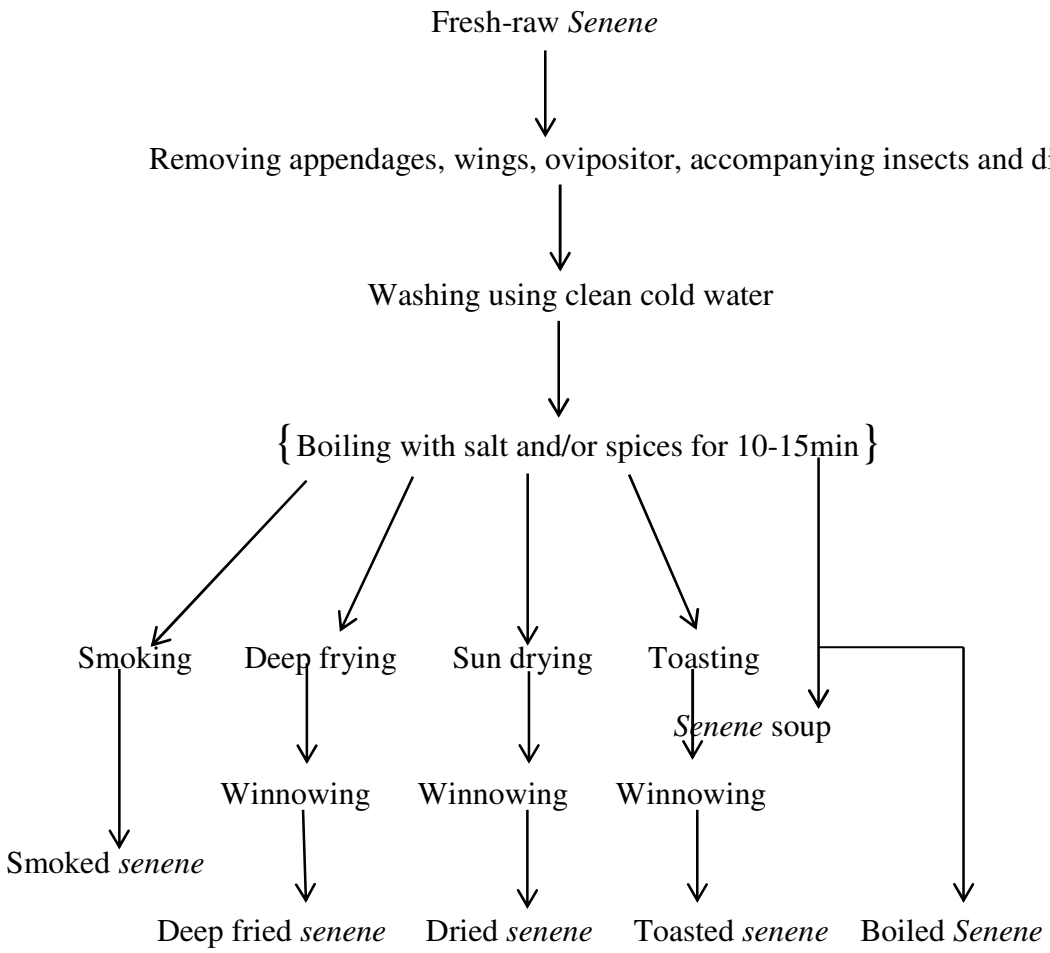

Figure 4.5: Fresh *senene* processing flow diagram

4.1.8 Smoking

This was reported to be the ancient traditional method of processing *senene* and has been used for decades. Results showed that 21% of *senene* consumers preferred smoked *senene* above others, dominated with 51-60 years age group (Fig. 4-7). Smoky aroma of smoked *senene* and its antique was among the mentioned reasons for its acceptance. Fresh-raw or boiled *senene* were rolled in fresh banana leaves then placed on the kitchen roof (*obutala* in *Haya* language). Others used a special roof extension for *senene* placed

along the direction of smoke from the burning firewood known as *akashelo* (Fig.4-6b). Smoking was explained to follow two similar processing lines with boiling procedure standing as distinguishing step between the two as shown in Figs. 4.5. Boiling was reported to be mandatory step for short time (2-4 days) smoked *senene*; it was optional where *senene* were to be smoked for a longer period. *Ekyangwe* is the name for special leaves burned together with firewood for *senene* smoking. The firewood used for *senene* smoking were those from trees characterized with slight or no smell preventing alteration of *senene's* natural flavour.*'You don't just smoke senene because there is smoke'* said a key informant when asked about the type of trees used for *senene* smoking. Eucalyptus, cassava stems (*Manihot esculenta*), umbrella tree (*Maesopsis eminii*), and traditional trees such as *msila* were reported to have the best firewood in *senene* smoking.

4.1.9 Toasting

As summarized in Fig.4-5, toasting was done by placing fresh raw or boiled *senene* in a hot pan, stirring them until they turned brown with meat-like smell. It is among the oldest methods still being practiced to date. Toasted *senene* becomes crunchy with less oil thus one can eat plentiful amounts before satiety; they are brownish in colour (Fig. 4.6d). In urban areas where technological advancement was high baking ovens were used in toasting *senene*.

4.1.10 Deep frying

This is currently the most (22%) used and preferred processing method in Kagera region mainly preferred by young and middle age group (Fig. 4.7). Cleaned boiled/fresh raw *senene* were placed in boiling cooking oil (cottonseed oil was common) for about 10 minutes until they turned deep-brownish (Fig. 4.6c). The simplicity of this method has made it common and most liked among *senene* traders.

4.1.11 Sun drying

Sun drying is mainly for preserving *senene* for future processing, followed by storage in sisal sacks or plastic buckets. *Senene* becomes ready for consumption within two days of sun drying. The process normally takes place on the locally made mat known as *ebigara* in *Haya* language (Fig.4.6a).

Figure 4.6: Processed *senene* and processing equipment (a) *Ebigara* (b&c) *Okashelo* (d) Deep fried *senene* (e) Toasted *senene*

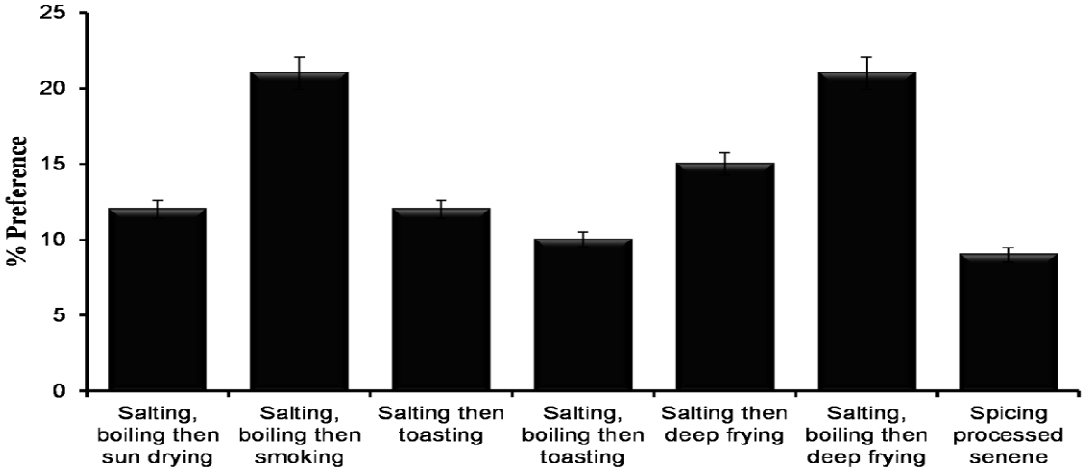

Figure 4.7: Response on consumer preferences on named *senene* processing method

4.1.12 Preservation and shelf-life

Fresh *senene* have a very short shelf-life of about 12 to 48 hours at room temperature of 24-28°C. Fresh raw *senene* are normally stored in polyethylene, sisal bags or mesh cloth bags that allow air to pass through. *Senene* traders normally use polyethylene bags to transport fresh *senene*, some spread *senene* on a mat temporarily before further processing. For longer shelf life, fresh *senene* were preserved using several traditional techniques such as smoking using firewood above cooking place (44%) and sun drying (Fig. 4-8). Nowadays, re-frying is commonly used (41%), deep freezers and refrigerators are also used for storage and preservation. Average reported shelflife for traditionally preserved *senene* is 12 months.

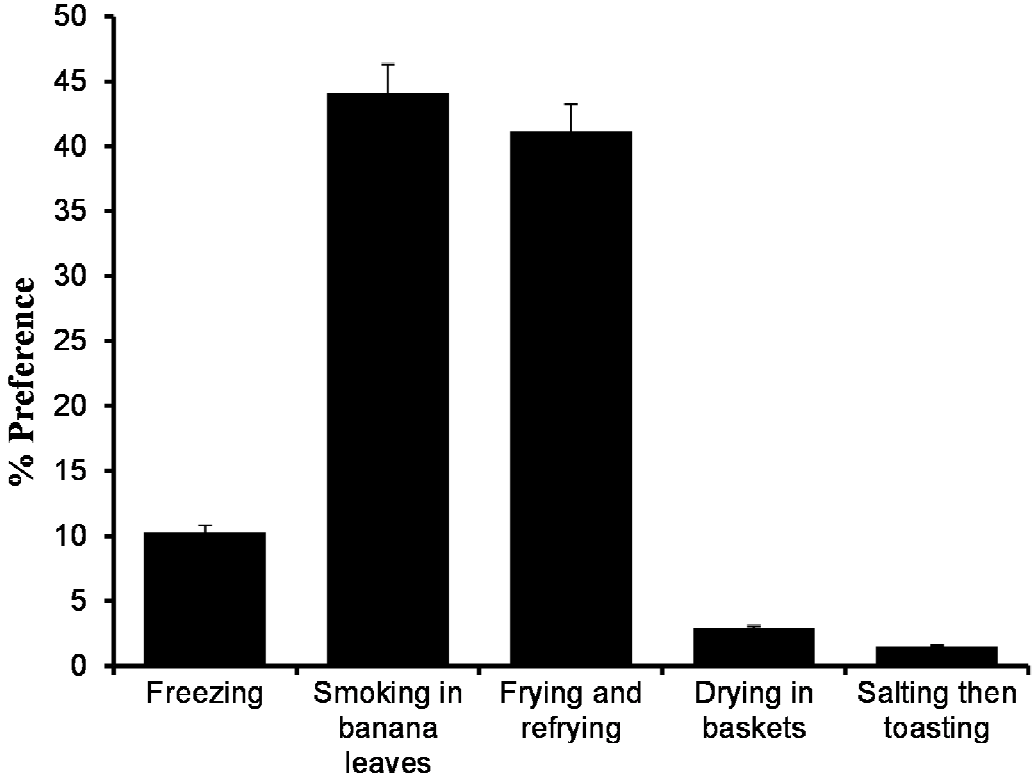

Figure 4.8: Response on consumer preferences on named *senene* preservation methods

4.1.13 Potential of *senene* in addressing child malnutrition

Use of *R. differens* in enriching currently used complementary foods in this region, namely boiled banana (32%) and cereal porridge (52%) can be of great contribution in reducing stunting rates Kagera region is named among the three regions exceeding 50% threshold on severe stunting (THDS, 2016). Apart from associated taboos towards giving *senene* to children, majority reacted positively on the issue of including it in infants and children's diet. Table 4.1 presents respondents' feelings and suggestions concerning feeding children on *senene*.

