KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

KUMASI, GHANA

COLLEGE OF SCIENCE

FACULTY OF BIOSCIENCES

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

NUTRIENT COMPOSITION, FUNCTIONAL PROPERTIES, DIGESTIBILITY AND FORMULATION OF SELECTED FOOD PRODUCTS FROM BREADFRUITS (*ARTOCARPUS* SPP. AND *TRECULIA AFRICANA)*

BY

FRANCIS APPIAH

OCTOBER, 2011

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A THESIS SUBMITTED TO THE DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENT OF THE DOCTOR OF SCIENCE (Ph. D.) DEGREE IN FOOD SCIENCE AND TECHNOLOGY

BY

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M. Sc. Food Science and Technology

OCTOBER, 2011

DECLARATION

I, Mr. Francis Appiah, hereby declare that this submission is my own work towards the award of Ph.D Food Science and Technology degree and that to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

Breadfruits (*Artocarpus altilis*, *Artocarpus camansi*, *Artocarpus heterophyllus* and *Treculia africana*) which grow in Ghana have been used as food security crops. In order to expand their use a survey was carried out in selected regions of Ghana using structured questionnaires to solicit baseline information on indigenous knowledge and traditional uses of the breadfruits. Standard procedures were then used to assess the physicochemical properties of the breadfruit flours as well as their digestibility. The data on chemical composition were used to establish predictive relationships for predicting digestibility, dry matter intake, net energy for production as well as relative food value. Selected food products were then formulated using breadfruit flours as substitute. The results of the survey showed that *Artocarpus altilis* and *A. camansi* were used for food (95.4%) while *T. africana* was mainly used for medicinal purposes (59%) and cocoa agroforestry (50.9%). With respect to their nutritional composition, the protein content of the flours of the nut-derived species (*A. heterophyllus*, *A. camansi* and *T. africana*) ranged between 12.23% and 17.72% whereas the crude fiber content varied between 1.67% and 2.91%, the carbohydrate content was between 57.00% and 70.15%. Potassium was the predominant mineral ranging from 533.95mg/100g in *T. africana* to 1313.3mg/100g in *A. camansi*. Magnesium levels varied widely between *A. camansi* (10.18mg/100g) and *T. africana* (167.71mg/100g). *T. africana* had significantly higher ($P<0.01$) calcium content (65mg/100g) than both *A. heterophyllus* (65mg/100g) and *A. camansi* (93mg/100g). On the other hand, sodium content ranged between 37.5mg/100g in *A. camansi* and 54.0mg/100g in *T. africana*. Phosphorus content varied widely between 201.60mg/100g and 440.00mg/100g. The iron content was highest in *A. heterophyllus* (9.38mg/100g) while *A. camansi* had the least (2.20mg/100g). The nut

flours had bulk densities ranging between 0.53 and 0.76g/cm^3. The functional properties were water absorption capacity (1.25-3.67g/g), oil absorption capacity (0.5-2.50ml/g), solubility (8.01-11.29%) and swelling power (4.84-6.32). The flours had peak viscosities ranging between 21.00BU and 125.00BU and setback values ranging between 7.67 and 38.00BU. On the other hand, the pulp (*A. altilis*) flours had the following attributes: crude protein (3.80%), crude fibre (3.12%), carbohydrates (79.24%), K (673.50mg/100g), Na (69.00 mg/100g), Fe (3.91 mg/100g), Mg (90.63 mg/100g), P (140.00 mg/100g), Ca (60.83 mg/100g), bulk density (0.57 mg/100g); water and oil absorption capacities (3.67g/g and 1.50ml/g respectively), solubility (11.55%), and peak viscosity of 354.33BU. No significant differences (P>0.01) were found in the tannin contents (3.44mg/100g to 4.30 mg/100g) of the breadfruit species. Lignin content was highest in *A. camansi* (12.1%) compared to the least (3.54%; *T. africana*). *T. africana* had the highest Digestible Dry Matter (78.51%) whereas *A. camansi* had the least (70.21%). Dry Matter Intake was highest in *A. altilis* (2.65% per kg body weight) and lowest in *T. africana* (1.72%/kg body weight). *T. africana* having the highest Net Energy for Production (88.00 Mca/lb) was similar to *A. heterophyllus* (86.77 Mcal/lb) but higher than *A. camansi*. *A. altilis* had higher Relative Feed Value (156.48) compared to *A. camansi* (137.13), *A. heterophyllus* (126.18) and *T. africana* (104.88). The predictors for Digestible Dry Matter were Acid Detergent Lignin, lignin, hemicelluloses and Nuetral Detergent Fibre. Dry Matter Intake was dependent on carbohydrate, fat, Acid Detergent Fiber, hemicelluloses and Neutral Detergent Fiber contents. On the other hand Net Energy for Production was predictable from Acid Detergent Lignin, lignin and hemicelluloses while Relative Feed Value was dependent on the carbohydrate, fat and Neutral Detergent Fibre content. Predictive equations were derived in this study. The

