PRODUCTION AND CHARACTERIZATION OF JACKFRUIT JAM

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ABSTRACT

This study aimed at producing and characterizing of jackfruit (*Artocarpus heterophyllus*) jam, by extracting pulps from jackfruits obtained from Morogoro market. Produced pulp was mixed with prepared lemon juice and sugar and allowed to cook on constant boiling/stirring until ready for set at 69% brix. Seventy untrained panelists performed sensory and general acceptability test using 7 point hedonic scale of the developed jam together with commercial mango jam as control. The results revealed no significant difference (P>0.05) in mean hedonic score between developed jackfruit jam and control. Consumer studies showed significant differences (P>0.05) in Hue (colour) and sweetness attributes between jackfruit jam and the commercial mango jam. Quantitative descriptive analysis showed significant difference (P>0.05) in mean intensity score of Hue and sweetness between the control and developed jackfruit jam. Jackfruit jam had very concentrated brown colour compared to control mango jam which had faint colour and was slightly sweeter compared to jackfruit jam. Principal component analysis (PCA) showed that jackfruit and commercial mango jam were separated along principal component one. Jackfruit jam had bright colour, it spreaded well and had strong aroma compared to control. Proximate analysis of fresh jackfruit showed protein (1.65%), carbohydrate (16.19 %), ash (0.41%), crude fat (0.03%), crude fibre (4.69%), moisture content (77.03%), pH (5.41), vitamin C (5.99mg/100g) and total acidity of (0.092g/100g). Jackfruit jam indicated carbohydrate (57.85 %), protein (0.88%), crude fat (0.055%), ash (0.22%), moisture content (39.6%), crude fibre (1.4%), vitamin C (10.36 mg/100g), pH (4.33) and total acidity of (0.26 g/100g). Mineral contents were slightly higher in fresh jackfruit compared to the developed jackfruit jam. The information obtained from this study concluded that jackfruit (*A. heterophyllus*) has shown favourable sensory attributes that can be used for jam making and other processed products to add value to the fruit.

DECLARATION

I, Devotha Gabriel Mushumbusi do hereby declare to the Senate of the Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted in any other Institution.

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DEDICATION

This work is dedicated to my beloved mother, the late Mrs. Candida Mushumbusi who passed away on 24/07/2015 you will always be my source of inspiration mom, to my father Burchard G. Mushumbusi, my beloved son Ethan Mutasingwa and my brothers Mulokozi Mushumbusi, Mutashobya Mushumbusi and his wife Blandina and their son Azarias Mwombeki, my aunt Theresa, Mrs. Christina Rwakatare, Mr. and Mrs. Adolph Rwelamila, for their patience and support that enabled me to complete this study.

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LIST OF ABBREVIATIONS

AOAC	Association of Official Analytical Chemists
BIS	Bureau of Indian Standards
COSTECH	Commission for Science and Technology
DCIP	Dichlorophenol indophenols
FAD	Funds for Agricultural Development
G	Gram
GMP	Good Manufacturing Practices
ISO	International Organization for Standards
Kg	Kilogram
Mg/100g	Milligram per hundred grams
PCA	Principal Component Analysis
PLSR	Partial Least Square Regression
SIDO	Small Industries Development Organization
SUA	Sokoine University of Agriculture
TBS	Tanzania Bureau of Standards
WFP	World Food Program

CHAPTER ONE

1.0 INTRODUCTION

Jackfruit (*Artocarpus heterophyllus* Lam.) is the largest tree borne fruit in the world, reaching up to 50 kg in weight and 60-90 cm in length. It belongs to the family Moraceae, along with *Ficus* spp, *Morus* spp. (Mulberry) and *Maclurapomifera Schneid* (Osage orange or hedge apple) (Chandler, 1958; Popenoe, 1974). The fruit is borne on side branches and main branches of the tree. There are two main varieties of jackfruits: one is small, fibrous, soft, and mushy, and the carpels are sweet, with a texture like that of a raw oyster whereas the other variety is crisp and crunchy, but not very sweet. The large seeds from this non leguminous plant are also edible, even though they are difficult to digest (Siddappa, 1957). A single seed is enclosed in a white aril encircling a thin brown spermoderm, which covers the fleshy white cotyledon. Jackfruit cotyledons are fairly rich in starch and protein (Singh *et al*., 1991).

Jackfruit contains vitamin A, vitamin C, thiamin, riboflavin, calcium, potassium, iron, sodium, zinc, and niacin among many other nutrients. Jackfruit has a low caloric content where 100 g of jackfruit only contains 94 calories (Mukprasirt and Sajjaanantakul, 2004). The fruit is a rich source of potassium with 303 mg / 100 g of jackfruit. Studies show that food rich in potassium helps to lower blood pressure. Jackfruit is also a good source of vitamin C which is an antioxidant that protects the body against free radicals, strengthens the immune system, and keeps the gums healthy (Umesh *et al*., 2010). Pureed jackfruit can be processed into baby food, juice, jam, jelly, and base for cordials (Roy and Joshi, 1995). Furthermore, it can be used to make candies, fruit-rolls, marmalades, and ice cream. With malnutrition experienced in Tanzania, processing jackfruit into jam will help to make the nutrients that it provides available throughout the year. Jackfruit is also reach in pectin, thus making it favourable for processing into jam.

1.1 Problem Statement and Justification

Jackfruit has been reported to contain high levels of protein, starch, calcium, and thiamine (Brukill, 1997). The bulbs (excluding the seeds) are rich in sugar, fairly well in carotene and also contain vitamin C (Bhatia *et al.*, 1955). Presence of carotenoids can be important for the prevention of several chronic degenerative diseases, such as cancer, inflammation, cardiovascular disease, cataract and age-related macular degeneration (Krinsky *et al.*, 2003; Stahl and Sies, 2005). Despite all those merits, jackfruit has remained the most underutilized fruits in Tanzania and many other parts of Africa.

In Tanzania, jackfruit is locally grown in limited regions i.e. Zanzibar, Tanga and Morogoro and its availability is only in fresh form. However, the post-harvest loss of the fruit is high because of lack knowledge on how to preserve and use it during off – seasons. Furthermore, the fruit has been underutilized due to lack of knowledge on processing and hence consumed only as fresh fruit. Little has been done to process or add value of the jackfruit in Tanzania regardless of its wide potential use in nutrition and medicinal benefits to humans (Singh *et al*., 1991; Gunasena *et al*., 1996; Babitha *et al*., 2004). Only small amount of jackfruit are dried by very few Small and Medium Enterprises in Morogoro (example; KUMTAM A.B.C enterprises) is involved in the drying process of jackfruit fresh and sell the dried products to earn some money (Fufumbe, R. personal communication, 2015). Lots of processed products such as pickles, jelly, ice cream, nectar halwa from jackfruit have been developed in different countries such as Malaysia, Thailand and Bangladesh (Singh *et al*., 2001; Elevitch and Manner, 2006; Ukkuru and

Pandey, 2005; Krishnaveni *et al.,* 2000 and KAU, 1999). Country that already has jackfruit jam in their markets is Grandmas, India (Shree Padre, 2011).

This study aims at developing jackfruit jam and evaluate its acceptability by consumers. This will add knowledge on how to process and preserve jackfruit thus reducing post-harvest losses. By adding value to the product it will promote widespread utilization of jackfruit nutrients. Also, post-harvest processing will increase demand for jackfruit and consequently stimulate increased jackfruit production in the areas where it is grown and possibly introduced in the areas where there is potential. Thus, the increased intake of processed jackfruit products will contribute to the nutrition and health benefits of the Tanzanian people throughout the year. Those engaged in jackfruit business will also earn more income through employment and product selling. This will in turn contribute to improve household food security and livelihood.

1.2 Objectives

1.2.1 General objectives

The overall objective of this research was to develop and characterize a jackfruit based jam product.

1.2.2 Specific objectives

i. To develop jackfruit jam
ii. To determine physico-chemical (proximate composition, TSS, pH, Titrable acidity, vitamin C and minerals) qualities of fresh jackfruit and developed jam
iii. To evaluate sensory properties and consumer acceptability of the developed and commercial jam

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Originality and Distribution of Jackfruit

There is a controversy in the literature about the exact region of origin of jackfruit. Some authors believed that Malaysia could be the possible centre of origin (Ruehle, 1967), while Martin *et al*. (1987) reported that jackfruit is indigenous to tropical Asia. However, most authors believe that it originated in the rain forest of the Western Ghats of India (Purseglove, 1968; Popenoe, 1974; Rowe-Dutton, 1985; Singh, 1986; Morton, 1987; Soepadmo, 1992). Jackfruit is now widely grown in many Asian countries especially Bangladesh, Myanmar, Nepal, Sri Lanka, Thailand, Malaysia, Indonesia, India and the Philippines. It is also grown in Southern China and in the Indo- Chinese region in Laos, Cambodia and Vietnam (Morton, 1987; Narasimham, 1990; Gunasena *et al.,* 1996). Jackfruit is also found in East Africa (e.g. Uganda, Tanzania), Mauritius as well as throughout Brazil and Caribbean nations such as Jamaica.