Table 4.1: Responses on Feeding Children with Senene

Information collected	Percentage respondents (%)
Population currently giving *senene* to children (n=51)	
Yes	76.0
No	24.0
Reasons for feeding children *senene* (n=43)	
Are nutritious	65.1
Children like *senene*	27.9
I just feed them	7.0
Reasons for not feeding children *senene* (n=18)	
They cannot digest *senene*	11.1
They cannot chew	33.3
They may chock and block air	38.9
It is a taboo	16.7
Readiness to give *senene* to children if well prepared (n=51)	
Yes	90.0
No	10.0
Commonly consumed complementary foods (n=59)	
Single cereal	39.0
Mixed cereals	13.6
Boiled Banana	32.2
Mixed cereals and legumes	8.5
Eat what adults eat	6.8
Opinions on using *senene* in complementary feeding (n=116)	63.8
It is a nutritious food	6.9
They should be given only *senene* soup	13.8
Senene should be ground and sieved for children to swallow	6.0
More research to be done	3.4
Heads should be removed before giving to children	2.6
Not a good thing because children will not be able to talk	1.7
It is an act of disrespect to give *senene* to children	1.7
Children likes *senene*	

Use of edible insects in addressing malnutrition has been evaluated. Silkworm pupae were included among essential ingredients for supplementary food to malnourished children in Congo (Bauserman *et al*., 2015). Edible insects have also been utilized to enrich plant-based complementary foods. In Kenya winged termites were used to enrich amaranth based complementary foods Kinyuru *et al.,*(2012) while in Cambodia, edible spiders were utilized to enrich a rice based complementary food (Skau *et al*., 2015)

4.1.14 *Senene* trade

In Kagera region, *senene* trade is carried out by both men and women; men dominating the collection end while women taking over the cleaning and processing (Fig. 4.4). Trade starts within Kagera region among *Hayas* as 43% report to obtain their *senene* from local traders. Both processed (mostly deep fried) in some cases fresh raw *senene* are largely sold in this market (Fig. 4.9). Deep fried *senene* are transported throughout Tanzanian regions with Dar es Salaam being the main destination, where 61% respondents reported source of income among potential uses of *senene*. The price of fresh *senene* during season averages Tsh 1,534.88 per kg while that of deep fried *senene* averages Tsh 4,254.05 per kg. Smoked, sundried and toasted types are not commonly found at the market place. The price of processed *senene* is more than twice that of fresh *senene* mainly due to tedious and laborious process of removing wings, appendages and ovipositor. *Senene* business is widely done; from hawkers selling locally packed *senene* along the road side to big stores and supermarkets all over Tanzania. Contribution to household income has not been reported, but most traders report that it covers almost half of their basic needs, including school fees. There is potential for women employment as cleaning and processing task is assigned to women, who normally receive their daily pay for about three months every year.

In Uganda, grasshoppers' trade is characterized by wholesalers who buy grasshoppers from collectors and sell to retailers, who reach consumers around Kampala (Agea *et al.,* 2008). Edible insects' business is growing to a thoughtful issue around the world for both wild collected and reared edible insects (Arnold van Huis *et al.,* 2012). It is reported that Belgium imports up to three tonnes and France five tonnes of dried mopane caterpillar annually from the Democratic Republic of Congo and Zambia (Chakravorty *et al.,* 2011; Siulapwa *et al.,* 2014).

Figure 4.9: *Senene* trade at Bukoba town *senene* market

4.2 Phytate Contents of Formulated flours and Soybeans under Different Germination Hours

Table 4-2 presents phytate results of soybeans at different treatments namely soaking, germinating and de-hulling.

Table 4.2: Phytate content of soybeans and formulated flour in mg/100g in DMB

Sample	Concentration (mg/100g)
Control washed	509.0±22.73[a]
Soaked_6H	238.4±7.47[b]
Soaked_D6H	209.6±5.35[bc]
Germinated_24H	219.6±5.74[bc]
Germinated_D24H	191.4±6.07[c]
Germinated_36H	135.4±3.16[d]
Germinated_D36H	125.1±8.91[d]
Germinated_48H	86.7±7.70[e]
Germinated_D48H	55.3±4.85f[f]
Germinated_60H	50.7±1.08[fg]
Germinated_D60H	50.0±0.86[fg]
Germinated_72H	49.3±5.41[fg]
Germinated_D72H	21.0±3.65[g]
CF 1	127.9±18.83[d]
CF 2	199.2±11.62[cd]
CF 3	193.13± 18.88[c]

Values are expressed as mean±SD in dry matter basis (n=3) Mean values with different superscript letter along the column are significantly different at $p<0.05$. D stands for de-hulled; H stands for germination hours

Phytates are known for reducing bioavailability of minerals by forming complexes and sequestering metal ions (Brni *et al*., 2017; Petry *et al*., 2014). Results shows that, maximum phytic acid reduction (47%) from509.0±22.73 to 238.4±7.47mg/100g was attained during soaking for 6 h. Soaking is reported to cause leaching, which is important step in phytates reduction, hence increasing palatability and reducing cooking time(Bau *et al*., 2000; Huang *et al*., 2014;Rusydi, 2012).Control sample of soybeans had the highest phytic acid levels of 509.0±22.73mg/100g while 72 h germination had lowest level with 21.0±3.65mg/100g. Germination showed significantly higher gradual reduction in phytate levels in soybean as reported by other researchers (Petry *et al*., 2014; Rusydi, 2012). Phytate contents reduction after soaking for 6 h and de-hulling (209.6±5.35mg/100g) was statistically similar to that of 24 h germination without de-hulling (219.6±5.74mg/100g). Composite flours were formulated from 48 h for their physical properties including stable texture and brittleness which would have had direct impact on the sensory qualities of the final product.CF1 (25% *senene*: 35% soybeans: 40% sweet potato), CF2 (20% *senene*: 40% soybeans: 40% sweet potato), and CF3 (15% *senene*: 35% soybeans: 50% sweet potato), had high phytate levels of 127.9±18.83, 199.2±11.62 and 193.13± 18.88mg/100g, respectively. This observation is significantly higher ($p<0.05$) than 48 h germination soybeans, which were used as ingredients in composite flour formulation. The increased levels of phytates may have been from other ingredients namely sweet potatoes and *senene* (Amagloh, 2012;Oliwoya *et al*., 2009). Phytase activity is reported to increase zinc and iron absorption 5fold (Brni *et al*., 2017; Troesch *et al*., 2009).

4.3 Proximate Composition

Table 4-3 presents proximate composition and energy levels of *senene* flour, sweet potato flour, soybean flour and of selected commonly used composite flour from the market.

Table 4-3: Proximate composition (g/100) of *senene* and flour samples

Parameter	Protein	Fat	Ash	Fibre	Carbohydrate	Energy (kcal/100g)
Fresh *senene*	33.7±1.26^{b}	50.1±0.34^{b}	3.9±0.32^{b}	9.1±0.92^{b}	3.1±0.62^{d}	598.1
Market sold *senene*	30.1±0.91^{b}	61.7±0.67^{a}	2.4±0.02^{de}	5.6±0.07^{c}	0.2±0.24^{d}	676.5
Deep fried *senene*	23.5±1.16^{c}	61.8±0.95^{a}	2.0±0.20^{e}	11.6±1.11^{a}	1.10.89^{d}	654.6
Toasted *senene*	39.8±1.05^{a}	47.9±0.95^{c}	2.7±0.09^{cd}	8.8±0.45^{b}	0.8±0.83^{d}	593.5
Soybean flour	38.5±2.53^{a}	19.6±0.36^{d}	5.6±0.09^{a}	12.6±0.41^{a}	23.7±3.21^{c}	425.2
Sweet Potatoes	3.9±0.38^{e}	0.41±0.05^{f}	3.1±0.01^{c}	3.9±0.42^{cd}	88.7±0.82^{a}	374.09
Market flour	8.2±0.87^{d}	4.2±0.37^{e}	2.4±0.06^{de}	3.8±0.10^{d}	81.4±1.07^{b}	396.2

Values are expressed as mean±SD dry matter basis (n=3). Values with different letters along the column are significantly different at p<0.05

Toasted *senene* had the highest protein contents of 39.8% comparable to that of 44% reported by other researchers (Rumpold & Schl, 2013; Siulapwa *et al.,* 2014). Increased amount of protein after toasting may have been attributed by the phenomenon of protein denaturation leading to more free amino acids being available during protein analysis. Crude protein, fat, ash, fibre and carbohydrate contents of soybean flours were in-line with those reported in literature (Lokuruka, 2010; Muzzarelli *et al.,* 2012; Arueya & Osundahunsi, 2015). Deep fried *senene* had the highest fat content of 61.8%.Fat levels observed in *senene* flour ranked higher than those of 48-49% reported in literature (Kinyuru *et al.,* 2010; Siulapwa *et al.,* 2014). There was a significant difference ($p<0.05$) for protein, fat and ash levels between fresh and processed *senene*. The increase in crude fibre content after deep frying of *senene* may have been resulted from formation of

complexes such as protein-fibre complex which occur due to high frying oil temperatures. Lowest fat levels were found in sweet potatoes 0.41% whose carbohydrate content was the highest (88.7%) similar to 83% reported by Gewa & Leslie(2015). Low energy levels were in sweet potato flour 374.09kcal/100g. Nutritional composition variation may have been attributed to the type of feed (van Huis, 2017).This is uncontrollable in a wild context. Protein from *senene* is animal protein with high bioavailability and good ratios of amino acids compared to that of plant protein (Kinyuru *et al.,* 2010). Table 4.4 presents protein, fat, carbohydrate and energy analysis of formulated flours and common used market flour.

Table 4.4: Protein, fat, carbohydrate and energy content of formulation ratios compared with RDA for 12-24 months age group

Senene:	***Soybeans:***	***Sweet potato***	**%Protein**	**%Fat**	**%Carbohydrate**	**Energy** kcal/100g	%RDA 1-2 years
CF1	*25:35:40*		25.0	19.0	44.0	446.8	81
CF2	*20:40:40*		24.9	17.6	45.1	438.4	80
CF3	*15:35:50*		21.4	14.3	52.8	424.9	77
Common market flour			8.2	4.2	81.4	396.2	72

All three formulations had nutrients and energy levels superior to commonly used flour from the market and contained ideal composition for complementary foods recommended by Lutter & Dewey, (2013) and (WHO/UNICEF, 2006). Energy levels were similar to other recent studies on insect-based complementary flours (Bauserman *et al*., 2015). A 100g of the product is able to provide energy, fat and protein levels above that recommended for 6 to 11 months children and more than 80% of recommended for 12 to 23months children (Lutter & Rivera, 2003;Codex, 2006). 100g of formulated flours can make 400ml of porridge. Therefore, as recommended by WHO (2002) that a child aged 9-23 months should feed 3-4 meals a day, one child can consume minimum of 200g of these flours per day. CF1 with 25% *senene*, 35% soybean and 40% sweet

potato has the highest protein, fat and energy levels. Protein level in all formulated flours was above that found in meat (Skau *et al*., 2015), and above Codex 2016 and EAC 72:2013 standards. The protein found in *senene* is reported to have higher PER, containing all essential amino acids (Siulapwa *et al.,* 2014; Skau *et al.,* (2015). This makes *senene* a suitable ingredient for complementary feeding.

4.4 Vitamins and Minerals Analysis

4.4.1 Vitamin A content

Table 4-5 presents retinol contents of processed *senene* and beta carotene contents of flours

Table 4-5: Vitamin A contents of *senene* and formulated flours

Vitamin A	Sample	Conc. (µg/100g)	RAE	% RDA 6-11months	12-24 months
Retinol	Fresh *senene*	110± 0.9^{c}		31	28
	Toasted *senene*	390± 3.9^{a}		>100	98
	Deep fried *senene*	290± 1.0^{ab}		83	73
	Market *senene*	210± 3.5^{bc}		60	53
Beta carotene					
	Fresh SP	2187.1±219.31^{a}	182.3	52	46
	SP Flour	1358.4±12.42$_{b}$	113.2	32	28
	Soybean flour	1633.8±29.07^{b}	136.2	39	34
	Market flour	386.15± 76.34^{c}	32.2	9	8

Values are expressed as mean±SD (n=2). Mean values with different superscript letter along the column are significantly different at p<0.05RAE; Retinol Activity Equivalent: 1 RAE =1g retinol = 12 µg beta-carotene. SP=Sweet potato

Retinol content among *senene* samples significantly differed with processing methods. Fresh *senene* had the lowest retinol content of 110µg/100g while toasted *senene* had the highest with 390 µg /100g. Increase of retinol contents with toasting may have been due to the release of fat globules from *senene* with heat as retinol is an oil soluble vitamin. This is higher than 280 µg/100g reported by Kinyuru et al.(2010) and a 100g of it can supply98% RDA for 12-23 month group. Fresh sweet potatoes had the highest beta carotene content of 2187µg /100g (182RAE) while common market flour had the lowest with 386µg /100g (32RAE). Beta carotene is sensitive to light and this could be the reason for fresh sweet potato having highest content. Common market flour was made from finger millet, maize, groundnuts and soybeans, which were all poor sources of beta carotene, hence the lower reported beta carotene contents. On the other hand, soybean flour and sweet potato flour had statistically similar beta carotene levels of 1.63mg/100g and 1.36mg/100g, respectively.