products formulated from the breadfruit flours were of acceptable quality in terms of colour, mouthfeel, aroma, taste and overall acceptability with levels of substitution being 20% for breakfast meal, shortcake and koose and 40% for tatale. The results showed that the breadfruit species had good physicochemical properties and digestibility and vindicate their use as stop-gap food. The flours could be suitable for food applications. Thus, increased use of these flours in food product applications would enhance and expand their use.

DEDICATION

I dedicate this work to my dear wife Mrs. Akua Pokuaa Appiah and my children; Jemima Zita Appiah, Frank Appiah, Martin Appiah and Ivan Appiah.

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CHAPTER ONE

1.0 INTRODUCTION

Breadfruits, of the genera *Artocarpus* and *Treculia* belong to the Family *Moraceae* and consist of over 50 species. The name breadfruit is a common name for fruits belonging to the genera *Artocarpus* (Morton, 1987) although it usually refers to *Artocarpus altilis* Ragone (2006a). Cultivars in these genera include *Artocarpus altilis*, *Artocarpus camansi*, and *Artocarpus heterophyllus*. *Treculia africana* Decne, of the genus *Treculia*, a member of the *Moraceae* family is a common cultivar in Africa. *Treculia africana* is commonly called African breadfruit (Enibe, 2001; Omobuwajo, 2007). Breadfruits are main staples in the Caribbean and are covered by the International Treaty on Plant Genetic Resources for Food and Agriculture (Ragone, 2007).

According to Morton (1987), breadfruits are believed to be native to a vast area extending from New Guinea through the Indo-Malayan Archipelago to Western Micronesia. Breadfruits enjoy wide distribution and are now grown throughout the tropics (Ragone, 2007). *Artocarpus altilis*, *Artocarpus camansi*, *Artocarpus heterophyllus* and *Treculia africana* are grown in about 90 countries in the tropics and subtropics (Rotary International, 2007). *Treculia africana* however, grows specifically in Africa (ICRAF, 2010). Breadfruits grow easily in a wide range of ecological conditions with minimal input of labour or materials and require little attention or care (NTBG, 2009). Breadfruits are found from sea level to about 1,550 m elevation. The latitudinal limits are approximately 17 ^{o}N and 17 ^{o}S, but maritime climates extend that range to the Tropics of Cancer and Capricorn (Ragone, 2007). In Africa, breadfruits are found in Senegal, Guinea-Bissau, Cameroun, Sierra Leone, Nigeria, Liberia and Ghana (Burkill, 1997). An average sized breadfruit tree has a canopy cover of 25 m^2 yielding 400-600 fruits per year. Yields are superior to other starchy staples due in part to their verticality of production (NTBG, 2009). Singh (2009) reported that a single tree produces between 150 kg and 200 kg of food per season.