2.2 Species of Jackfruit

Artocarpus heterophyllus Lam, belongs to the family Moraceae, along with *Ficus* spp. (Fig), *Morus*spp. (Mulberry) and *Maclurapomifera Schneid* (osage orange or hedge apple) (Chandler, 1958; Popenoe, 1974). This family encompasses about 1,000 species in 67 genera, mostly tropical shrubs and trees, but also a few vines and herbs (Bailey, 1949). Jackfruit (*A. heterophyllus*) is a congener of (i.e. member of the same genus as) breadfruit (*Artocarpus saltilis*) as well as a number of other culturally and economically important trees (e.g. *A. mariannensis*, *A. camansi*, *A. integer*, *A. lakoocha*, *A. odoratissima* and *A. lingnanensis*) (Elevitch and Manner, 2006).

2.3 Description of the Fruit

The jackfruit, the largest of all cultivated fruits, is oblong to cylindrical and typically 30 to 40 cm in length, although it can sometimes reach 90 cm. Jackfruits usually weigh 4.5 to 30 kg (commonly 9 to 18 kg), with a maximum reported weight of 50 kg. The heavy fruits are borne primarily on the trunk and on the interior parts of main branches. Jackfruit is a multiple aggregate fruit (i.e. it is formed by the fusion of multiple flowers in an inflorescence). It has a green to yellow-green exterior rind. The hard outer covering is derived from the enlarged female flowers. The whitish fibrous pulp within contains many seeds (as many as 500 per fruit). The acid to sweetish (when ripe) banana-flavored flesh (aril) surrounds each seed. The heavy fruit is held together by a central fibrous core. In the Northern Hemisphere, the fruiting season is mainly late spring to early fall (March to September), especially in summer. A few fruits mature in winter or early spring. (Little and Wadsworth, 1964; Seddon and Lennox, 1980; Vaughan and Geissler, 1997; Elevitch and Manner, 2006). In Tanzania the jackfruit normally matures from early September to end of March but the peak season is usually November.

2.4 Growth Requirement

The jackfruit is adapted to humid tropical and sub-tropical climates. It thrives from sea level to an altitude of 1,600 m. The species extends also into much drier and cooler climates than that of other *Artocarpus* species (Popenoe, 1974) such as breadfruit. Jackfruit can be grown in a wide range of climates from intermediate to wet and moist types in India and Sri Lanka. The tree bears good crops particularly between latitudes of up to 25º N and S of the equator, and up to 30º N and S (Soepadmo, 1992). Trees grown above 1,330 m grow poorly and the fruits if any are of poor quality. The quality is better at the lower elevation from 152-213 m (Crane *et al.*, 2003). For optimum production, jackfruit requires warm, humid, climates and evenly distributed rainfall of at least 1,500 mm (Baltazar, 1984; Concepcion, 1990). Growth will be retarded if rainfall is less than 1,000 mm. Jackfruit trees are not tolerant to continuously wet and/or flooded soil conditions and the trees may decline or die after 2-3 days of wet soil conditions. For the production of jackfruit the annual rainfall should be 1,000-2,400 mm or more.

2.5 Nutrition Composition of Jackfruit

Jackfruit contains vitamin A, vitamin C, thiamin, riboflavin, calcium, potassium, iron, sodium, zinc, and niacin among many other nutrients. Jackfruit has a low caloric content: 100 g of jackfruit only contains 94 calories (Mukprasirt and Sajjaanantakul, 2004). Jackfruit is a rich source of potassium with 303 mg found in 100g of jackfruit. Studies show that food rich in potassium helps to lower blood pressure. It is also rich in energy, dietary fiber which makes it a good bulk laxative. Jackfruit seeds are a good source of starch (22%) and dietary fiber (3.19%) (Hettiarachchi *et al*., 2011). Jackfruit seed contains lignans, isoflavones, saponins, all phytonutrients and their healthy benefits are wide-ranging from anticancer to anti hypertensive, anti aging, antioxidant, antiulcer, and so on (Omale and Friday, 2010).

2.6 Nutrition Benefit of Jackfruit

Jackfruit contains phytonutrients: lignans, isoflavones, and saponins that have health benefits that are wide ranging. These phytonutrients have anticancer, antihypertensive, antiulcer and anti-aging properties. The phytonutrients found in jackfruit, therefore, can prevent formation of cancer cells in the body, can lower blood pressure, can fight against stomach ulcers, and can slow down the degeneration of cells that make the skin look young and vitae. Jackfruit also contains niacin that is known as vitamin B3 and necessary for energy metabolism, nerve function, and the synthesis of certain hormones.

A portion of 100 g of jackfruit pulp provides 4 mg niacin (Soobrattee *et al*., 2005). The recommended daily amount for niacin is 16 mg for males and 14 mg for females (Institute of Medicine, 2000). The jackfruit contains many carotenoids (De Faria *et al*., 2009) including all-trans-*β*-carotene which is important antioxidant for human health (Cadenas and Packer, 1996). Jackfruit containing carotenoids can be important for the prevention of several chronic degenerative diseases, such as cancer, inflammation, cardiovascular disease, cataract, age-related macular degeneration (Krinsky *et al*., 2003; Stahl and Sies, 2005). It is also rich in energy, dietary fiber which makes it a good bulk laxative. The fiber content helps to protect the colon mucous membrane by decreasing exposure time and as well as binding to cancer causing chemicals in the colon (Morton, 1987) as well as mineral and vitamins. In addition, it is one of the rare fruit that is rich in B-complex group of vitamins. It contains very good amounts of vitamin B-6 (pyridoxine), niacin, riboflavin, and folic acid. The pulp and seeds of jackfruit are considered as a cooling and nutritious tonic.

2.7 Medicinal and Functional Properties of Jackfruit

The presence of high fiber content (3.6 g/100 g) in the jackfruit prevents constipation and produces smooth bowel movements. It also offers protection to the colon mucous membrane by removing carcinogenic chemicals from the large intestine (colon) (Siddappa, 1957). Jackfruit is rich in magnesium (27 mg/100 g in young fruit and 54 mg/100 g in seed) (Gunasena *et al.,* 1996). It is a nutrient important in the absorption of calcium and works with calcium to help strengthen the bones and prevents bone-related disorders such as osteoporosis (Singh *et al*., 1991).

Jackfruit also contains iron (0.5 mg/100 g), which helps to prevent anemia and also helps in proper blood circulation (Singh *et al.,* 1991). Copper (10.45 mg/kg) plays an important role in thyroid gland metabolism, especially in hormone production and absorption and jackfruit is loaded with these important micro minerals (Gunasena *et al*., 1996). The benefit of eating jackfruit is that it is a good source of vitamin C. The human body does not make vitamin C naturally it must be eaten in food that contains vitamin C to reap its healthy benefits. Jackfruit is gluten-free and casein-free, thus offer systemic anti-inflammatory benefits to skin. Jackfruit also contains antioxidants and has vitamin C, flavonoids, potassium, magnesium and fiber. Vitamin C is vital to the production of collagen, a protein that provides skin with structure and gives it its firmness and strength (Babitha *et al*., 2004).

Potassium in the jackfruit is found to help in lowering blood pressure and reversing the effects of sodium that causes a rise in blood pressure, which affects the heart and blood vessels. This helps in preventing heart disease and stroke. Potassium also helps in preventing bone loss and improves muscle and nerve function. Another heart-friendly property found in the jackfruit is due to vitamin B6 that helps reduce homocysteine levels in the blood thus lowering the risk of heart disease (Fernando *et al*., 1991). Jackfruit seed powder contains manganese and magnesium elements (Barua and Boruah, 2004). Seeds also contain two lectins namely jacalin and artocarpin. Jacalin has been proved to be useful for the evaluation of the immune status of patients infected with human immunodeficiency virus 1 (Haq, 2006).

Table 1: The use of jackfruit in local medicine

No.	Plant part	Use
1	Roots	An extract of roots is used in treating skin diseases, asthma and diarrhea.
2	Leaves	An extract from leaves and latex cures asthma, prevents ringworm infestation and heals cracking of feet. Leaf extract is given to diabetics as a control measure. Heated leaves are reported to cure wounds, abscesses and ear problems and to relieve pain. An infusion of mature leaves and bark is used to treat gallstones. A tea made with dried and powdered leaves is taken to relieve asthma. The ash of jackfruit leaves burned with maize and coconut shells is used alone or mixed with coconut oil to heal ulcers.
3	Flowers	Crushed inflorescences are used to stop bleeding in open wounds.
4	Fruits	Ripe fruits are laxative.
5	Pulp	The jackfruit pulp and seeds are nutritious tonic and useful in overcoming the influence of alcohol on the system.
6	Seed	The seed starch is given to relieve biliousness. Roasted seeds are regarded as an aphrodisiac. Increased consumption of ripe jackfruit kernels alleviates vitamin A deficiency. Extract from fresh seeds cures diarrhea and dysentery. Extract from seeds (or bark) helps digestion.
7	Bark	An extract from bark and rags (non edible portion of ripe fruits) or roots helps cure dysentery. The bark is made into poultices. Ash produced by burning bark can cure abscesses and ear problems.
8	Latex	Mixed with vinegar, the latex promotes healing of abscesses, snakebites and glandular swellings.
9	Wood	The wood has a sedative property; its pith is said to aid abortion

Source: Haq (2006).

2.8 Other Uses of Jackfruit

The fruit provides about 2 MJ of energy per kg /wet weight of ripe perianth (Ahmed *et al*., 1986). The unripe fruits are used in vegetable curries and pickles (Prakash *et al.,* 2009). The ripe fruits are used to make ice cream, squash, drinks, halwa, jam, and jelly. The pulp is desiccated and used as dried fruit during off season. Fruit can also be used to prepare alcoholic liquor (Elevitch and Manner, 2006).