4.4.2 Calcium, iron and zinc contents

Table 4-6 presents calcium, iron and zinc contents of processed *senene* and flours

Table 4-6: Mineral contents of flours and *senene* samples

	Minerals (mg/100g)		
Sample	**Ca**	**Fe**	**Zn**
Deep fried *senene*	5.53±0.33^{bc}	2.91±0.92^{bc}	6.95±0.76^{a}
Fresh *senene*	5.52±1.33^{bc}	3.55±5.43^{ab}	6.73±1.63^{a}
Toasted *senene*	6.69±0.21^{bc}	5.33±0.45^{a}	7.62±1.51^{a}
Market *senene*	15.87±0.03^{a}	2.87±0.04^{bc}	4.65±0.08^{ab}
Common market flour	2.73±0.04^{c}	2.65±0.03^{bc}	1.82±0.02^{bc}
Soybean flour	14.46±2.81^{a}	4.09±9. 91^{ab}	3.30±0.03^{bc}
Sweet potato flour	8.06±0.45^{b}	1.05±0.05^{c}	0.39±0.001^{c}

Values are expressed as mean±SD dry matter basis (n=2)

Mean values with different superscript letters along the column are significantly different at $p<0.05$

Calcium (Ca), iron (Fe) and zinc (Zn) differed significantly ($p<0.05$) among *senene* samples and flour samples. Processing did not affect Ca and Zn content of *senene* samples as the values were statistically not different for fresh, toasted as well as deep fried *senene*. Deep fried *senene* bought processed from Bukoba market had unexpectedly higher Ca content (15.87mg/100g), differing from the rest of *senene* samples (range 5.5 and 6.6mg/100g). Fe content ranged from 2.87 to 5.3mg/100g, thus a 100g of toasted *senene* can supply about 45% of the RDA for Fe and more than 200% of the requirements of Zn for 6-11months children group. Mineral contents in *senene* samples were below those reported by Kinyuru *et al*.(2010)and in-line with the findings by Siulapwa *et al*. (2014). Among the three formulated flours, soybean had the highest Ca, Fe and Zn contents however, Fe and Zn from *senene* are reported to be of higher bioavailability than that from plant sources (Kelemu *et al*., 2015; Skau *et al*., 2015; Testa *etal*.,2016).Hence supplementation of plant foods with edible insects brings a perfect nutrients combination.

4.5 Microbial Counts

Table 4.7 shows microbial counts for fresh *senene*, processed *senene* and flours.

Table 4.7: Microbial quality of senene and flours

Sample	Total plate count (log cfu/g)	Total coliforms (log cfu/g)	*E. coli* (log cfu/g)	*Salmonella* spp.	Yeasts & Moulds (log cfu/g)
Fresh *senene*	6.9±0.01^{a}	7.0± 0.00^{a}	6.5± 0.04^{a}	ND	7.0± 0.01^{a}
Toasted *senene*	5.8±0.02^{hi}	ND	ND	ND	ND
Deep fried *senene*	5.4±0.03^{j}	ND	ND	ND	ND
Market *senene*	5.7±0.00^{i}	5.5±0.04^{de}	ND	ND	5.9± 0.14^{ef}
Market flour	6.7±0.01^{d}	5.0±0.00^{g}	4.3± 0.00^{c}	ND	6.9± 0.00^{a}
Soy flour	6.4±0.00^{e}	ND	ND	ND	6.3± 0.02^{cd}
Sweet Potato flour	6.3±0.01^{f}	6.4±0.03^{bc}	ND	ND	6.0± 0.01^{e}
CF1_May	6.7± 0.01^{cd}	6.3±0.01^{bc}	ND	ND	6.5±0.02^{bc}
CF1_June	6.3±0.02^{g}	5.1±0.10^{fg}	ND	ND	5.7±0.12^{f}
CF1_July	6.8±0.002^{bcd}	4.8± 0.28^{g}	ND	ND	5.8±0.08^{f}
CF2_May	6.7±0.01^{cd}	6.6± 0.01^{b}	ND	ND	6.6±0.01^{b}
CF2_June	5.3±0.06^{j}	5.8± 0.02^{d}	ND	ND	5.7±0.02^{f}
CF2_July	6.8±0.00^{abc}	5.7±0.04d^{e}	ND	ND	6.1±0.00d^{e}
CF3_May	6.7±0.02^{d}	6.4± 0.01^{bc}	ND	ND	6.3±0.00^{cd}
CF3_June	5.9±0.03^{h}	6.3± 0.02^{c}	ND	ND	5.1±0.05^{g}
CF3_July	6.8±0.00^{ab}	5.3± 0.09^{ef}	ND	ND	6.6±0.02^{b}
MAL	**5**	**2**	**0**	**0**	**5**

Values are expressed as mean±SD (n=2) Values with different letters along the column are significantly different at $p<0.05$ ND means not detected. MAL means maximum allowable limit (Codex, 2006; KEBS, 2008; EAS 72:2013).Months after formulations shows storage months during shelf life studies.

Microbial counts were significantly higher for fresh *senene* (6.5log cfu/g) than for processed *senene* and formulated flours. The findings agree with other researchers

explaining that raw edible insects are known to have high microbial counts. Up to 8.6log cfu/g has been reported in raw grasshopper (Klunder *et al*.,2012;Stoops, *et al*., 2016). Fresh *senene* had the highest coliform count, which may have been caused by crushing during sample preparation that allowed release of microbiota from intestine. Coliforms were not detected in toasted *senene* and deep fried *senene*, showing that treatment with heat during their preparation had the ability to eliminate a large number as also suggested by Grabowski and Klein (2017) hence fit for consumption. Although currently, specific microbiological criteria for edible insects are not settled, Belgium (FASFC, 2014), and the Netherlands (Bureau Risicobeoordeling en Onderzoeks programmering, 2014) have recommended microbiological criteria containing process hygiene and food safety criteria for edible insects. In this concern, fresh *senene* counts met the <6.7log cfu/g standard of the Belgium's food safety aspects of insects intended for human consumption (FASFC, 2014).

Sweet potato flour microbial counts of 6.45log cfu/g may have been a result of contamination during milling as community hammer mill was used. Although both sweet potato and soybean flour were milled in the same mill sweet potato flour had higher microbial load, this may be accounted for by the fact that sweet potato flour was the first to run through the mill hence may have swept the initial microbial load away with it. All formulated flour samples were within maximum allowable limits for complementary foods. Preparation of porridges involves boiling for up to 20 min., time, which a good number of detected coliforms is expected to have been destroyed. *E.coli (*6.25 and 4.3log cfu/g) was detected in fresh *senene* and common market flours, respectively, that was higher than the <1 requirement by Codex,(2006); Belgium (FASFC, 2014) and Netherlands. Processed *senene* and flour samples were free from *E.coli* contamination signifying no faecal contamination. Confirmation results showed that the *E.coli* found in fresh *senene* was not the virulent type. All samples were free from *Salmonella* spp contamination. Therefore, the product was free from pathogenic microorganisms as required by Codex standards and EAS 72:2013).

Highest yeast and mould contamination was found in fresh *senene* with 7log cfu/g, this is in line with that of 3.5-7.2log cfu/g reported by Stoops *et al*. (2016) but higher than that of 5.7log cfu/g reported by Klunder *et al*. (2012). Processed *senene* were free from yeast and mould contamination. In all samples, yeast species dominated the moulds. Identified common mould species using the guide by Naveen Kango (2010) included *Fusarium* spp., *Cladosporium* spp. and *Penicillium* spp. (Fig. 4-10). Additionally, common market flour revealed *Aspergillus* spp., which could lead to possible mycotoxin contamination.

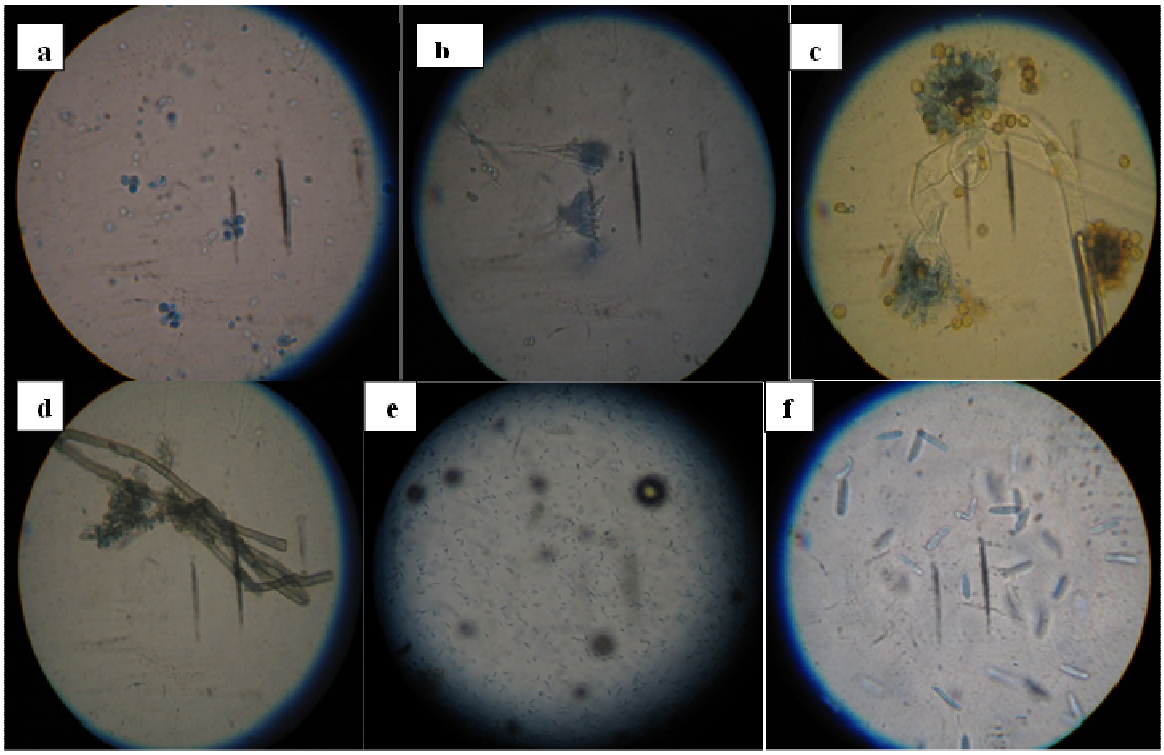

Figure 4.10: (a-f) Microbial results 1000× magnified pictures

a) Yeast cells (b) *Penicillium* spp. c&d) *Aspergillus* spp e)*Cladosporium* spp. f) *Fusarium* spp.

4.6 Consumer Acceptability Results

4.6.1 Sensory evaluation for complementary flours

Figure 4-12 shows sensory evaluation results by semi-trained panellists who were food science students. CF1 was most liked flour with significantly highest score of 4.4 out of 5 hedonic scales for general acceptability, showing high acceptability of new formulated flours. CF3 was statistically similar to CF4(Common used flour from the market), this implies that formulated product did not pose strange sensory attributes as it had mean scores that were statistically similar to commonly used market flour.

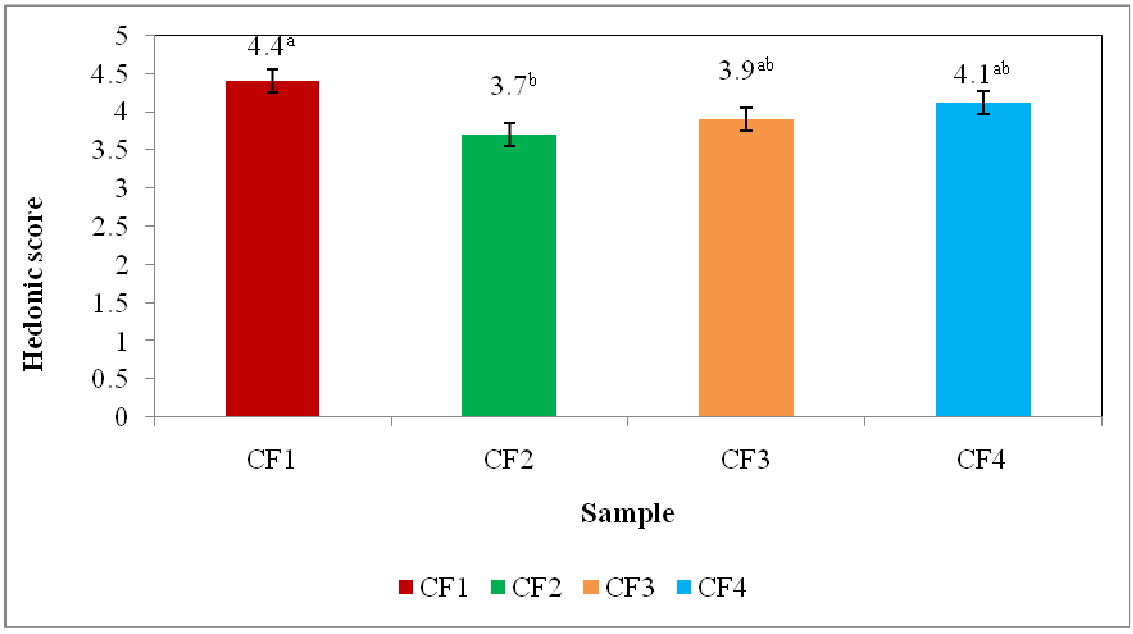

Figure 4.11: Mean hedonic scores for flour samples by students. Values are expressed as mean ± SD (n=26).