Breadfruits are used as food and may be eaten ripe as fruit or unripe as a vegetable. Malayans peel firm-ripe fruits, slice the pulp and fry it in syrup until it is crisp and brown. It can also be fried, baked, steamed, boiled and made into pudding. In West Africa, it is sometimes made into puree (Morton, 1987). In the animal industry, the under-ripe fruits can be cooked for feeding pigs and it is a potential feed material for poultry. Breadfruit leaves and barks are also eaten by domestic livestock. Its latex is used for making chewing gums. The wood is used for furniture and surf boards. The fiber in the bark is fashioned into clothing. In Trinidad and Bahamas a decoction of the breadfruit leaf is believed to lower blood pressure and relief asthma (Morton, 1987). Additionally, a powder of roasted leaves is employed as remedy for enlarged spleen and toasted flowers are rubbed on gums to soothe aching tooth (Logie, 2010).

The importance of breadfruits notwithstanding, they are underutilized and neglected (Quartermain, 2006; Omobuwajo, 2007). Their underutilization is partly due to social stigmatization, both in Ghana and other parts of the world, as food for slaves and the poor. They are generally considered as unimportant food crops. These have therefore led to their neglect (Spore, 2007). Although breadfruits have been neglected they have untapped potential which needs to be harnessed (Enibe, 2002; Beyer, 2007). The World

Food Program encourages the incorporation of highly nutritious but neglected foods in the diets as a means of combating malnutrition (Grosskinsky and Gillick, 2000). To this end, research into breadfruits as dietary component has recently gained attention. Nelson-Quartey *et al.* (2007) produced infant formulations from *A. altilis* and *A. camansi* flours while Oduro *et al*. (2007) produced a breakfast meal from *A. altilis* pulp flour. Roberts *et al*., (2007) reported on the potential of breadfruits for production of fried chips. Most studies conducted treated the properties of breadfruit on an ad hoc basis, without considering differences due to cultivars (Baccus-Taylor *et al.*, 1999). To increase their popularity and expand their use in the food industry, Ragone (2007) suggested that appropriate postharvest handling and storage should be explored. Enibe (2002) as well as Beyer (2007) indicated that breadfruits have the potential to contribute to food security and need to be better utilized through food processing techniques, which could be achieved by having information on the biochemical and nutritional status of the fruits. Similarly, Baccus-Taylor and Akingbala (2007) have emphasized the need for research into available species of breadfruits, their nutrient and functional properties among others for food and industrial use to fill the knowledge gap. Information on these would increase utilization of breadfruit, improve nutrition, enhance food security and assist in commercializing breadfruits as a source of income.

The following research questions were posed prior to the start of the study:

1. What are the indigenous uses and knowledge on the different breadfruits species in Ghana?
2. Do the flours of the different breadfruit species have good physico-chemical and functional properties that would allow them to be used in food formulations?

3. What relationships exist among the physico-chemical properties of breadfruit flours?
4. Do the breadfruit species have good digestibility that would allow bioavailability of their nutrients?
5. Are there existing relationships between chemical composition and digestibility of the breadfruit species?
6. How do the different breadfruit flours perform when used for food product development?

The main objective of this study which was based on the research questions, therefore, was to facilitate the expansion of the end-use of breadfruits as food through the profiling of their nutritional as well as the physico-chemical properties of their flours.

Specifically the study sought to:

1. Document baseline indigenous knowledge on the use of *Artocarpus altilis*, *Artocarpus heterophyllus*, *Artocarpus camansi* and *Treculia africana* in Ghana
2. Determine the physico-chemical properties of flours from *Artocarpus altilis* pulp, and *Artocarpus heterophyllus*, *Artocarpus camansi* and *Treculia africana* beans
3. Establish empirical relationships between the functional and proximate/mineral properties of the breadfruit flours to facilitate food product formulation
4. Determine the tannin content and digestibility of breadfruit species
5. Identify existing relationships between chemical composition and digestibility coefficients
6. Formulate selected food products from the flours of the breadfruit species