Figure 1: Preserved jackfruit in sugar syrup

Source: APAARI (2012)

Figure 2: Jackfruit beverages

Source: APAARI (2012)

Jackfruit has been reported to contain high levels of protein, starch, calcium, and thiamine (Burkill, 1997). The seeds may be boiled or roasted and eaten or boiled and preserved in syrup like chestnuts. Roasted, dried seeds are ground to make flour that is blended with wheat flour for baking (Morton, 1987). In addition to unique flavor of the ripe fruit, the jackfruit seed is widely consumed as a dessert or an ingredient in Asian culinary preparations. The jackfruit seeds are used in cooked dishes and its flour is used for baking. Jackfruit seeds are fairly rich in starch (Singh *et al*., 1991). Mature jackfruits are cooked as vegetables and used in curries or salads (Narasimham, 1990). Ripe fruits can be eaten raw, or cooked in creamy coconut milk as dessert, made into candied jackfruit or edible jackfruit leather. Pureed jackfruit is also manufactured into baby food, juice, jam, jelly, and base for cordials. In India, the seeds are boiled in sugar and eaten as dessert (Roy and Joshi, 1995).

Figure 3: Preserved jackfruit bulbs under vacuum
Source: APAARI (2012)

Figure 4: Jackfruit toffee
Source: APAARI (2012)

Jackfruit is also processed into other products. For instance, jackfruit leather and jackfruit chips can be made from dried jackfruit pulp (Nakasone and Paull, 1998). Jackfruits are made into candies, fruit-rolls, marmalades, and ice cream. Other than canning, advances in processing technologies too, have pushed toward more new products (Narasimham, 1990). Freeze-dried, vacuum-fried, and cryogenic processing are new preservation methods for modern jackfruit-based products.

Various parts of the jackfruit tree have been used in medicine and its wood as an important source in the timber industries (Roy and Joshi, 1995). Jackfruit is an important tree in home gardens in India, the Philippines, Thailand, Sri Lanka, and other regions where Jackfruit is grown commercially and is perhaps the most widespread and economically important *Artocarpus* species, both providing fruit and functioning as a visual screen and ornamental. The wood of jackfruit, which ages to an orange or red-brown color, is highly durable, resisting termites and decay (Elevitch and Manner, 2006). A yellow dye is sometimes extracted from the wood and used for dyeing clothes, especially in India and the Far East (Seddon and Lennox, 1980).

Rinds and other waste parts of the fruits have high value as a nourishing feed for livestock, especially for sheep (Sudiyani *et al.,* 2002). The leaves are not eaten by humans but are used as food wrappers in cooking and fastened together to make plates in many parts of the Indian subcontinent. However, young leaves are. readily eaten by cattle and other livestock. Sole feeding of jackfruit tree leaves can meet the maintenance requirements of a goat, similar results have been reported from the evaluation of digestibility of leaves for pigs (Ly *et al.,* 2001). Jackfruit leaves are good sources of calcium (Ca) and sodium (Na) and if combined with rice bran give better growth for ruminants.

2.9 Jackfruit Jam

Jam is an intermediate moisture food prepared by boiling fruit pulp with sugar (sucrose), pectin, acid, and other ingredients (preservative, coloring, and flavoring materials) to a reasonably thick consistency, firm enough to hold the fruit tissues in position (Baker *et al*., 2005; Lal *et al*., 1998). Jam is a mixture brought to a suitable gelled consistency of sugars, the pulp and/ or purée of one or more kinds of fruit and water (www.agriculture.gov.ie). Generally, jam is produced by taking mashed or chopped fruit or vegetable pulp and boiling it with sugar and water. The proportion of sugar and fruit varies according to the type of fruit and its ripeness, but a rough starting point is equal weights of each. When the mixture reaches a temperature of 104 °C, the acid and the pectin in the fruit react with the sugar, and the jam will set on cooling (Berolzheimer *et al*., 1959).

The jackfruit pulp can be used to make jam. The addition of a synthetic flavoring agent such as ethyl or n-butyl ester of 4-hydroxybutyric acid at 100 and 120 ppm, respectively, will greatly improve the taste of the jackfruit products (ICUC, 2004). Other fruit jams in supermarkets are mixed with a generous amount of sugar, which increases the risk for diabetes. On the contrary, jackfruit jam is full of natural sugars and low in calories making it an ideal food source to reduce body weight.

2.10 Existing Jackfruit Jam

Outside of its countries of origin, fresh jackfruit can be found at Asian food markets, especially in the Philippines, Thailand, Vietnam, Malaysia, Cambodia, and Bangladesh. Many of these countries process jackfruit into jam in a traditional way, but Kerara, Vietnam and Sri lanka have started small industries for processing jackfruit. In Kerala, India two varieties of jackfruit predominate and koozha .Varikka has a slightly hard inner flesh when ripe, while the inner flesh of the ripe koozha fruit is very soft and almost dissolving. A sweet preparation called chakka varattiyathu (jackfruit jam) is made by seasoning pieces of varikka fruit flesh in jaggery, which can be preserved and used for many months (www.enwikipedia.org). Also the Grandmas food company in Kerara, India produces jackfruit jam as one of its products (www.tradeindia.com). In Vietnam they produce different jackfruit products including jackfruit and pineapple fruit of 225g (naturallyvietnam.com). Advances in jackfruit jam development have been seen in quiet a few numbers of scientific publications. Eke- Ejiofor and Owuno (2013) did a study on the Physico-chemical and sensory properties of jackfruit (*Artocarpus heterophyllus*) jam and concluded that the developed jam had high total acidity this shows it can be stored for a long period. With its high nutrients composition and sensory attributes it can successfully be used for jam preparation. Also, (Ihediohanma *et al.*, 2014) evaluated the sensory quality of jam produced from jackfruit. He concluded that jackfruit is promising industrial source of pectin which can be successfully applied in food gel systems and the lower pH create preserved and stable jam which is less prone to microbial spoilage. Furthermore, production of pectin using jack fruit should be encouraged and use of jam produced from jack fruit could be an innovation.

2.11 Requirements for Jam Making

Factors that have an influence on quality of jam consist of color content, taste, flavor, and texture and nutritional value. All the parameters mentioned are affected from the nature of the raw material and the processing conditions. For manufacture of traditional jam fruit, sugar, pectin and organic acids such as citric acid are used. In traditional products a high content of soluble solids is desired in order that the products shelf life increases and it can be stored and transported in ambient temperatures. The high content of soluble solids is achieved by adding sugar to around 55%. The quality of the raw material and the manufacturing process are the indicators of the final products quality (Nindo *et al*., 2005). Citric acid is considered necessary to correct the balance which is needed in jam production. Lime and lemon juice are high in citric acid therefore they can be used as a replacement of citric acid in jam manufacture (Cancela *et al*., 2005). The added sugar acts as a dehydrating agent for the pectin molecules, permitting closer contact between the chain molecules (Suutarinen, 2002). Pectin is also the most important in the food industry as a thickening agent because it brings changes in the texture or flow behavior of the final product (Endress *et al*., 2005).

According to Bureau of Indian Standards (BIS) and Prevention of Food Adulteration (PFA) specifications, jam should contain more than 68.5% total soluble solids (TSS) and at least 45% fruit (PFA, 2004). Whereas, the Codex Alimentarius Commission (Standard 79, 1981) specify that the finished jam should contain more than 65% TSS. Good jam has a soft even consistency without distinct pieces of fruit, a bright colour, good flavour and a semi-jelled texture that is easy to spread but has no free liquid (Isabel and William, 1990). Product quality is the major determinant of consumer choice. The ingredients affect the jam quality in terms of both subjective (sensory) and objective (textural and rheological) attributes. Product quality is one of the prime factors in ensuring good final processed jackfruit products. It is known that quality is a combination of various parameters such as colour, appearance, shape, size, texture and taste. Therefore jackfruit should be well ripened, free from defects example sunburn, cracks bruises and decay in order to get suitable jam product (Sallel *et al*., 2000).

2.12 Product Development technologies/concept

The new product development literature emphasizes the importance of introducing new products in the market for continuing business success. Its contribution to the growth of the companies, its influence on profit performance and its role as a key factor in business planning have been well documented (Urban and Hauser, 1993; Cooper, 2001; Ulrich and Eppinger, 2011). New products are responsible for employment, economic growth, technological progress, and high standards of living. In the last few decades, the number of new product introductions increased dramatically as the industry became more aware of the importance of new products to business. For every seven new product ideas, about four enter development stage, one and a half are launched, and only one succeeds (Booz *et al*., 1982). As the number of dollars invested in NPD goes up, the pressure to maximize the return on those investments also goes up.

The product development process consists of the activities carried out by firms when developing and launching new products. A new product that is introduced in the market evolves over a sequence of stages, beginning with an initial product concept or idea that is evaluated, developed, tested and launched on the market (Booz *et al*., 1982). This sequence of activities can be viewed as a series of information gathering and evaluation stages. In effect, as the new product evolves, management becomes increasingly more knowledgeable (or less uncertain) about the product and can assess and reassess its initial decision to undertake development or launch. The product development process differs from industry to industry and from firm to firm. Indeed it should be adapted to each firm in order to meet specific company resources and needs.

Many have tried to develop a model that captures the relevant stages of the NPD process (Ulrich and Eppinger, 2011; Cooper, 2001). A number of detailed models have been developed over the years, the best known of which is the Booz *et al*. (1982) model, shown in Figure 5. It is based on extensive surveys, in depth interviews, and case studies and appears to be a fairly good representation of prevailing practices in industry.