Figure 4-11presents mean hedonic scores by mothers from Mafiga and Sabasaba health centres. CF4 (commonly used market flour) had the highest acceptability score of 4.5 of 5 on hedonic scale. Among the reasons given for liking the commonly used flour than other flours was that they are used to it.

Some disliked the formulated flours due its yellowish-brown colour claiming they have always known that porridge flour should be whitish. CF3, the second most liked flour with 4.3score, had close statistical similarity with common market flour. This may have been attributed by the whitish colour of CF3that had less *senene* and more sweet potatoes.

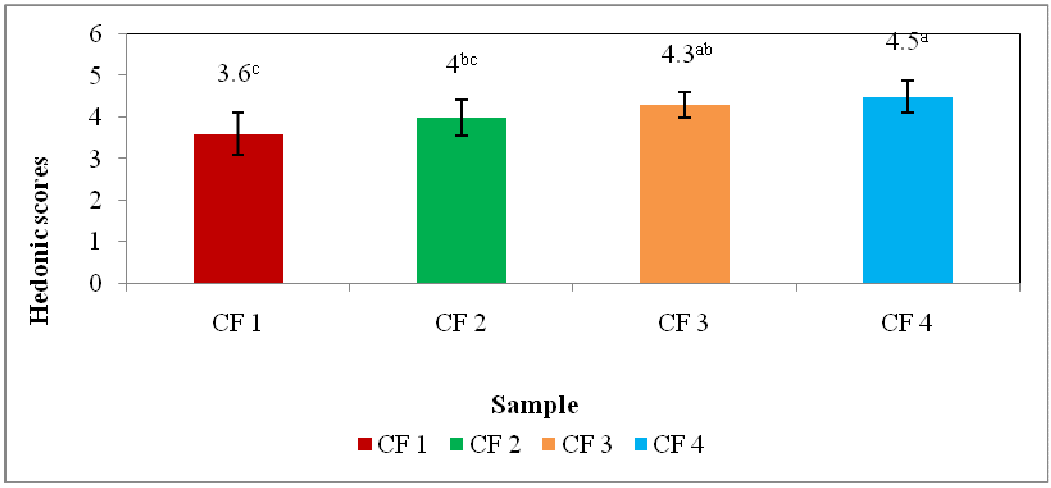

Figure 4.12: Mean hedonic scores for flour samples evaluated by mothers at Mafiga and Sabasaba health centres. Values are expressed as mean± SD (n=57).

4.6.2 Sensory evaluation for porridges from formulated complementary flours

Mean hedonic scores for the evaluated porridge samples(Fig.4-13) are shown in Figure 4-14. There were significant ($p<0.05$) differences in overall liking between samples. Furthermore, decreasing *senene* amount differed significantly ($p<0.05$) with CF3 (15%

senene) porridge sample having scored higher values than CF2 (20% *senene*) and CF1 (25% *senene*).

Figure 4.13: Formulated flours, market flour and porridges from the formulated flours

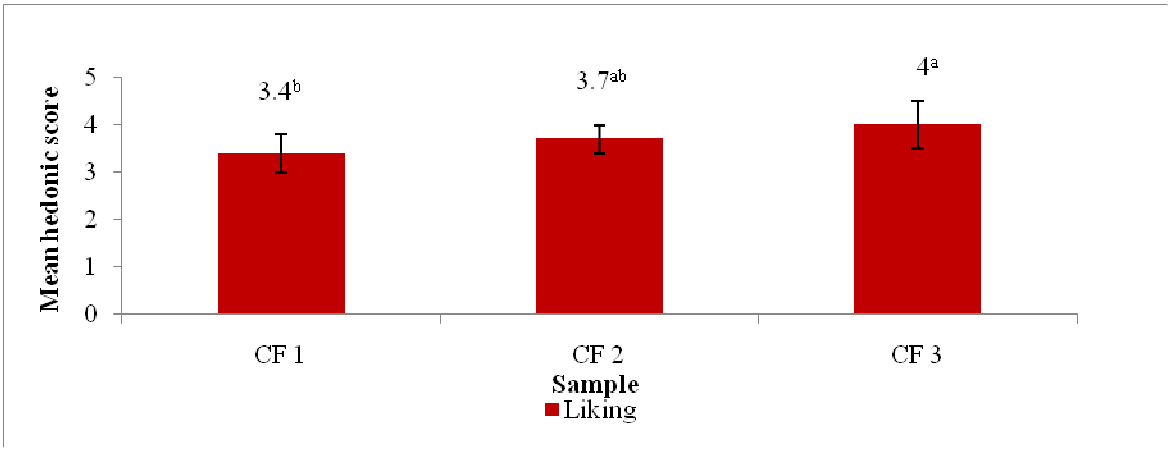

Figure 4.14; Mean overall acceptability values of porridge samples by consumers. Values are expressed as mean ±SD (n=56). Bars values with different letters are significantly different at p<0.05

4.6.3 Quantitative descriptive analysis of complementary flours

Figure 4-15explains mean intensity ratings for descriptive attributes. The results showed significant difference in mean intensity scores ($p<0.05$) among the three flour samples. Panellists were able to distinctly differentiate colour among CF1, CF2 and CF3. *Senene* flour made the flour to have yellowish-brown colour. Therefore, flour colour went whiter with decreasing amount of *senene*. CF2 and CF3 were rated to be closely similar in whiteness, aroma and appearance. CF1 had higher intensity scores in aroma, colour and hands feel while CF3 had higher intensity mean scores in whiteness and appearance. The aromatic 25% toasted *senene*in CF1 and the oiliness nature of *senene* made the flour soft and aromatic leading to higher aroma and hand feel mean intensity scores.

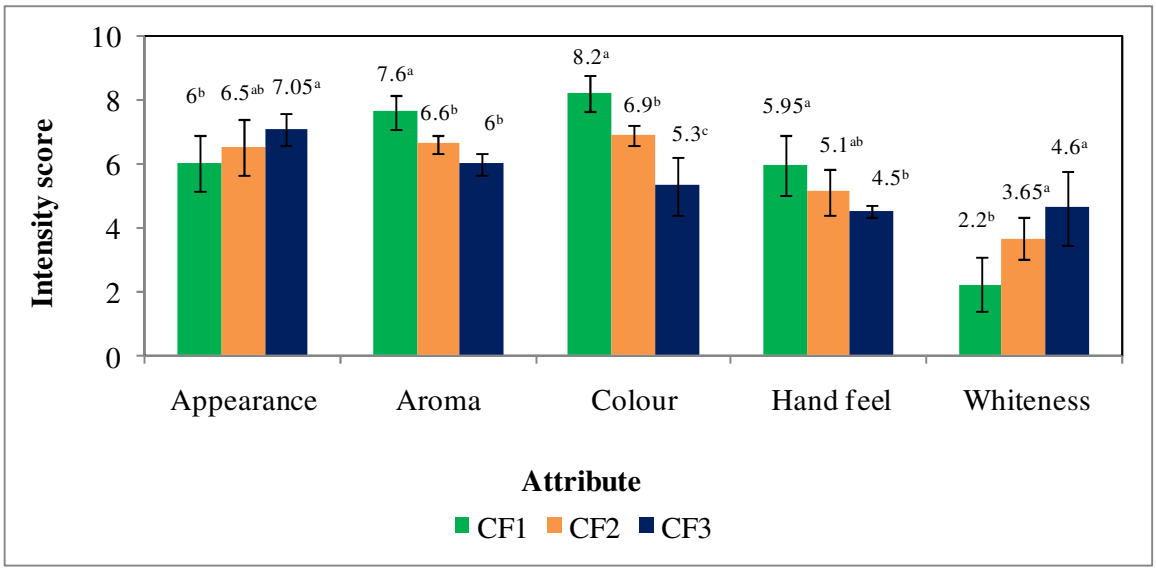

Figure 4.15: Mean intensity ratings of descriptive attributes of flour samples. Values are expressed as mean±SD (n=3). Bars with mean values having different superscripts letters are significantly different at $p<0.05$

4.6.4 Quantitative descriptive analysis of porridges made from complementary flours

Figure 4-16 shows mean intensity ratings of descriptive attributes of porridges from *senene* based flour. The results show significant ($p<0.05$) differences in mean intensity scores between samples with different *senene* quantity. Porridge from CF1 with 25% *senene* had higher oiliness, colour, mouthfeel and aroma scores than other samples. These attributes may have been a result of higher *senene* composition in CF1 flour than others. Its oiliness may have caused the soft mouth feel. Porridge from CF3 with 15% *senene* had highest appearance and whiteness scores. The whiteness may have been attributed to higher amount of sweet potato flour in CF3 than in CF2 and CF1flours.

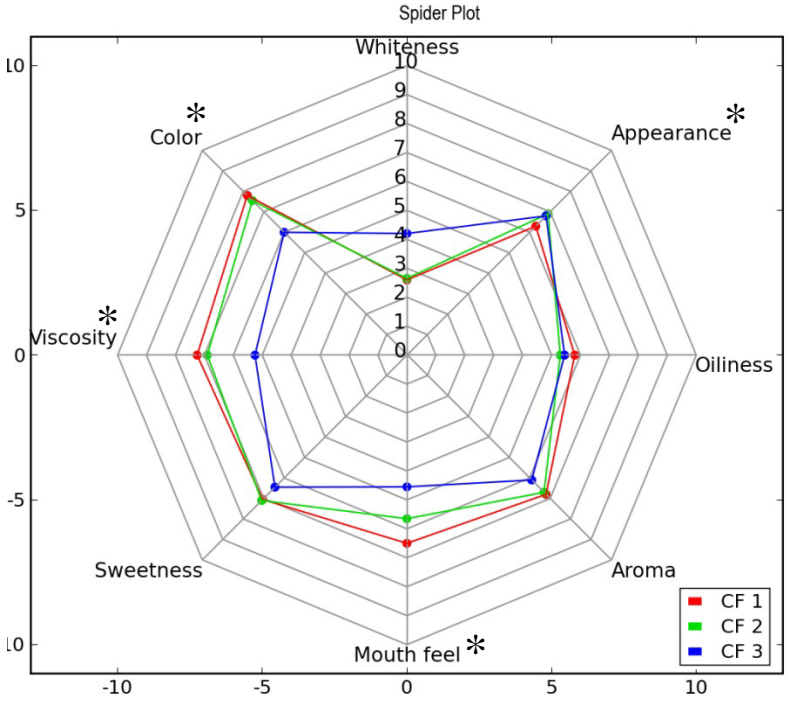

Figure 4-16. Spider plot showing mean intensity values of sensory attributes by descriptive panel. Asterisks mean values are significantly different at $p<0.05$

4.7 Preference Mapping

4.7.1 Principal component analysis

Figure 4-17shows a bi-plot with two first significant principal components from the principal component analysis (PCA) on the average sensory attributes.

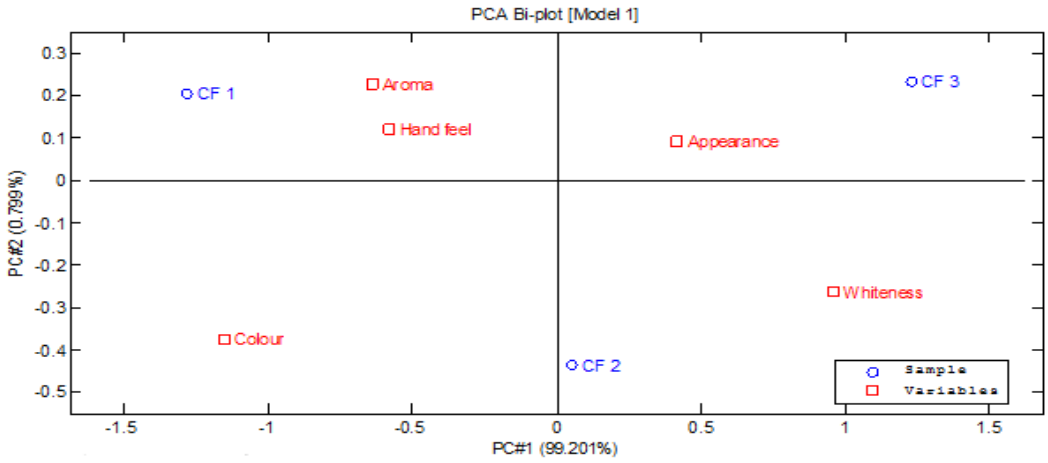

Figure 4- 17: Bi-plot from PCA of descriptive sensory data for flour samples

PC1 accounted for 99.20% systematic variations of the data while PC2 accounted for the remaining 0.799%. Four samples were well separated with their corresponding attributes. CF1 was well separated from CF2 and CF3 along PC1 while CF2 was well separated from CF1 and CF3 along PC2. Results shows that CF1 was positively correlated to aroma, colour and hand feel while CF2 and CF3 were positively correlated to appearance and whiteness along PC1. Variation between CF2 and CF3 was based on appearance and whiteness along PC1 while variations between CF1 and CF3 were based on aroma, hand feel and appearance along PC2. Therefore, variation between products was mainly explained by attributes aroma, hand feel and colour on one side and attributes appearance and whiteness on the other side along PC1.

Figure 4-18 shows bi-plot with the two first significant principal components from Principal Component Analysis (PCA) on average sensory attributes. The obtained results showed principal component PC1 accounted for 94.7% of the systematic variation in the data while principal component PC2 accounted for 5.3%. Porridge samples were well separated meaning the panelists were able to distinguish the samples. CF3 porridge was well separated from CF1 and CF2 along PC1 while CF2 was well separated from CF1 and CF2 along PC2. CF1 and CF2 porridges correlated positively with descriptive attributes mouthfeel, oiliness, aroma, sweetness, viscosity and colour attributes and they correlated negatively with appearance and whiteness attributes. CF3 porridge sample correlated positively with attribute whiteness and appearance. The findings indicate that, the variation between samples was explained by attributes mouthfeel, whiteness, and appearance.

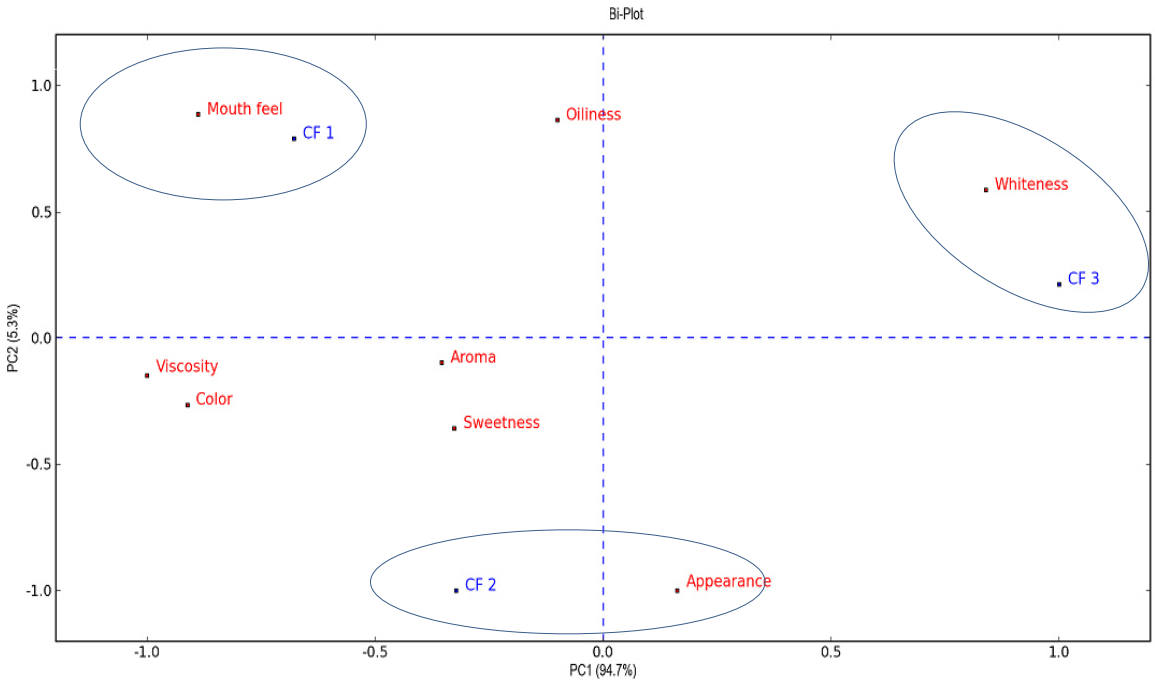

Figure 4-18: Bi-plot from PCA of descriptive sensory data for porridge samples

4.7.2 Relationship between sensory data and consumer data by PLSR for students

Figure 4-19shows the results from a Partial Least square Regression (PLSR) using descriptive data as X variables and liking by students as Y-variables. PLSR has the ability to detect variation in the sample liking which is crucial in product development. Results show that most consumers fall to the right of vertical axis Y, meaning the direction of liking was towards CF1 with aroma, hands feel and colour as associated attributes. Very few consumers on students' side shows to fall on left hand side of vertical axis Y liking CF2 and CF3 associated with appearance and whiteness. The X axis shows preference on CF1 and CF3 than CF2.

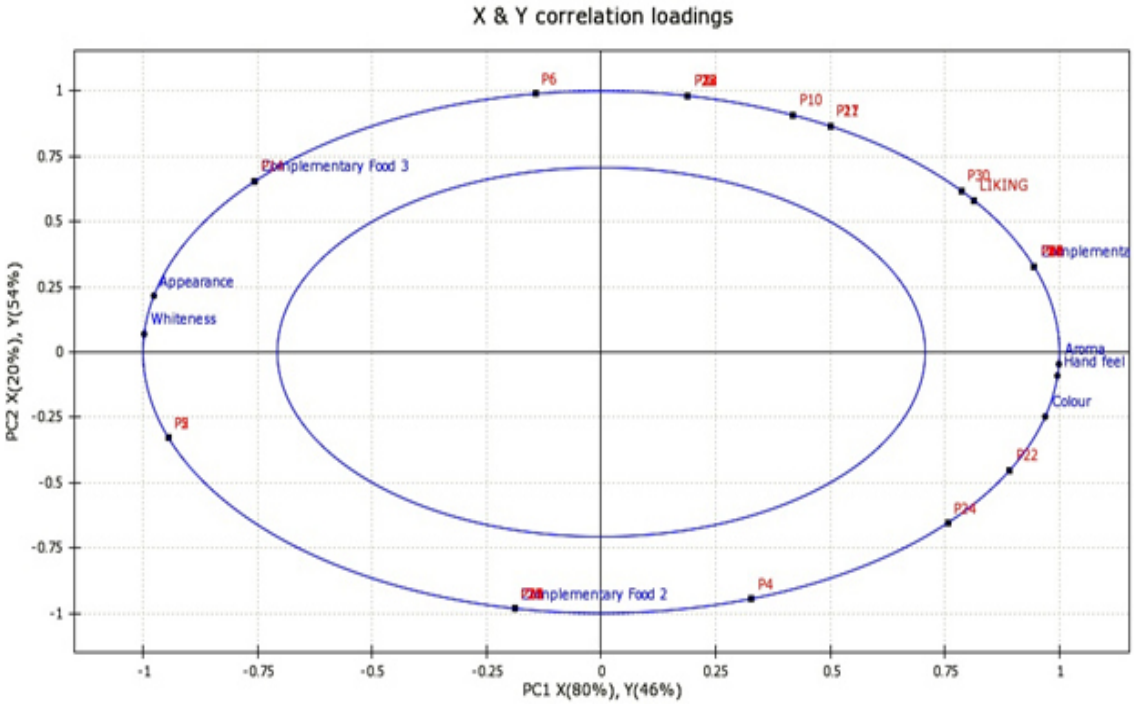

Figure 4- 19: Correlation loadings from a partial least squares regression of flour samples with descriptive data as X variables and hedonic rating by students as Y variables.

Figure 4-20shows the results from a partial least square regression PLSR using descriptive data as X variables and liking by mothers as Y-variables. The findings shows that most mothers fall on right side of Y axis, which means they had higher preference on appearance and whiteness correlating positively with CF2 and CF3. Some mothers fell on left of Y axis showing preference to CF1 characterised by aroma, hands feel and colour attributes. This is interesting in product development as it reveals the variations and attributes that accounted for variation. Referring to hedonic results (Fig 4-12 and 4-13) it can be stated that students and mothers had opposing acceptability results as mothers preferred CF3 while students preferred CF1. From PLS we can argue that both mothers and students preferred CF1 for its colour, hands feel and aroma alsoCF2 and CF3 for their whiteness and appearance.

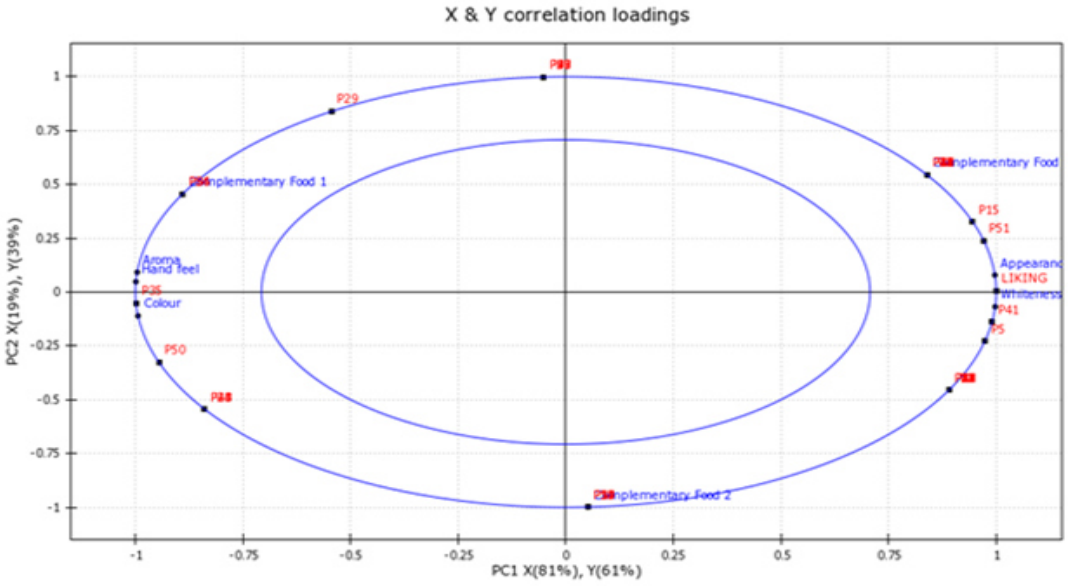

Figure 4-20: Correlation loadings from partial least squares regression of flour samples with descriptive data as X variables and hedonic rating by mothers as Y variables.

4.8 Shelf Life Stability Studies on Formulated Composite Flours

4.8.1 Free fatty acids (FFA)

Free fatty acids ranged from 0.15 to 0.23mg/g for flours during the first month of storage (Fig. 4-21). The highest FFA value was attained during the sixth month of storage, with the reading of 1.18mg/g. FFA indicates the formation of new free fats, which is an indication for deterioration of fat and fatty foods. CF1 with 25% *senene* showed speedy increase in FFA levels throughout the storage period (0.23 to 1.18mg/g), the trend was similar to CF2 with 20% *senene* between first to third months of storage. FFA levels for CF2 and CF 03 unexpectedly, decreased between fifth and sixth month then increased again between sixth to seventh months. All flours had the FFA value below 2mg/g recommended by Codex (1992) up to six months of storage.