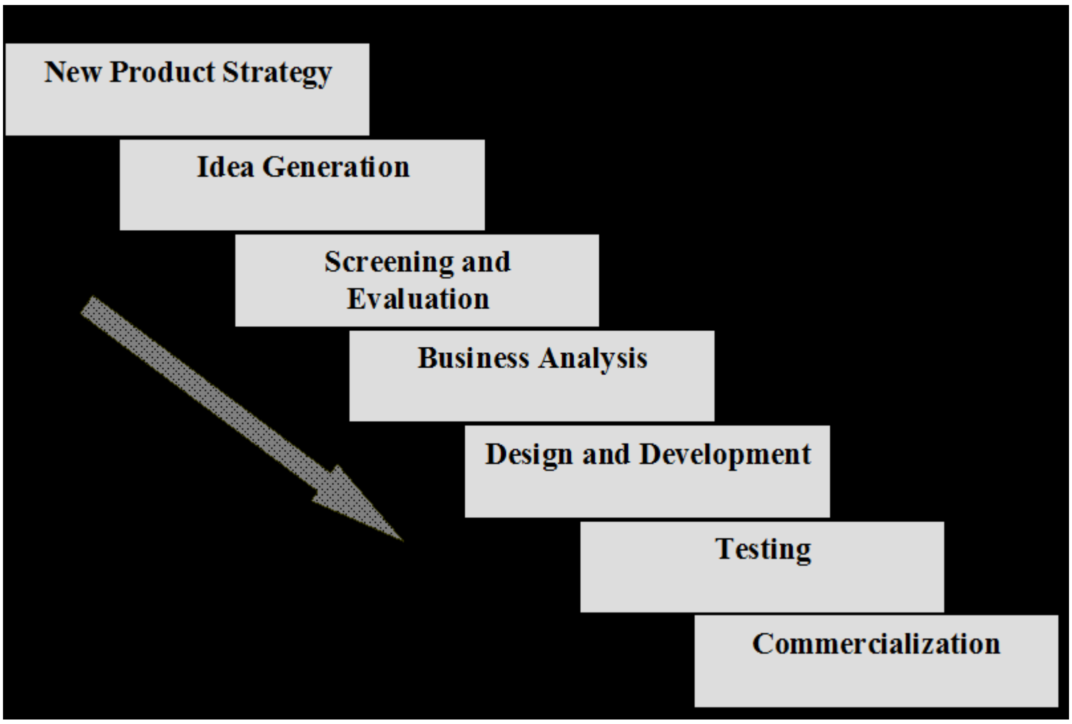

Figure 5: Stages of new product development (Booz *et al*., 1982)

The stages of product development model are as follows:

i. New Product Strategy- links the NPD process to company objectives and provides focus for idea/concept generation and guidelines for establishing screening criteria,
ii. Idea generation- searches for product ideas that meet company objectives,
iii. Screening- Comprises of an initial analysis to determine which ideas are pertinent and merit more detailed study,
iv. Business analysis- Further evaluates the ideas on the basis of quantitative factors, such as profits, Return-on-investment and sales volume,
v. Development- Turns an idea on paper into a product that is demonstrable and producible,
vi. Testing- Conducts commercial experiments necessary to verify earlier business judgments and
vii. Commercialization- Launching of products (Bhuiyan, 2011).

2.13 Method of Statistical Analysis

2.13.1 Principal component analysis

Is a multivariate technique that simplifies and describes interrelationships among multiple dependent variables (in sensory data these are usually the descriptors) and among objects (in sensory data these are usually the products) (Anderson, 2003; Tabachnik and Fidell, 2006). PCA normally performs on the mean data for products averaged across panelists and replications. PCA transforms the original dependent variables into new uncorrelated dimensions, and this simplifies the data structure and helps one to interpret the data (Johnson and Wichern, 2007). The product of PCA is frequently a graphical representation of the interrelationships among variables and objects. The technique is useful when several dependent variables are correlated with one another, a situation that often occurs with sensory descriptive data. From the ANOVA, one may find that many descriptors significantly discriminate among the samples; however, several descriptors may be describing the same characteristic of the product. The technique of PCA has a long history in sensory and consumer research. The input to PCA usually consist of attributes ratings describing a set of products and often the mean rating are used as input, although in some cases raw data from individuals are used (Kohli and Leuthesser, 1993). Given that many attributes have been evaluated, some will be correlated. A product that receives a high value on one attribute will receive a high value on a positively correlated attribute. The PCA finds these patterns of correlation and substitutes a new variable, called a factor, for the group of original attributes that were correlated. PCA can be applied to any data set where there are attributes ratings for a set of products as in descriptive analysis.

Principal components are obtained through a linear combination of the dependent variables that maximizes the variance within the sample set. The first principal component (PC) accounts for the maximum possible amount of variance among the samples. Subsequent PCs account for successively smaller amounts of the total variance in the data set and are uncorrelated with (orthogonal to or at 90^0 angles to) prior PCs.

Score plots, loading plots, score and loadings (bi-plots) and correlation loadings plots are commonly used in PCA to present the result. Score plots is a plot of the relation between the objects in the projected space and it is useful for detecting groups in the data or doubtful observations. Samples which are close to each other have similar overall properties and samples which are far apart are very different (Mongi, 2015). Loading plots is a pair of loading vectors and it shows the relation between the original variables and the principal components. Variables with a large loading value will show up far away from the origin in the plot and those with a small loading will fall close to the origin.

2.13.2 Physical

According to Tanzania standards (2013) jam can be prepared from fruit which is substantially sound, wholesome, of suitable ripeness and clean, not deprived of any of its main constituents, except that it is trimmed, sorted and otherwise treated to remove objectionable bruises, stems, toppings tailing, cores, pits stone fruits and may or may not be peeled. Also, the end products shall be of a suitable consistency, properly set, and shall possess colour and flavour normal for the type or kind of fruit ingredients, and shall be reasonably free from defective materials normally associated with the fruits. Jams shall be packed in suitable containers which shall have no action on the products. The containers shall be well filled with the product.

The food additives may be added to jams and shall be added to the product in accordance with the recommended Good Manufacturing Practices (GMP):

Table 2: Food additives

Additives	Maximum level in the end product
Citric acid	In sufficient amount to maintain the pH at a level of 2.8 -3.5.
L. tartaric acid	In sufficient amount to maintain the pH at a level of 2.8 -3.5.
Pectin	Limited by GMP
Preservatives: Benzoic acid	1g/kg

Source: TBS (2013)

Metal contents-Jams shall not contain any metal contaminants in excess of the quantities specified in Table 3.

Table 3: Limit for metal contaminants in jams

Characteristics	Requirement	Method of test
Arsenic (as As)	0.5	TZS 1502:2012
Tin (as Sn)	250	TZS 1492:2012
Copper (as Cu)	10	TZS 1495:2012
Zinc (as Zn)	50	TZS 1500:2012
Lead (as Pb)	1.0	TZS 268:1986

Source: TBS (2013)

2.13.3 Chemical

When tested according to the method prescribed in TZS 1496:2012, the total soluble solids in jams shall be not less than 65 % mass by mass. The acidity of finished jam normally varies between 0.5 to 1%. Jam are usually produced at pH of 3.3, because gelation depends on proper balance of soluble solids and pH in the medium (Joshi and Verma, 2000).

2.13.4 Microbiological

According to Indian standards, when jam is tested by the method prescribed in 18 of IS 2860:1964 the product shall be (a) free from microorganisms capable of development under normal conditions of storage, (b) shall not contain substances originating from microorganisms which may represent a hazard to health. The product shall not contain any mould filaments when tested in accordance with the method (Howard moulds counting slide).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was conducted at Sokoine University of Agriculture (SUA). Product development and laboratory analysis was done at the Department of Food Science and Technology laboratory.

3.2 Materials

Three fresh ripe jackfruits (*Artocarpus heterophyllus Lam*) were purchased from Mawenzi market in Morogoro Municipality. Sugar, lemons, plastic basin, muslim cloth and sieves were all purchased from Morogoro market. Jam bottles were purchased from Small Industries Development Organization. Analytical food grade reagents and chemicals were obtained from Food Science and Soil Science laboratories at SUA. And commercial mango jam was purchased from local food shop.

3.3 Methods

3.3.1 Research design

A purposive sampling procedure was used to collect a fresh ripen jackfruit from Morogoro Municipal market in order to obtain fruits with better quality. A total of 3 jackfruits were collected and processed into jam and the remaining fresh sample was kept for further analysis. Also commercial mango jam bottles were picked randomly at the food store. Complete Randomized design (CRD) was used in this study. And the principal factor was jam type (mango, jackfruit). Mathematical expression is shown in equation 1.

$$Y_{ij} = \mu + t_i + e_{ij} \quad \text{……………………………………} (1)$$

Where Yij is observation for i^{th} treatment appearing in j^{th} row and k^{th} column, μ is a general mean effect, ti is the effect of i^{th} treatment appearing in j^{th} row and k^{th} column and eij is error term. The effect of these factors on proximate, vitamin C, mineral contents and sensory properties were determined.