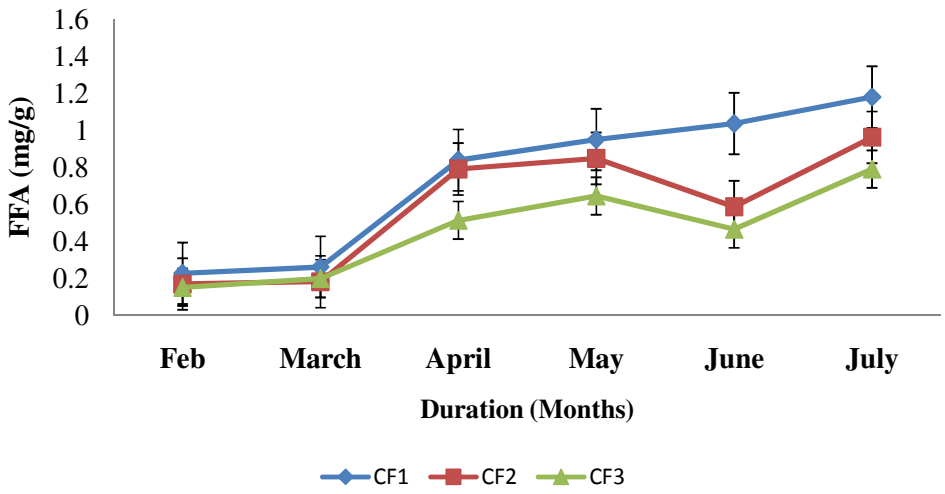

Figure 4-21: Changes of FFA values of composite flour stored at room conditions for six months

4.8.2 Peroxide value (PV)

Peroxide values trend for CF1 and CF3 was in zigzag pattern throughout storage time (Fig. 4-22), this indicates formation and breakdown of peroxide and hydroperoxides. CF2 had a linear trend increasing from 3.06 to 4.2meq/kg during the sixth month of storage. *Senene*'s fat is reported to contain more of polyunsaturated fatty acids which are prone to deterioration during storage; however, formulated flours with *senene* in them did not show extreme deteriorations in six months of storage. All peroxide values in flour samples were within Codex quality standards as they did not exceed 10meq/kg standard of 1991.

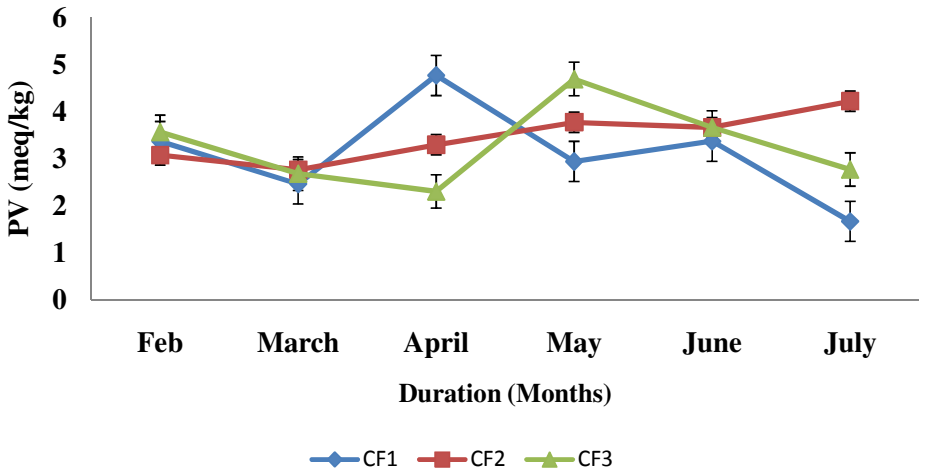

Figure 4-22: Changes of PV of composite flour stored at room conditions for six months

4.8.3 Moisture contents

There was a decrease in moisture content for CF3 from 8.3 to 7.8% during first month of storage (Fig. 4-23). CF2 acquired moisture and has its moisture content levels raised from 2.3 to 7% between first and second month of storage. The trend changed again during the fourth month of storage where the moisture content for CF3 dropped from 11.2 to 9.5% while that of CF2rose to 10.9% nearing that of CF1 with 10.4%. The trend may have been attributed by weather changes causing moisture balance between product and surroundings, dry season reached its peak between June and July in Morogoro region.

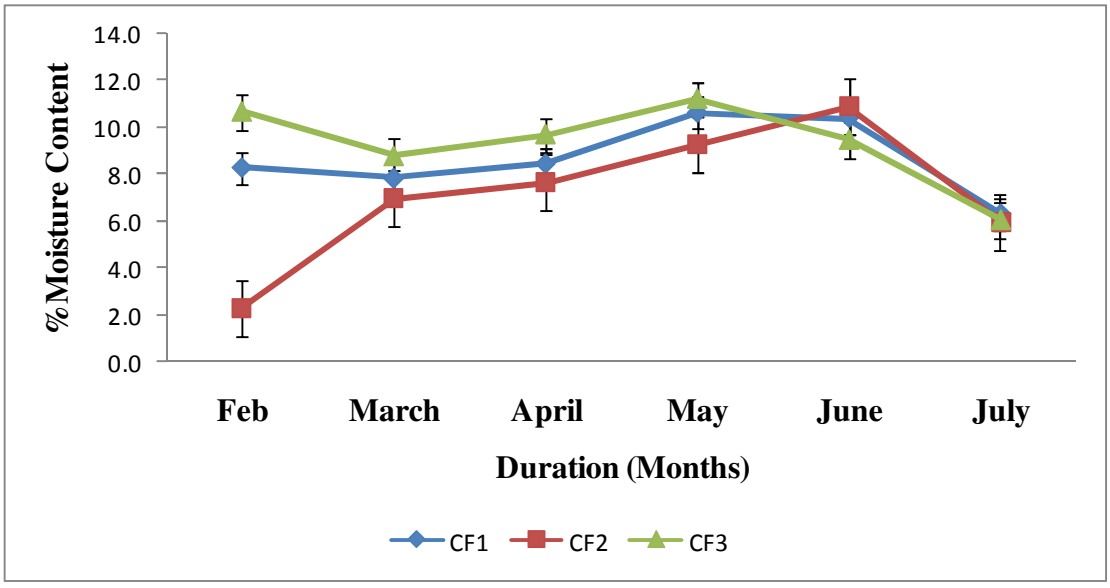

Figure 4-23: Changes of moisture contents of composite flour stored at room conditions

4.8.4 Sensory evaluation results of formulated flours stored at room conditions for six months

Figs. 4-24 to 4-28 shows changes in sensory attributes of formulated flours in six months of storage.

4.8.4.1 Colour and appearance

Changes in colour and appearance are shown in Figs. 4-24 and 4-25. The colour and appearance change was not significant among the flours throughout the storage time. There was a significant drop in colour rating between fifth and sixth month ($p<0.05$). The flours maintained the average score of four (4) on 5 point hedonic scale, the colour of flours was moderately liked until the end of storage period.

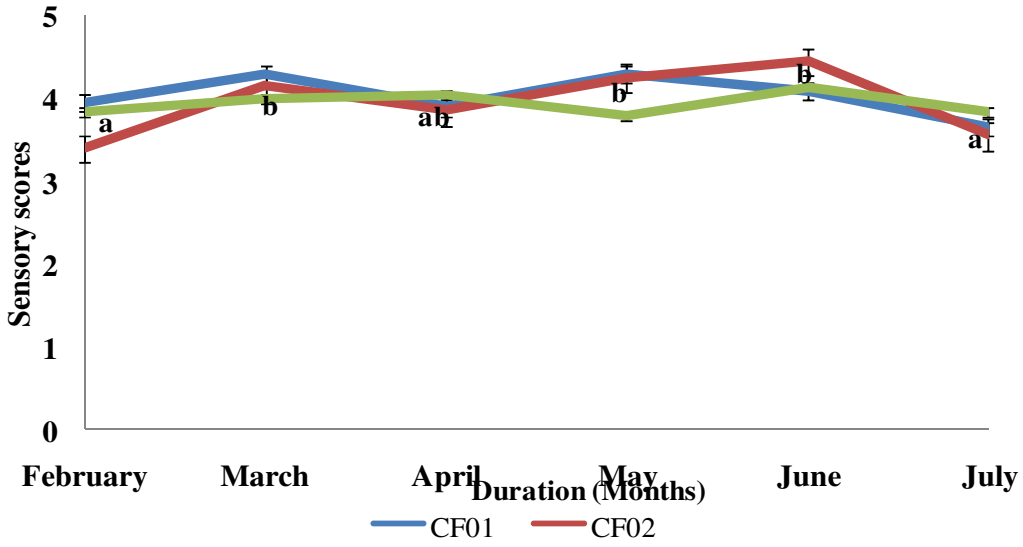

Figure 4-24: Changes of colour liking of flour samples by consumers with storage time

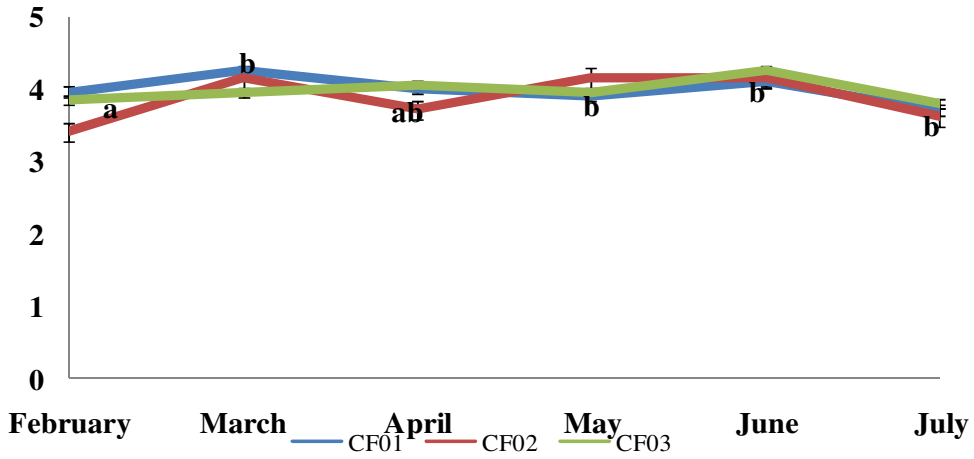

Figure 4-25: Changes of appearance liking of flour samples by consumers with storage time smell and texture

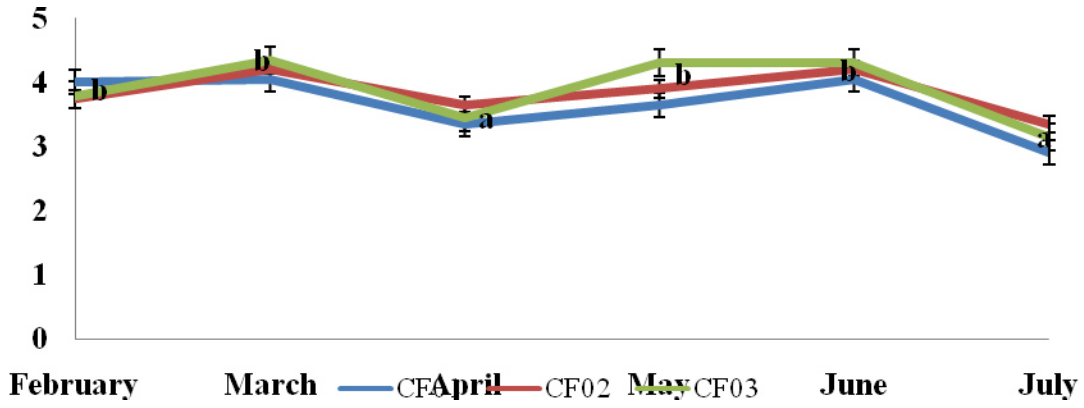

Figure 4-26: Changes of smell liking of flour samples by consumers with storage time

4.8.4.2 Smell and texture

Fig. 4-26 shows that there was a significant drop in smell liking score ($p<0.05$) by end of sixth month to all flour samples. This may have been attributed by formation of rancid smell caused by secondary products of oxidation hence resulted to fat deterioration. Change in the texture of flours was not significant (Fig 4-27).

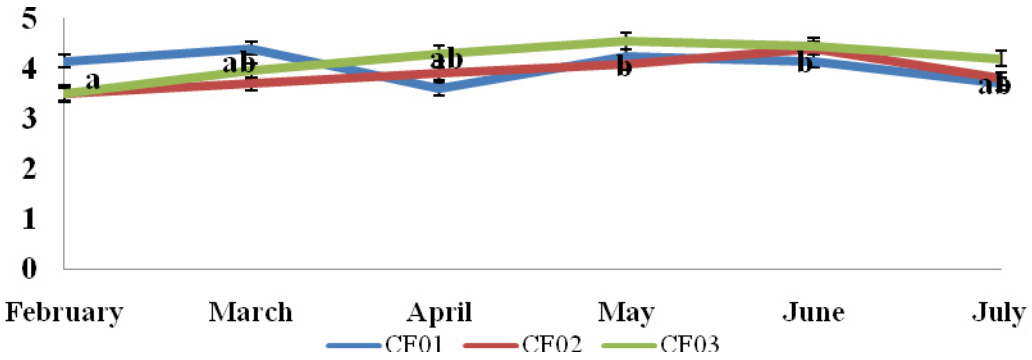

Figure 4-27: Changes of texture liking of flour samples by consumers with storage time

4.8.4.3 General acceptability of flours throughout storage period

Generally, there was a significant drop in sensory acceptability of formulated flours with storage time as shown in Fig. 4-28 ($p<0.05$). However,CF2 and CF3 maintained the score of four (4) out of five (5) on hedonic scale, meaning these flours were liked moderately until sixth month of storage. The scores dropped to three (3) for CF1 (25% *senene*: 35% soybean flour: 40% sweet potato flour) during the sixth month of storage, meaning the flour at this point was neither liked nor disliked.

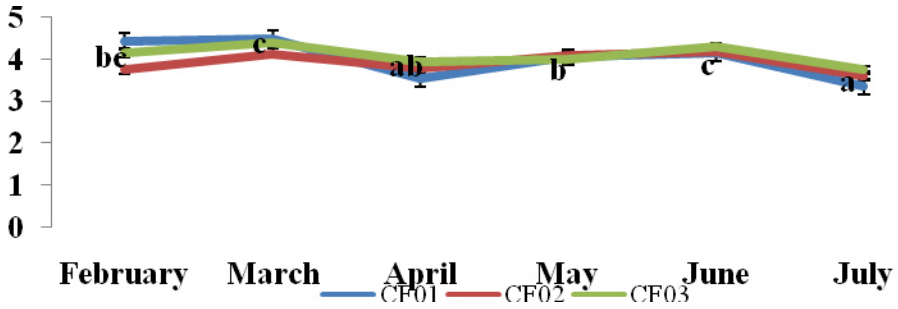

Figure 4.28: Changes of acceptability liking of flour samples by consumers with storage time

4.8.5 Sensory evaluation results of porridges from formulated flours during storage

Table 4-8 presents shelflife results showing the effect of time on sensory attributes of CF1 porridge from stored formulated flours.

Table 4.8: Effect of time (months) on sensory attributes

Month	Colour	Appearance	Smell	Taste	Texture	Consistency	Overall Acceptability
February	3.5±1.17^{c}	3.3±1.13^{c}	3.05±1.17^{b}	2.8±1.15^{c}	3.4±1.19^{b}	3.7±1.04^{b}	3.3±1.52^{c}
March	4.1±0.97^{a}	3.9±1.07^{a}	4.0±0.86^{a}	3.8±1.06^{a}	3.6±0.83^{ab}	4.1±0.94^{a}	4.1±0.76^{a}
April	4.2±0.99^{a}	4.0±1.05^{a}	4.0±0.86^{a}	3.8±1.12^{a}	3.6±0.83^{ab}	4.0±0.94^{a}	4.1±0.76^{a}
May	3.9±0.93^{ab}	3.6±0.94^{b}	3.6±1.09^{ab}	3.8±1.07^{a}	3.6±0.76^{ab}	3.8±0.89^{ab}	3.7±0.99^{b}
June	4.1±0.85^{a}	4.1±0.79^{a}	3.9±0.91^{a}	3.3±0.92^{b}	3.9±0.75^{a}	3.7±1.17^{b}	4.0±0.79^{a}
July	3.4±1.14^{c}	3.4±1.14^{c}	2.9±0.85^{b}	2.9±0.97^{c}	3.2±0.93^{c}	3.8±0.85^{ab}	3.3±1.13^{c}

Values are expressed as mean±SD dry matter basis (n=2) Mean values with different superscript letter along the column are significantly different at $p<0.05$

There were no significant changes in colour, appearance, smell and taste between first and sixth month of storage. The liking scores increased significantly from second to fifth month of storage. This may have been the effect of panelists getting familiar with product. Lower taste and smell scores during the last month may have been caused by formation of rancid flavour as a result of fat deterioration. The trends observed in the porridges were quite similar to those experienced from their respective flours (Figs. 4-21 to 4-25).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The study observed that traditions, cultures and beliefs of studied societies highly influenced dietary choices and adoption of a developed product. The understanding of ancient processing methods and indigenous technologies can play a crucial role in innovations across food industry. *R. differens* being an important edible insect among societies around the lake zone, has drawn the attention of among others entomologists, botanists as well as food scientists and nutritionists. *Senene* carries economic potentiality essential for improvement of women and smallholder farmers' income apart from been an important delicacy to *Haya*. Fresh *senene* did not contain the virulent strains of *E. coli* despite of being highly loaded with microorganisms.

Formulated composite flours were nutritious and microbiologically safe than common consumed composite flour in Morogoro. *Senene* was proven to be a nutritious ingredient useful in enriching plant-based complementary foods, supplying such essential nutrients like protein, zinc, heme iron and retinol. Germination was shown to be a potential way of reducing anti-nutrients in soybean to increase bioavailability.

Complementary flour from *senene* was shelf-stable under room conditions, with good sensory attributes maintained for six months.

5.2 Recommendation

Studies on improvement of mentioned indigenous processing technology are highly required to assure quality and safety of marketed *senene*. Promotion of *senene* as a delicious food among all consumers should be encouraged by both researchers and social workers in order to circumvent the challenges posed by culture. Environmental

conservation policies and regulations should be emphasized for the sustainability of edible insects. Exploration of edible insects other than *senene* consumed by different societies in Tanzania is required to increase rich protein sources. Studies on enriching other common starch plant ingredients used in complementary feeding like maize cassava, millet and sorghum flours with edible insects are needed. Shelf life studies under different keeping temperatures are encouraged to evaluate keeping qualities of *senene*-based complementary flours.

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APPENDICES

Appendix 1: Guiding questions on longhorn grasshopper's consumption

Information collection questions on longhorngrasshopper's sample collection.

1. How often do you consume longhorn grasshoppers? Are there any benefits for consumption?
   Mara ngapi katika mwaka unakula senene? Je kuna faida zozote katika ulaji wa senene?
2. Do you give senene to infants and young children?Why?
   Je, una kawaida ya kuwalisha watoto wadogo senene?Kwa nini?
3. What food materials do you normally use to prepare infants and baby foods?
   Je, hua unatumia mazao gani kuandaa chakula cha watoto wachanga na watoto wadogo?
4. What are other methods of preparation apart from roasting?
   Je, kuna namna nyingine ya kuandaa senene ukiacha hii ya kukaanga?
5. Are there occasions where insects are consumed live?
   Je, kuna wakati senene huliwa wakiwa wabichi?yaani bila kupikwa?
6. On what time of the year is senene available? At what price?
   Ni wakati gani hua senene wanapatikana kwa wingi? Wakati huo ni bei gani kwa kilo?
7. What methods of collection do you use?
   Njia zipi mnatumia kukusanya senene?
8. If there were roasted senene and products sold off season will you be willing to buy? At what price per kg of roasted senene?
   Je, uko tayari kununua senene waliokaangwa kipindi ambacho sio msimu wa senene? Uko tayari kununua kilo moja kwa shilingi ngapi?
9. Apart from senene, are there other insects been consumed? mention them?

Je, kuna wadudu wengine ambao huliwa katika maeneo yenu ukiacha senene?Wataje?

10. Are there any other uses of such insects apart from food?
    Je, kuna matumizi mengine ya wadudu ukiacha kuliwa kama chakula?
11. Are there any preservation methods for insects to ensure a longer shelf life?
    Je, ni njia zipi hutumika kuhifadhi senene bila kupoteza ubora wake?
12. Are there any reported allergic reactions upon consumption of senene? Which are those?

Je, kuna madhara yoyote kiafya ambayo yalishamtokea mtu kufuatia ulaji wa senene?

Appendix 2: Questionnaires used in collecting information about senene-swahili version

DODOSO KUHUSU ULAJI WA SENENE

Maswali yafuatayo yatatusaidia katika Utafiti juu ya ulaji wa senene na matumizi ya senene katika kutengeneza lishe ya watoto

Kabila……Umri…… Kazi/Chanzo cha mapato……..

Elimu……..Jinsia…….

1. Je unapenda kula senene? **(1)NDIYO (2) HAPANA**

2. **Je kuna faida gani upatazo katika ulaji wa senene? (Kwa nini unakula?)**
   a. Ni heshima
   b. Wana virutubishi muhimu kwa afya (virutubishi gani)……..
   c. Watamu sana
   d. Nawapenda tu
   e. Ni mboga ya wakati wote
   f. Sababu nyingine (Taja)……

3. **Ni njia gani unazotumia kuandaa senene wabichi kabla ya kula?**
   a. Kuchemsha kisha kukausha kwa jua **(elezea)……..**

b. Kuchemsha kisha kukausha na moshi (Miti gani hutumika kwa moshi huo wa kukaushia senene,kwa mda gan e.t.c)**…….....**

c. Kukaanga bila mafuta**……** (kwa mda gani na moto kiasi gani)**……**

d. Kuanika juani**……...**(kwa siku ngapi,kutumia vifaa gani,usafi ukoje,wanaanika chini au kwenye vichanja)**…….……**

e. Kukaanga kwa mafuta**…….**(mafuta gani, kiasi gani, kwa mda gani)

f. Kuchemsha na chumvi kisha kukaanga kwa mafuta

g. Kuchemsha kwa chumvi kasha kukaanga bila mafuta

h. Nyingine (TAJA)**…….**

Unapendelea kula senene zilizoandaliwa kwa njia gani

…….……

4. Je, una kawaida ya kuwalisha watoto wadogo (1-5years old) senene?

1) NDIYO

(a)wana virutubishi **(b)** watoto wanapenda **(c)** ni utamaduni

11) HAPANA

(a)hawawezi kumeza **(b)**wana vichwa vigumu **(c)** hawataongea **(d)** watakua na vichwa kama vya senene

Kwa nini? TOA SABABU**.....**

…….

5. Senene wabichi huwa unawahifadhi kwa njia gani kabla ya kukaanga/kuchemsha/kukausha?

a. Mifuko ya salfet/plastic
b. Gunia
c. Ndoo ya plastic
d. Neti/chombo chenye matundu
e. Nyingine…….

6. Senene wabichi wanaweza kukaa mda gani bila kuharibika.

a. Masaa 6 hadi 10
b. Masaa 12 hadi 24
c. Siku 3 hadi 5

7. Je, kuna wakati huwa unakula senene wakiwa wabichi?yaani bila kupikwa?

1) NDIYO **(a)** ni watamu **(b)**wana virutubishi zaidi **(c)** sababu nyingine……..taja

11) HAPANA **(a)** utaumwa tumbo na kuhara **(b)** hawana ladha **(c)** wanakua na wadudu

8. Ni wakati gani hua senene wanapatikana kwa wingi?..

a. Mwezi wa 4 hadi 5
b. Mwezi wa 9 hadi 12

Wakati huo ni bei gani kwa ndoo ndogo?.....

9. Njia zipi unatumia kukusanya/kupata senene kwa ajili yako?

I. Kuokota chini asubuhi
II. Kutegesha mitego
III. Kuokota ziwani
IV. Kupewa na ndugu
V. Kununua kwa wakusanyaji/wauzaji

10. Je, Senene hupatikana wa kutosha wakati ambako sio msimu wa senene?

1) NDIYO 11) HAPANA

Kikombe kimoja huwa shilingi ngapi?**.**

a. 1,000-3,000 Tsh
b. 5,000-10,000Tsh

11. Je, kuna wadudu wengine ambao huliwa katika maeneo yenu ukiacha senene?

1) NDIYO 2) HAPANA…….. **Wataje**

……

12. Je, kuna matumizi mengine ya wadudu ukiacha kuliwa kama chakula?

1) NDIYO 11 2)HAPANA

a. Mboga ya ugali
b. Chambo kwa samaki/panya
c. Kuandaa vitafunwa kama sambusa
d. Chanzo cha mapato
e. Kukamuliwa mafuta
f. Chakula cha kuku/samaki
g. Nyingine……..(taja)

13. Je, hua unatumia mazao gani kuandaa chakula cha watoto wachanga na watoto wadogo (miaka 1 had5)?

a) Nafaka b) Ndizi c) Mikunde d) Anakula nachokula

Nyinginezo**…….**(TAJA)

14. Je, umewahi kufanya au unafanya biashara ya senene? 1) NDIYO 2) HAPANA

Kama jibu ni Ndiyo, Je, Inakupatia sehemu gani ya kipato chako?

(a) Chote kukidhi mahitaji yangu yote **(c)** Kukidhi robo ya mahitaji

(b) Kidogo kukidhi nusu ya mahitaji **(d)** Hakuna faida

15.Je, ni njia zipi unazotumia kuhifadhi senene bila kupoteza ubora wake?

1) kubanika kwenye majani ya migomba 11) kurudia kukaanga 111) Nyingine (Taja)**……..**

Ipi ni bora zaidi na ambayo hata baada ya muda mrefu senene hua na ladha ileile……..