3.3.2 Jam production

Fresh ripe jackfruits were washed thoroughly with tap water to remove all the dirty. Then they were cut diagonally and fresh bulbs were separated from seeds and other unwanted materials. The bulbs weighed about 7.8 kg were mixed with 7 litres of water and boiled for about 10 minutes to soften the mixture for easy homogenization. After boiling the mixture was blended with fruit grinder (Kenwood, ellipsis 550w) and later sieved with a 2mm mesh sieve and the resulting jackfruit fruit pulp was weighed to 13 kg. Then 7 kg of sugar and 670mls of lemon juice together were added to the pulp whereby the lemon juice was used to add acid in order to lower pH and increase pectin in jam. The following formula was used to determine the amount of sugar to be added to the fruit pulp to meet the jam requirement:

$$\text{Sugar to be added} = \frac{\text{TSS (final)} - \text{TSS (pulp)}}{100} \times W \qquad (2)$$

Where TSS (final) - is required sugar level of the jam which is 69%; TSS (pulp) - sugar level of the pulp and W- weight of the pulp used (in grams). The juice mixture was boiled on a gas cooker until the brix reached 69^0. The hot jam was then poured into sterilized bottles and covered with a lid and left to cool at room temperature (Molla *et al.*, 2011).

Select the fully ripe jackfruit

↓

Wash with clean water

↓

Lengthwise cut the fruit into half

↓

Take bulb and remove seeds

↓

Blend the bulb with water and boil for 10 minutes and extract juice

↓

Add 7kg sugar and 670ml lemon juice into 13kg juice

↓

Cook until the TSS reach to 69 °Brix

↓

Determine end point through flake test

↓

Sterilize bottle and pour into bottle and then close with lid

↓

Label and store in room temperature (28-32 ºC)

Figure 6: Flow diagram for jam manufacture (Modified from Molla *et al.,* 2011)

3.3.3 Chemical analysis

The proximate analysis (moisture, ash, fat, crude fiber, crude protein) minerals of the fresh jackfruit and jam were analyzed according to standard AOAC (1995) and for vitamin C according to AOAC (2000). Moisture content was determined by method number 925.09, ash content by method number 923.03, crude fibre by method number 920.86, crude protein by macro kjeldah method number 920.87 and Carbohydrate content was calculated as percentage difference. Total soluble solids (Brix %) was determined using a hand refractometer- Mettler Toledo model LXC59107 Japan, pH was determined using a digital pH meter model – pH 010 (ATC), Total titratable acidity (TTA) was determined by the AOAC (1995) method. The samples were analyzed in duplicate for crude protein, crude fiber, crude fat, moisture, and ash contents. The average values of the two measurements were obtained.

3.3.3.1 Determination of crude protein

Crude protein content of fresh and jackfruit jam were determined by macro kjeldah method number 920.87. About 1gm portion of the samples was weighed onto a tarred filter paper. The samples were wrapped securely and dropped into a 100ml Kjeldahl digestion tube. A blank was prepared by dropping a piece of filter paper without sample into a separate 100 ml digestion tube. To each tube, 2 g of Kjeldahl catalyst and 5.0 ml of concentrated sulphuric acid was added. Samples were digested until a clear, blue solution was obtained and digestion continued further to allow the nitrogen held in the heterocyclic ring to be released. The digest was cooled and then 20 ml of distilled water was added to dissolve the content. The dilute digest was distilled using macro-distillation apparatus (Kjeltec^{TM}8200 Auto Distillation Unit, 2012). 50 ml of 40% sodium hydroxide was added to the digest to facilitate the release of ammonia. Ammonia was extracted by steam distillation and collected in a 50 ml flask containing 4% boric acid. The distillate was titrated with 0.1520N HCl standard solution using bromocresol green methyl red mixture as an indicator. Nitrogen content was calculated using the formula shown in equation 3

$$\% \text{ Nitrogen} = \frac{\text{(Titre blank) in ml} \times \text{conc. of acid N/mol}}{\text{Weight of samples (g)}} \times 100 \ldots\ldots\ldots\ldots (3)$$

Percentage protein was calculated from the percentage nitrogen using the factor 6.25 for plant materials as shown in equation 4

% CP= % N x Factor (6.25) ………………………………………………… (4)

3.3.3.2 Determination of moisture content

Moisture content of fresh and jackfruit jam was determined by method number 925.09 as described by AOAC (1995). The crucibles were washed and dried in an oven at 105^0C for three hours and cooled in desiccators. Then crucibles were weighed. About 2 g of the sample was weighed in the crucible. The sample was spread in the crucible and subjected into drying in an oven (Wagtech model -H.O.V.200CIAO300HYO, Britain) at 105^0C for approximately 48 hrs. After drying, the crucibles were transferred to the desiccators for cooling. The crucibles were reweighed after cooling. The percentage moisture content was then calculated with the formula shown in equation 5.

Calculation:

$$\% \text{ moisture content} = \frac{(W_1 - W_2)}{W_1} \times 100 \quad \text{……} (5)$$

Whereby;

W_1 is weight of sample (gm) before drying and W_2 is weight of sample (gm) after drying

3.3.3.3 Determination of dietary fiber

Dietary fiber of fresh and jackfruit jam were determined by method number 920.86. About one gram of each samples were taken for crude fibre determination with Fibertec^{TM}1020 FOSS model 2012. The samples were first digested by dilute sulphuric acid (0.125M) for 30 minutes and washed three times with hot water. The residue was then digested by dilute alkali (0.125M KOH) for another 30 minutes and then washed by hot water three times. Digested residue was dried in an oven for 5 hours then cooled and weighed. The residue was then placed in muffle furnace – (Carbolite, Aston Lane, Hope, Sheffied, S30

2RR, England) and incinerated for 2 hours temp 525^{0}C, then cooled and weighed again. Total fibre content was calculated by using the formula shown in equation 6:

$$\% \text{ crude fibre} = \frac{W_1 (g) - W_2 (g) \times 100}{W (g)} \qquad (6)$$

Where :

W_1 is weight of sample residue before incineration (g), W_2 is weight of sample residue after incineration (g) and W is weight of dry sample taken for determination (g)

3.3.3.4 Determination of crude fat

Crude fat of fresh and jackfruit jam were determined by ether extraction using the Soxtec System (Soxtec^{TM} 2055 FOSS model 2012) AOAC (1995) method number 920.65 was used. The method involved extracting crude fat from the samples into petroleum spirit (40-60^{o}C), which was then evaporated, and the weight of the crude fat was determined. About 6 grams of pre-dried samples were weighed and placed into extraction thimble. The thimbles were covered with fat free cotton and placed in the central part of the Soxtec apparatus. 60 ml of petroleum ether were poured into the pre-dried and pre-weighed cups and adjusted to the Soxtec extractor where extraction process took place for approximately one hour. After extraction, the cups with fat extract were further dried in the oven at 105^{o}C for 30minutes, and then cooled in desiccators for 30 minutes and the weighed. Percentage crude fat content was calculated using equation 7

$$\% \text{ Crude fat} = \frac{\text{Weight of crude fat (g)} \times 100}{\text{Weight of dry samples (g)}} \qquad (7)$$

3.3.3.5 Determination of ash content

The ash content of fresh and jackfruit jam samples was determined by using a muffle furnace (Carbolite, Aston Lane, Hope, Sheffied, S30 2RR, England) as described in standard method (AOAC, 1995), official method 923.03. About 5 grams of each sample in duplicate were placed in a pre-weighed crucible and dried in an oven at 105^{0}C for about approximately 48 hours. The dried samples were weighed and then placed in muffle furnace at 550^{o} C for 3 hours until white or grey ash was obtained. The samples were then cooled in desiccators to room temperature and weighed. Percentage ash was calculated using equation 8.

$$\% \text{ Ash} = \frac{\text{weight of ash (g)} \times 100}{\text{Weight of sample (g)}} \quad \ldots\ldots (8)$$

3.3.3.6 Determination of carbohydrate

Carbohydrate content of fresh and jackfruit jam was calculated as percentage by difference (AOAC, 1995). The following formula is depicted in equation 9.

$$\% \text{ Carbohydrate} = 100 - (\% \text{ Moisture} + \% \text{ Protein} + \% \text{ Crude fibre} + \% \text{ Crude fat} + \% \text{ Ash content}). \quad \ldots\ldots (9)$$

3.3.3.7 Determination of minerals content

Mineral content of fresh jackfruit and jam were determined by the use of Unicam 919 Atomic Absorption Spectrophotometer U.K method described in AOAC (1995), Official Method number. 968.08. Test portions were dried and then ashed at 450^{0}C under a gradual increase (about 50^{0}C/hr) in temperature. The obtained ash from ash determinations were used for analysis of minerals according to the AOAC (1995) procedures. The ash was dissolved in 20 ml of 1N HCl and heated for 5minutes at 70^{o}C.The solute was then transferred quantitatively to a 100 ml volumetric flask and made up to volume with distilled water. Mineral content (Calcium, sodium, iron, zinc, and potassium) were determined by Atomic Absorption Spectrophotometer method as described in Method number 968.08. It was done at the department of soil science, laboratory at SUA. The absorbance of sample and standard solutions was determined. The standard curve plot of absorbance against the known concentration of standard solutions was used to determine the concentration of minerals in samples and expressed as shown in equation 10.

$$\text{Mineral content mg/100g} = \frac{R \times \text{Extract vol. (L)} \times D.F}{S\ (Kg)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (10)$$

Where,

R is mineral concentration in ppm (mg/Kg) as calculated using linear regression equation, D.F is Dilution Factor and S is sample weight (Kg)

3.3.3.8 Determination of vitamin C

Vitamin C for fresh jackfruit bulb and jackfruit jam was determined by 2, 6-Dichlorophenol indophenols (DCIP) sodium salt method (AOAC, 2000 method 967.21). Under this method, titration was performed in the presence of phosphoric acid/acetic acid solution to maintain proper acidity (pH 1 - 3) for titration and to inhibit oxidation of the acid whereby 5g of grinded jackfruit sample as well as jam sample were taken into 250ml erlenmeyer flask. 50ml of Orthophosphoric acid were added to extract, to lower pH as well as to deproteinize the sample. The extracted samples were then filtered and titrated against standardized Dichlorophenol indophenols until pink color which is the end point of the reduction process was observed. The volume of Dichlorophenol indophenols used was recorded and vitamin C content in samples was calculated according to equation 11.

$$\text{Mg of ascorbic acid} = (X-B) \times (F/E) \times (V/Y) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (11)$$

Where:

X is titre value, B is blank, F is mg of ascorbic acid equivalent to 1.0ml indophenols, E is number of ml assayed, V is initial assay solution volume and Y is volume of sample aliquot titrated.