Ipi ambayo senene hubadilika ladha haraka (*zinabadilikaje?kukereketa kooni au etc.***)……..**

16.Je, kuna madhara yoyote kiafya ambayo yalishakupata kufuatia ulaji wa senene?

1) NDIYO 11)HAPANA

kama jibu ni NDIYO madhara gani ulipata

1) Kuhara 11) Kuumwa tumbo 111) kutapika 1V) kichefuchefu

V) Mengine..(taja)**……..**

17.Je, unatumia senene kutengeneza/kuandaa vyakula vingine? Mfano mchuzi wa mboga, kwenye ndizi za kupika ,unga wa senene n.k…

(elezea)**……**

…...

……

……

18.Yapi maoni yako juu ya matumizi ya senene katika kuandaa chakula cha watoto.....

“***Ahsante kushiriki kwani lishe bora ya jamii yetu ni jukumu letu sote”***

Appendix3: Sensory Evaluation of Complementary Porridge Flour

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

SENSORY EVALUATION OF COMPLEMENTARY PORRIDGE FLOUR

Panelist

No…….Gender.....Age.....Date.....Time.....

Instructions

Below is a sensory assessment evaluation sheet of different kinds of porridge flours. You are required to assess their smell, colour, appearance,texture and their general acceptability using a scale of 1-5.

Use the guide below to help you choose appropriate ratings.

1-dislike extremely,

2-dislike slightly

3-neither like nor dislike

4-like slightly

5-like extremely

Attributes	**Sample codes**			

Colour				
Appearance				
Smell				
Texture/Hand feel				
Overall acceptability				

Comments based on sample code(s)

.....

.....

Appendix4 Sensory evaluation of complementary porridge

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

SENSORY EVALUATION OF COMPLEMENTARY PORRIDGE

Panelist no.: …… **Gender**:.....**Age:**..... **Date:**.....**Time:**.....

Instructions

Below is a sensory assessment evaluation sheet of porridges from different kinds of flours. You are required to assess their **taste**, **smell**, **colour**, **appearance,texture**, **consistency** and their **general acceptability** using a scale of 1-5.

Use the guide below to help you choose appropriate ratings.

1-dislike extremely,

2-dislike slightly

3-neither like nor dislike

4-like slightly

5-like extremely

Attributes	**Sample codes**				
Colour					
Appearance					
Aroma (smell)					

Taste					
Texture/Mouth feel					
Consistency					
Overall acceptability					

Comments based on sample code(s)

.....

.....

Appendix 5: Quantitative Descriptive Analysis form for complementary porridge

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

Quantitative Descriptive Analysis form for complementary porridge flour

Name……Age…… Sex……...Time……

Please evaluate each of the coded samples in the order they listed. Choose appropriate number in the scale from 1 to 9, where 1 is low intensity and 9 is high intensity. How do you

find the following characteristics for the extruded snacks? Put the appropriate number against each characteristic.

Sample #.....

Whiteness _____

Grey 1 2 3 4 5 6 7 8 9 very white

Colour (Brownish)

_____

Faint 1 2 3 4 5 6 7 8 9 very concentrated

Appearence_____

Less appealing 1 2 3 4 5 6 7 8 9 very appealing

Hands feel (softness)

_____

Small size particles 1 2 3 4 5 6 7 8 9 larger particles

Aroma _____

Not aromatic 1 2 3 4 5 6 7 8 9 very aromatic

Stickiness_____

Less sticky 1 2 3 4 5 6 7 8 9 very sticky

What is your total liking of the product?

_____

Don't like it 1 2 3 4 5 6 7 8 9 Like a lot

Appendix 6: Quantitative Descriptive Analysis form for complementary porridge

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

Quantitative Descriptive Analysis form for complementary porridge

Name……Age…… Sex……...Time……

Please evaluate each of the coded samples in the order they listed. Choose appropriate number in the scale from 1 to 9, where 1 is low intensity and 9 is high intensity. How do you find the following characteristics for the extruded snacks? Put the appropriate number against each characteristic.

Sample #.....

Whiteness _____

Grey 1 2 3 4 5 6 7 8 9 very white

Colour _____

Faint 1 2 3 4 5 6 7 8 9 very concentrated

Viscosity_____

Less viscous 1 2 3 4 5 6 7 8 9 very viscous

Sweetness_____

Less sweet 1 2 3 4 5 6 7 8 9 very sweet

Mouth feel _____

Poor feel 1 2 3 4 5 6 7 8 9 best feel

Aroma _____

Not aromatic 1 2 3 4 5 6 7 8 9 very aromatic

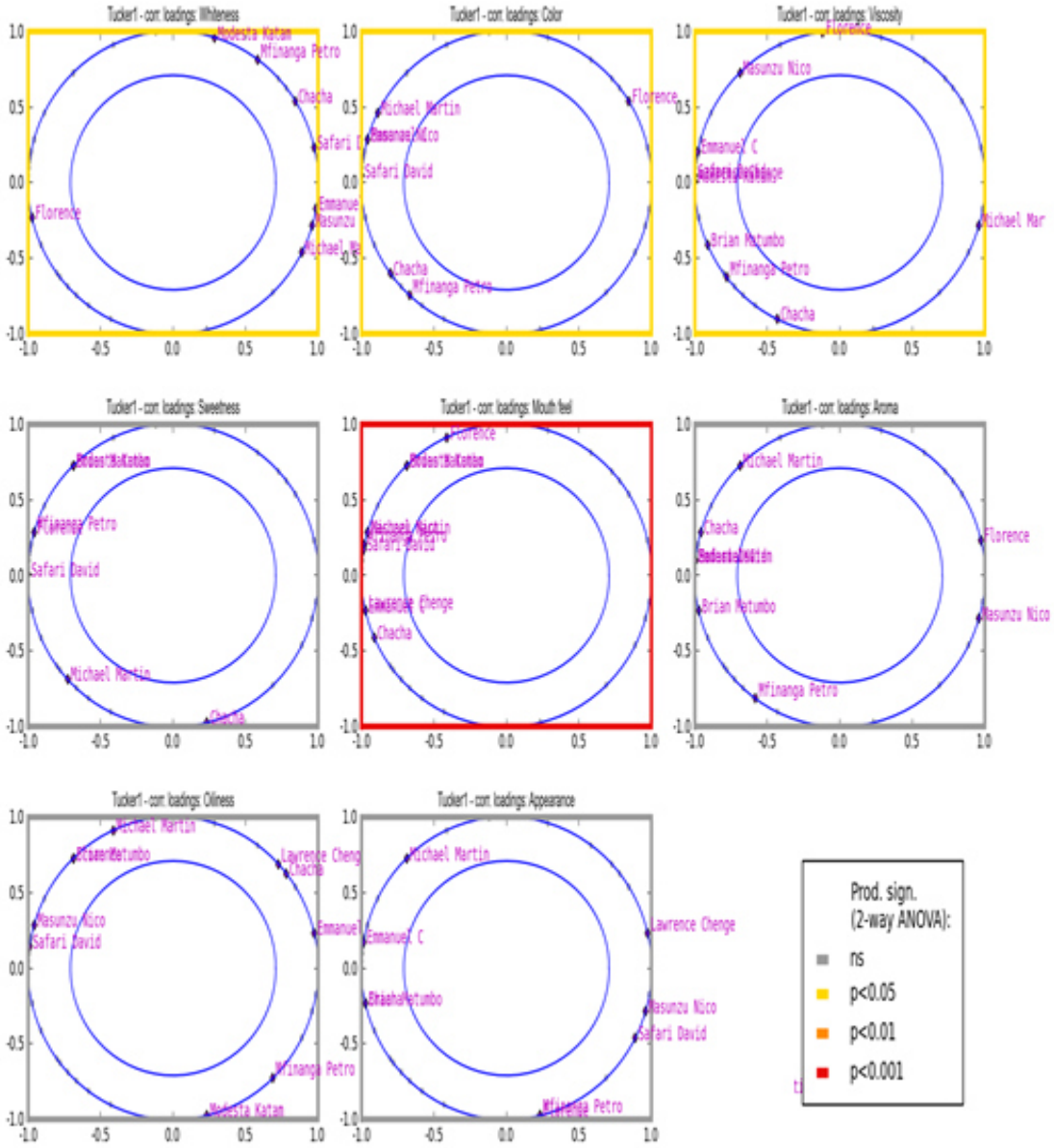
Oiliness_____

Less oily 1 2 3 4 5 6 7 8 9 very oily

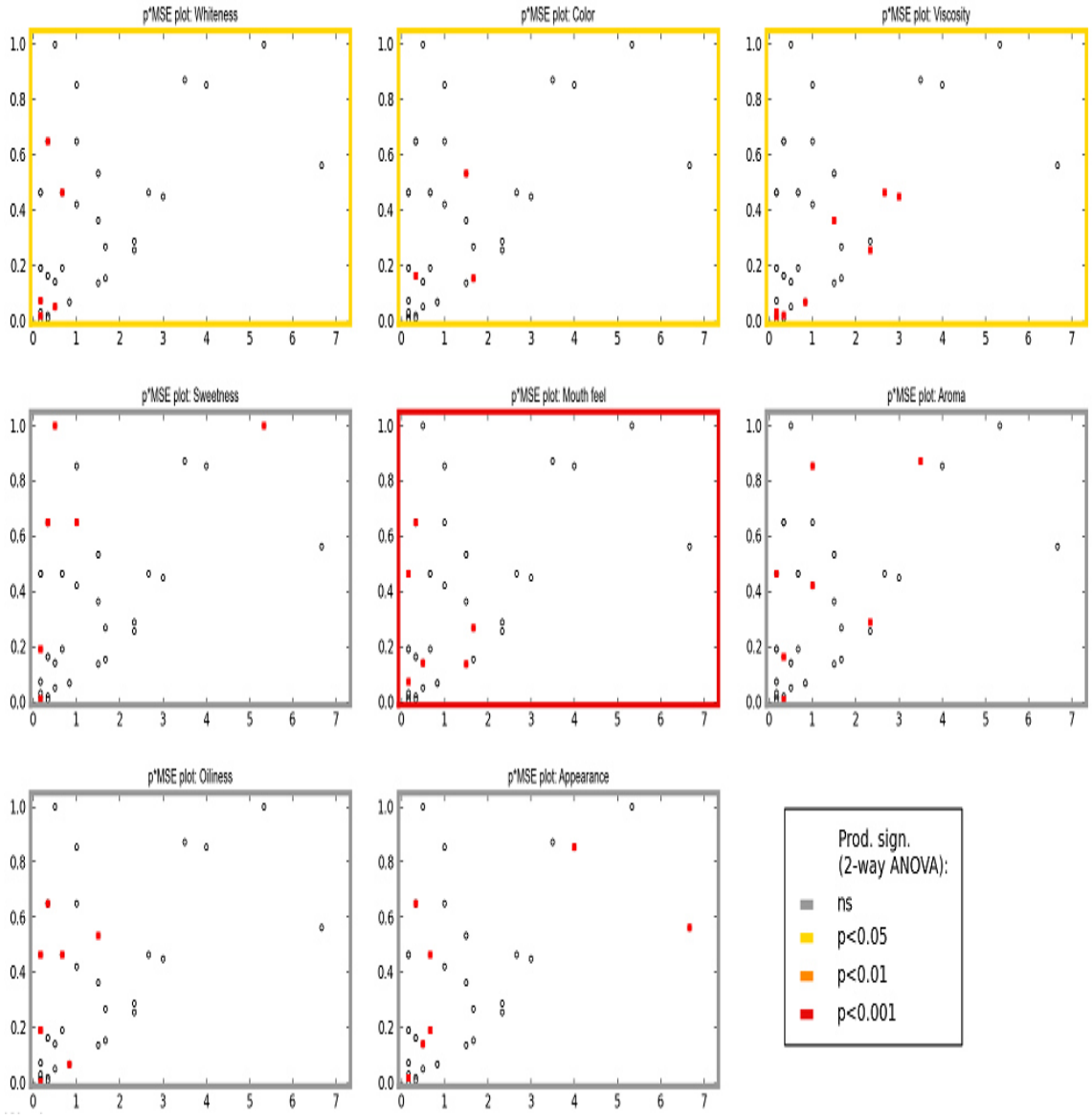
Appearance_____

Less appealing 1 2 3 4 5 6 7 8 9 very appealing

Appendix 7: Panel performance



Tucker plot showing panel agreement of attributes



P*MSE plots showing discrimination and reproducibility of panel members

Appendix 8: Pictures of acceptability panels at SUA food lab for students and clinic for mothers








Appendix 9: Pictures of sweet potatoes and soy bean flour processing