3.3.3.9 Determination of total titrable acidity

Acidity, expressed as total titratable acidity (TTA) was determined according to AOAC (1995) method 942.15 and 920. 49 standard methods by titrating 5 ml of the jackfruit pulp and jam diluted to 250 ml of boiled water against 0.1 M NaOH standard solution using 0.3

ml phenolphthalein indicator for each 100ml of solution to pink end point persisting for 30 seconds (AOAC, 2000). Reported acidity as ml 0.1N NaOH per 100 ml was calculated as shown in equation 12.

$$\text{Total titrable acidity g/100g} = \frac{\text{Titre volume x N x 100}}{\text{Sample weight}} \quad (12)$$

Where N is Normality of the Alkali used

3.3.4 Sensory evaluation

3.3.4.1 Consumer study

Developed and control jam samples were subjected to sensory evaluation using a 7 point hedonic scale ranging from dislike very much to like very much. Seventy one consumer panelist members were selected randomly within SUA University to perform consumer test where commercial mango jam was used as a control. All evaluation sessions were held in the laboratory of Food Science at Sokoine University of Agriculture. All samples were presented before the panelists at room temperature under normal lighting conditions in white disposable plastic cups and coded with three-digit numbers. Spoons were provided to the panelists and drinking water was provided for oral rinsing. The samples attributes assed were color, taste, texture, taste, aroma, spreadibility and overall acceptability.

3.3.4.2 Qualitative descriptive analysis

Also, a quantitative descriptive analysis test was carried out to assess the performance of panel members. A descriptive sensory profiling was conducted at the Department of Food Science and Technology by trained sensory panel of 9 assessors, comp of 7 male and 2 female with age ranging from 22 to 28 years according to method described in Lawless and Heyman (2003). The assessors were selected and trained according to ISO 8586 (1993). In a pre-testing session the assessors were trained in developing sensory descriptors and the definition of the sensory attributes .The assessors developed a test vocabulary describing differences between samples and they agreed upon to a total number of attributes on whiteness, colour (Hue), aroma and sweetness. Nine point structure line scale was used and nine (9) panelists were asked to rate for intensity of an attributes as described by Lawless and Heyman (2010). The left side of the scale corresponded to the lowest intensity of each attribute (value1) and the right side corresponded to the highest intensity (value 9) (Appendix 2) 2 jam samples were carried out in two sessions and each assessor evaluated 2 samples (jam) for the first session, 2 samples for the second samples (jam). The samples were coded with 3-digit random numbers that were served to each panelist in a randomized order and instructed to rate the whiteness, colour hue, aroma and sweetness attributes. Portable water was served alongside the samples for rinsing the mouth before evaluating another sample during the test. Thus the average responses were used in the univariate and multivariate analyses.

3.3.5 Statistical analysis

The data were analysed by using R statistical package (R Development Core Team, Version 3.0.0, Vienna, Austria) for Analysis of Variance to determine the significant ($p<0.05$). Mean was separated by Turkey's Honest Significant difference ($p<0.05$). Principal components analysis (PCA) was used to determine the main sources of systematic variation between variables in a data set. Results were expressed as mean ± SD and presented in tabular and graphical forms.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Developed jackfruit jam

Figure 7 shows jackfruit jam products produced from the mixture of jackfruit pulp and sugar and packed in sterilized glass jam bottles and labeled

Figure 7: Jackfruit jams (*Artocarpus heterophyllus*)

4.2 Chemical Properties of Jackfruit jam

4.2.1 Carbohydrate

Carbohydrate content was 16.19 % in unprocessed jackfruit while in jackfruit jam it was 57.85 % with jackfruit jam having the highest value than fresh jackfruit. This is expected because processing increased carbohydrate as moisture is reduced in the unprocessed state. These results were slightly close to the findings of fresh jackfruit, jackfruit jam and pineapple jam 13.92%, 30.90% and 48.48% by (Eke-Ejiofor and Owuno, 2013). Also Mohd Naeem *et al*. (2015) reported carbohydrate content range of (65.99 - 67.65 g/100g) in grape, strawberry, apricot and blueberry jams. High carbohydrate content in jams can be associated with the large presence of sugar.

Table 4: Chemical analysis of fresh jackfruit and jackfruit jam

Parameters	Fresh jackfruit	Jackfruit jam
Moisture (%)	77.03	39.60
Carbohydrate (%)	16.19	57.85
Protein (%)	1.65	0.87
Crude fat (%)	0.03	0.05
Ash (%)	0.41	0.22
pH	5.41	4.33
Titrable acidity (g/100g)	0.05	0.34
TSS (%)	23.80	68.0
Vitamin C (mg/100g)	5.99	10.36

4.2.2 Moisture

Moisture content of jackfruit jam was found to be 39.6% while that of fresh jackfruit was 77.03% with the jam having the least value (Table 4). This difference in moisture between processed and unprocessed jackfruit is expected because of the sugar added and heating process involved during jam making that caused moisture evaporation. These results were found to be higher compared to the findings of Eke-Ejiofor and Owuno (2013) who reported the moisture content of jackfruit jam to be 24.60%, pineapple jam (23.29%) and that of fresh jackfruit (73.60%). The difference may be due to geographical location and different existing varieties. The moisture content of the food is normally used as indicator of its shelf life (Fellows, 2000). Higher moisture content suggests that the jams have a short shelf life. According to FAD/WFP, 1970 the moisture level of jam made from stone fruit, an apricot, peach and other fruit is 29.6%.

4.2.3 Protein

Protein content of jackfruit jam was found to be 0.88% while fresh jackfruit contained 1.65%. These results were close to the findings of Watt *et al.* (1963) who observed protein content in the edible portion to be 1.3 % and 0.46 %, 0.19% and 1.12% for jackfruit jam, pineapple jam and fresh jackfruit respectively. According to jam nutritional labeling, the most common ingredients are fruits, sugar, pectin and citric acid. None of these ingredients used are rich source of protein, hence low protein content of jam (Mohd Naeem *et al*., 2015). Most processed products such as jams tend to have lower nutritional values when compared to fresh fruits due to exposure to the heat generated during processing (Jawaheer *et al*., 2003).

4.2.4 Crude fat

Fresh jackfruit had 0.03 % fat whereas jackfruit jam had 0.055%. The results of fresh jackfruit was slightly higher than that of strawberry, blueberry and grape jams which ranged from 0.01% - 0.03% as reported by Mohd Naeem *et al*. (2015) which explain very low fat contents in jackfruit jam. Fat is also a major source of energy and provide essential lipid nutrients. In many foods the fat component plays a major role in determining the overall physical characteristics, such as flavor, texture, mouth feel and appearance (Muhammad *et al*., 2009). Norman (1976) reported that, fat content of different fruits is usually not greater than 1%. Also Haque *et al*. (2009) observed that the fat content of different fruits ranged between 0.0084% and 1.27%. Jackfruit contains no saturated fatty oil and cholesterol making it a healthy fruit to savour (Priya *et al*., 2014). The research results showed that both the jam and fresh jackfruit contained small amount of fat which is for human health especially those under weight control programs.

4.2.5 Ash

The ash content of the jackfruit jam was found to be 0.22% and that of fresh jackfruit 0.41%. These findings are comparable to those reported by Eke-Ejiofor and Owuno (2013) for jackfruit jam 0.27 % and fresh jackfruit 0.43%. Goswami *et al*. (2011) also reported different fresh jackfruit (*A. heterophyllus*) types for ash values of (0.98, 1.04, 1.11, 0.88 and 0.70). Haque *et al*. (2009) reported that ash contents of fresh fruits ranged from 0.053% to 0.902%. Ash content is a measure of the total amount of minerals present within a food, although most minerals have fairly low volatility at high temperatures of 500^0C; some are volatile and may be partially lost, *e.g.,* iron and zinc (www.people.umass.edu). Ash is important in terms of nutrition because it tells how dense the minerals are in a particular food sample. Generally, low ash content indicates that the food product analyzed is not a rich source of minerals.

4.2.6 Crude fibre

The percent crude fibre of the fresh jackfruit was 4.69 % (Table 4). This value is slightly higher compared to the value 3.06 % reported by Singh *et al.* (1991). The difference may be due to varietal distinctions and the geographical location while crude fibre in jackfruit jam was 1.4%. The fiber content of jackfruit helps protect the colon mucous membrane by binding to and eliminating cancer-causing chemicals from the colon.

4.2.7 pH

The results (Table 4) show that pH of the fresh jackfruit and jam was 5.41 and 4.33, respectively. Eke-Ejiofor and Owuno (2013) reported the pH value of fresh jackfruit, jackfruit jam and pineapple jam to be 5.57, 3.36 and 3.35, respectively. The pH of jam is an important factor for optimum gel condition. Also low pH in food will prevent the microbial growth.

4.2.8 Titrable acidity

Total titrable acidity of fresh jackfruit was found to be 0.051g/100g and that of jackfruit jam was recorded as 0.34 g/100g (Table 4). The values obtained were close to those reported by Eke-Ejiofor and Owuno (2013) who found jackfruit jam value to be 0.313g/100g and fresh jackfruit 0.058. Jam had higher acidity content the reason mybe due to addition of lemon juice during jam making. However Goswam *et al.* (2011) found the value of total acidy of five different varieties for fresh jackfruit to be high ranging from (0.46 – 0.91%). The total acidity in fresh jackfruit is low at the ripe stage (0.130%) and it shows little change consequently (Bhatia *et al.,* 1955). Also, Nandini (1989) reported that firm types of jackfruit have lower acidity (0.300%) than soft (0.550%) types. The importance of high acidity in developed food product shows that it can be stored for some time. Also acidity is useful to correct the balance which is needed in jam production.

4.2.9 Total soluble solids

Fresh jackfruit was found to contain TSS of 23.80% and the developed jackfruit jam contained 68.0 %. Eke-Ejiofor and Owuno (2013) reported the value of 23% for fresh jackfruit and 40 % brix for jackfruit jam. According to India standards the total soluble solids of jam should not be less than 68.0% BIS 5861 (1993). The sugar present in the jam includes that of natural and added sugar reduces the available moisture for microbial growth thus extending shelf life of the product. Sugar contributes to soluble solids, an effect that is essential for the physical, chemical properties, thus providing body and mouth feel, improves appearance (color and shine) and makes gelation of pectin possible (Hyvönen and Törmä, 1983).

4.2.10 Vitamin C

Vitamin C was recorded as 5.99 mg/100g for the fresh jackfruit and 10.36 mg/100g for developed jackfruit jam. The acid present in the jam was expected to be high due to addition of lemons during jam making. Sharma *et al.* (2011) reported the value (11.20 mg/100g) ascorbic acid for quince jam. The results of vitamin C for fresh jackfruit is comparable to the findings by Goswami *et al.* (2011) who reported high vitamin C value of 8.18 mg/100g, 7.26 mg/100g, 7.13 mg/100g, 5.20 mg/100g and 4.57 mg/100g for different fresh jackfruit varieties. Vitamin C is an antioxidant that protects the body against free radicals, strengthens the immune system, and keeps the gums healthy (Umesh *et al*., 2010). Frequent consumption of jackfruit and jackfruit jam will helps the body develop resistance against infectious agents and scavenge harmful free radicals (Southampton Center for Underutilized Crops, 2006).

4.2.11 Mineral composition

Table 5 shows the mineral composition of the developed jackfruit jam and fresh jackfruit. The jackfruit jam prepared had (28.10 mg/100g), sodium (6.12 mg/100g), potassium (251.89 mg/100g), zinc (0.17 mg/100g) and iron is (0.27 mg/100g). Mohd Naeem *et al*. (2015) reported the low value of sodium content in strawberry jam 1.37mg/100g followed by grape jam 4.1mg/100g, while apricot and blueberry jams have almost high sodium content of 8.92mg/100g and 9.23mg/100g and these values are close to that found in this study. Apricot jam, grape jam and strawberry jam were all found to contain very low amount of zinc ranging (0.01mg/100g - 0.07mg/100g) except for blueberry which had no zinc at all. Beenu *et al*. (2014) reported the value of iron to be 6.2mg/100g and 1.6mg/100g in guava pulp and guava jam respectively. Also reported calcium content of guava pulp to be 28.2mg/100g and guava jam 26.7mg/100g.

Table 5: Minerals composition of jackfruit jam and fresh jackfruit

Sample	Calcium	sodium	Iron	Zinc	Potassium
	Concentration in mg/100g				
Jackfruit jam	28.10	6.12	0.27	0.17	251.89
Fresh jackfruit	29.42	7.48	0.52	0.32	253.40

On the other hand, the fresh jackfruit was found to contain calcium (29.42 mg/100g), zinc (0.32 mg/100g), sodium (7.48mg/100g), potassium (253.40mg/100g) and iron (0.52 mg/100g). The results of fresh jackfruit are close to that found on literature for different fresh jackfruit varieties: calcium (20-37mg/100g), sodium (2-41mg/100g), potassium (191-407gm/100g), zinc (0.42mg/100g) and iron (0.5-1.1mg/100g) as reported by Soepadmo (1992); Gunasena *et al*. (1996); Azad (2000). The difference in minerals contents that was found in this study maybe due to location factor and varieties. Calcium is crucial in development of bones and teeth especial in children (Shi *et al*., 2003). The health benefits of Zinc include proper functioning of immune system, digestion, control of diabetes, improves stress level, energy metabolism, acne and wounds healing (Vinson *et al*., 2003). Iron directly helps treating anaemia as it is used in the formation of red pigment called haemoglobin in red blood (Shi *et al*., 2005). Potassium and sodium in a human body are important in regulating the various types of body processes, such as acid-base balance, maintenance of osmotic pressure, nerve conduction, muscle contraction and control of heart beat (Deb, 1998).

4.3 Quantitative Descriptive Analysis

Mean intensity ratings of descriptive attributes of the products are shown in Figure 8. The results showed significant differences ($p>0.05$) in mean intensity scores in Hue (colour), spreadibility and sweetness between the commercial mango jam and developed jackfruit jam. Jackfruit jam had higher mean intensity score in Hue (colour), aroma and spreadibility than commercial mango jam which showed high score in sweetness and whiteness. This means the colour of jackfruit jam was very concentrated naturally compared to commercial mango jam. The aroma intensity in jackfruit jam appears to be more aromatic compared to commercial mango jam though they are not statistically different at (p>0.05). Commercial mango jam was very sweet compared to developed jackfruit jam. No difference between whiteness and aroma was observed between the samples.

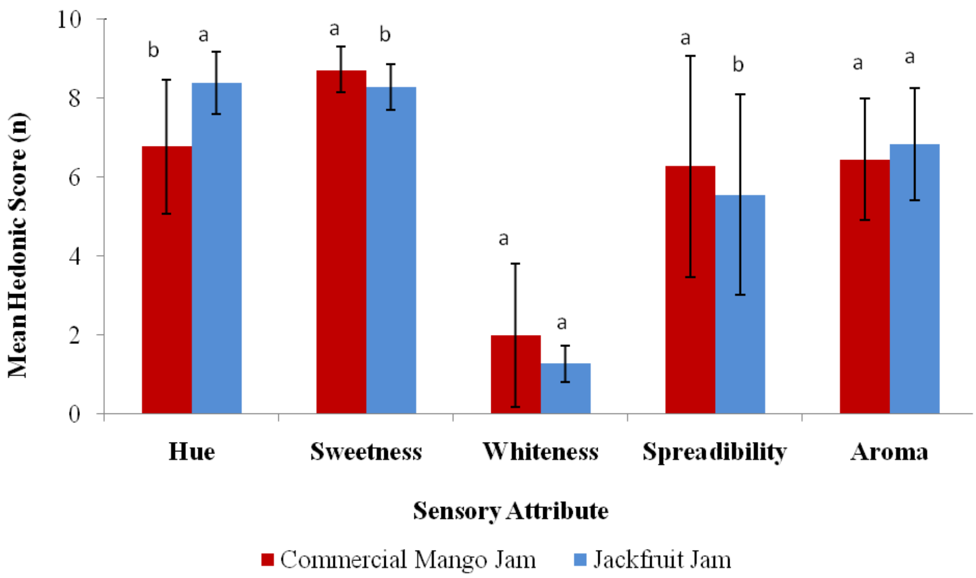

Figure 8: Mean intensity score for sensory attributes between jackfruit jam and commercial mango jam

4.4 Principal Component Analysis

- **Principal component of descriptive sensory data**

Fig.8 show bi-plot with the two first significant principal components from principal component analysis (PCA) on average sensory attributes. Bi-pot is a combination of score-plot and loading-plot whereby score plot shows relation between objects and loading plot shows the relation between original variables and the principal components. The variation along PC1 was between the commercial mango jam and jackfruit jam whereby (PC) 1 accounted for 100% of the systematic variation in the data and PC2 accounted for 0% variation. Jackfruit jam and commercial mango jam products were well separated along

PC1. Commercial mango jam correlated positively with descriptive attributes whiteness and sweetness and correlated negatively with aroma, this means that the colour was little faint and was little sweeter compared to jackfruit jam. Jackfruit jam correlated positively with attributes Hue, spreadibility and aroma which means the colour was bright, it spreads well and it has strong aroma compared to commercial mango jam. The results indicate the contrast between two products were explained by attributes whiteness and sweetness on one side and attributes aroma, spreadibility and Hue on the other side along PC1, while PC2 results were explained by attributes spreadibility and aroma.

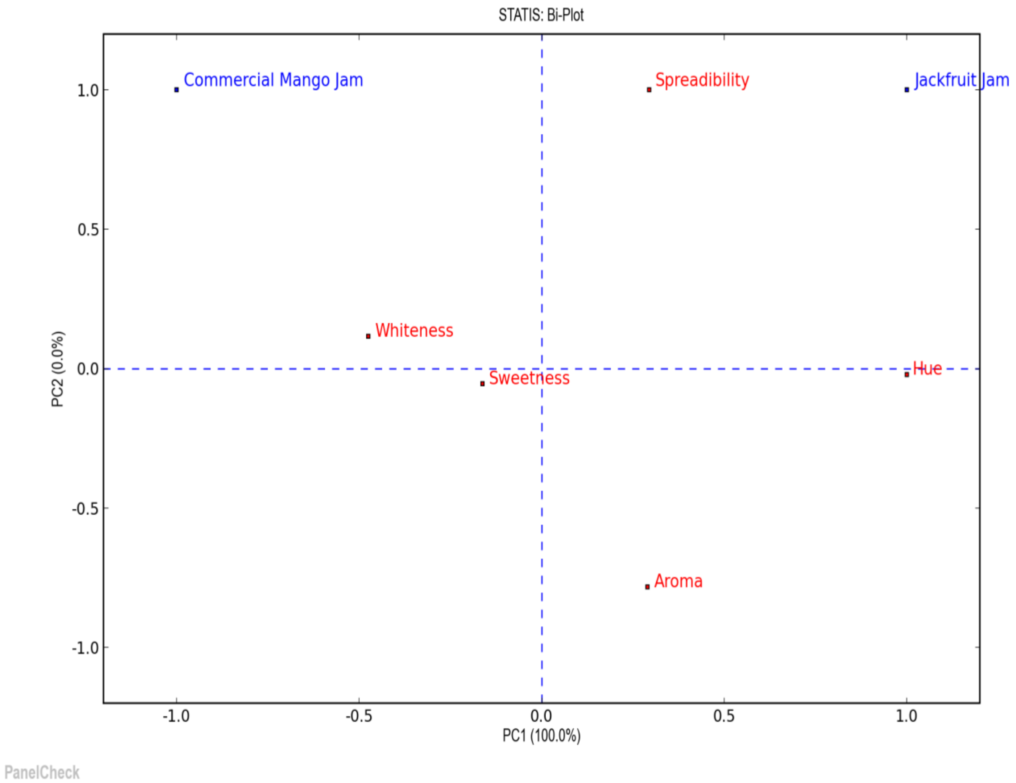

Figure 9: Bi-plot from PCA of descriptive sensory data for commercial mango jam and jackfruit jam samples

4.5 Consumer Study

4.5.1 Consumer characteristics

Consumer characteristics for the hedonic test for the analyses commercial mango jam (control) and jackfruit jam are presented in (Table 6). Panelist (54.93%) were male and the remaining percent were female. 97.18% of the panelists fall on the age group of 20-31 years while the remaining percent was in age group of 31- 40 years. Education level was also one of the consumer characteristics where 83.10% of panelists are studying bachelor degree, 12.68% are studying Diploma and the remaining percent (4.23) do Master Degree. With preference, on commercial mango jam 81.69% of panelists preferred the product if brought to the market while 18.31% did not prefer it. On the other side 78.87% preferred jackfruit jam if found it in the market while the remaining 21.13% did not prefer to buy it. The reasons why they would not buy it are because of the aroma which appeared not to be satisfactory to the panelists and the taste of the jackfruit jam that appeared to have too much sugar in it. 50% of the panelists are regular consumer of jam, this show that a good number of people are familiar with such products, so if this new developed jam gets introduced to the market consumers will accept it.

Table 6: Characteristics of consumer panel (n=71)

Characteristic	Category	Frequency (N)	Percent (%)
Gender	Male	39	54.93
	Female	32	45.07
Age group	20 -30 years	69	97.18
	31-40 years	2	2.82
Education level	Diploma	9	12.68
	Bachelor	59	83.10
	Masters	3	4.23
Preference			
Commercial Mango	Yes	58	81.69
	No	13	18.31
Jackfruit Jam	Yes	56	78.87
	No	15	21.13
Regular consumption of Jam			
Commercial Mango	Yes	36	50.7
	No	35	49.3
Jackfruit Jam	Yes	35	49.3
	No	36	50.7

4.5.2 Overall acceptability test

Mean hedonic scores of commercial mango jam and developed jackfruit jam are shown in (Table 7). The results show that there is no significant difference at ($p>0.05$) between commercial mango jam and the jackfruit jam although jackfruit jam seemed to have a higher mean value (5.92). This means the panelists had accepted both the developed jackfruit and commercial mango jam at levels of between like and like moderately.

Table 7: Scores for overall acceptability of jam products (n=71)

Product	Overall acceptability
Commercial Mango jam	5.89±1.17[a]
Jackfruit jam	5.92±1.31[a]

Mean value along the column with the same superscript are not significantly different at $p<0.05$

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the results of the study, it is concluded that jackfruit has lots of nutrients both macro and micronutrients even when processed into jam. The developed jackfruit jam has shown to be accepted by consumers. When compared with commercial mango jam there was no significant differences at ($p>0.05$) between the two jams in aroma and whiteness attributes. Moreover, jackfruit jam showed high score in hue (colour) and aroma. It is an opportunity for exploring the possibility of producing other value added food products in order to preserve the fruit during off seasons and also to reduce post-harvest losses.

5.2 Recommendations

i. The developed new jackfruit jam has been well accepted however some improvement can be made to make it more attractive to consumers. The colour and flavour are some of the attributes that can be improved to make it more acceptable.

ii. Because of its highly perishable in nature, to preserve the jackfruit for longer period should be promoted through production of many other value added food products such as jelly, jackfruit juice, squash, leather, wine, candy bar, ice cream, yoghurt, pickle, vinegar, jackfruit chips, jackfruit preserve bulbs, all these can be processed by simple techniques so as to reduce postharvest losses and can be sold in domestic as well as external market to increase income. Government through extension workers and NGOs should promote the cultivation of this jackfruit on a commercial scale in order to increase farmers' income and improve their livelihood.

iii. Raw materials involved in the production should be of proper maturity, good quality variety and free from any source of contamination since the quality of the final product depends on the quality of the raw materials.

iv. A regular training of the small scale farmers and entrepreneurs and other stakeholders on how to process by simple technologies jackfruit and its advantages in order to allow them have a full knowledge of the technology that will always strengthen their economic status by creating employment for them.

v. Further research is needed in order to understand more about jackfruit because it has many species so one can identify which species are good for developing specific processed food products which are of healthy benefits potential. Advantage should be taken of the potentiality of this fruits which is rich in many important nutrients.

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APPENDICES

Appendix 1: Questionnaire for Hedonic test of jackfruit jam for hedonic test.

Sensory Evaluation Form
Consumer test for jam
Panelist No…………………….. Sex……………………………..
Age group (a) 20-30 (b) 30-40 (c) 45 and above
Time……………………………….. Date………………………………....
Education level (a) Bachelor degree (b) Master's degree (c) other specify………………..
Please taste each of the (2) coded products. Indicate how much you like or dislike each sample by checking the appropriate sample attribute and indicate your reference (1-7) in the column against each attribute. Put the appropriate number against each attribute.

7- Like very much
6 – Like moderately
5- Like
4- Neither like nor dislike
3- Dislike
2- Dislike moderately
1- Dislike very much

Attributes	902	685
Appearance/ colour		
Taste		
Aroma		
Spreadibility		
Overall acceptability		
Would you prefer to buy a product?	Yes No	Yes No

Are you the frequent user of this product? (a) Yes (b) No
Comments
……………………………………………………………………………………………
……………………………………………………………………………………………
………………

Appendix 2: Questionnaire for QDA of jackfruit jam

QDA PANEL PERFOMANCE

Introduction

Descriptive tests are among the most sophisticated tools in the sensory science. It is the most useful and highly informative class of sensory tests tempting to provide a quantitative specification of all the sensory attributes of food or product based on perceptions of a group of qualified subjects.

Name………………………………………………

Sex…………………..Time………………

Please evaluate each coded sample 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 jackfruit jam? Put the appropriate number against each characteristic.

Sample number ....

Hue

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

Sweetness

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

Whiteness

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

Spreadibility

Low viscous 1 2 3 4 5 6 7 8 9 high viscous

Aroma

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

Figure: Panelist doing sensory test

Comments from External and Internal examiners

NO	Comments	What has been done
1	Product development concept/ technologies/approaches	This part is seen on chapter 2.12, page 15
2	Advances in jackfruit jam development	It has been written on chapter 2.10, page 13
3	Research methodology: Basis for ingredients used including proportion for each.	The basics have been explained on page 14 method has been adopted
4	Problem statement need to be improved	Problem statement have been improved accordingly as seen on page 2
5	Physical and chemical qualities of jam should be separated	I have separated the physical and chemical qualities as seen on page 3 of the documents
6	Conduct shelf life study to ascertain the life span of the developed product	The main objective was to develop a jam and evaluate if its acceptability, to conduct a shelf life is a next stage after the product have been developed. This require another resource in order to perform shelf life study
7	Old literature	I acknowledge the comment, but these old literatures are the one available for this study and there are only few current literature available for jackfruit study and I have put them where necessary
8	Research design was not indicated	I have put the research design on page 21 chapter 3.3.1
9	Sensory evaluation section should be well written and divided into QDA and consumer test in methodology and results sections	I have made some correction on sensory part and divided it into QDA and consumer test in methodology on chapter 3.3.4 page 29
10	Conduct physical and chemical statistical test	The statistical test was done where it was needed to give desired information