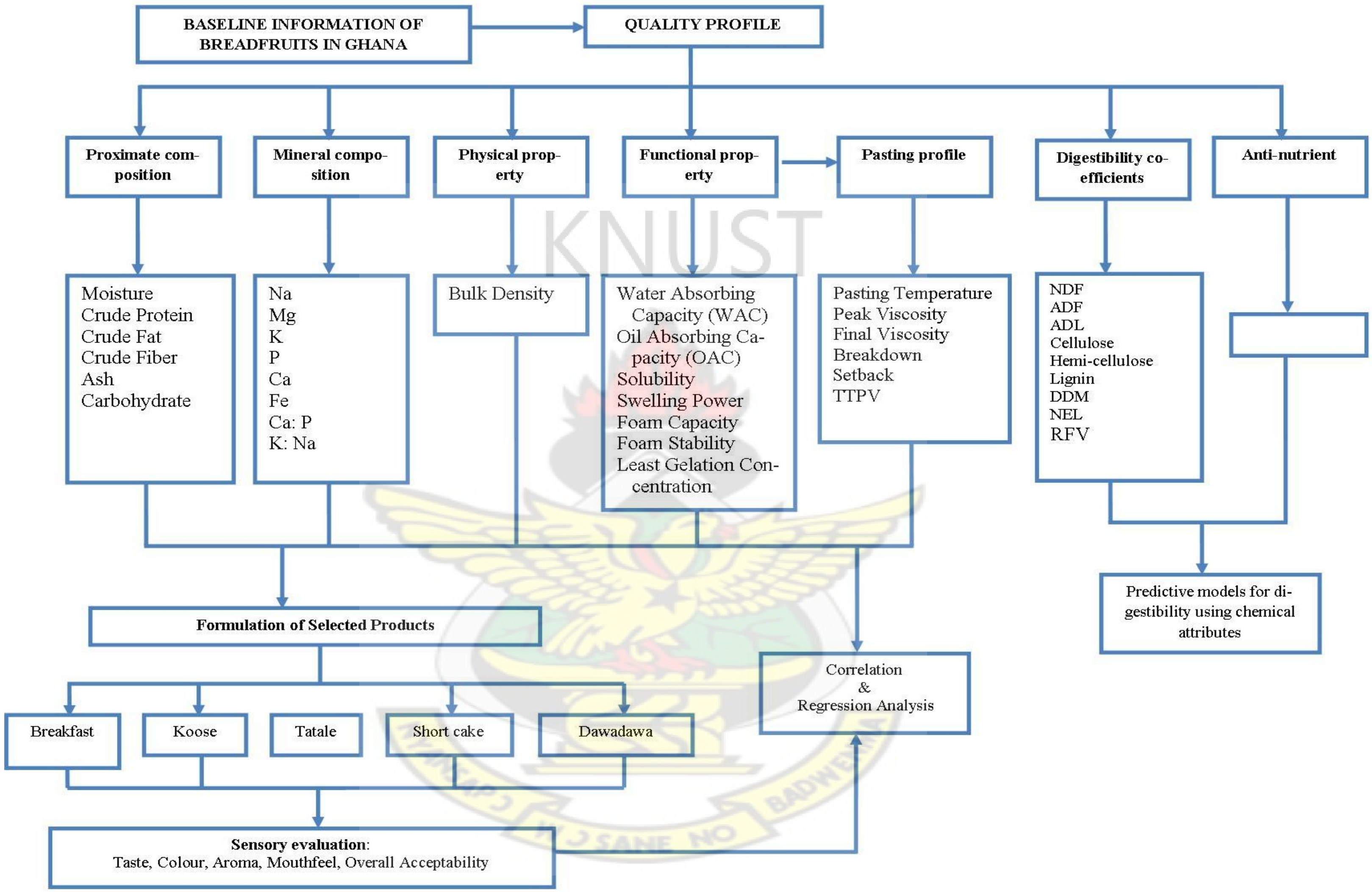

Figure 1-1: Flow diagram of work

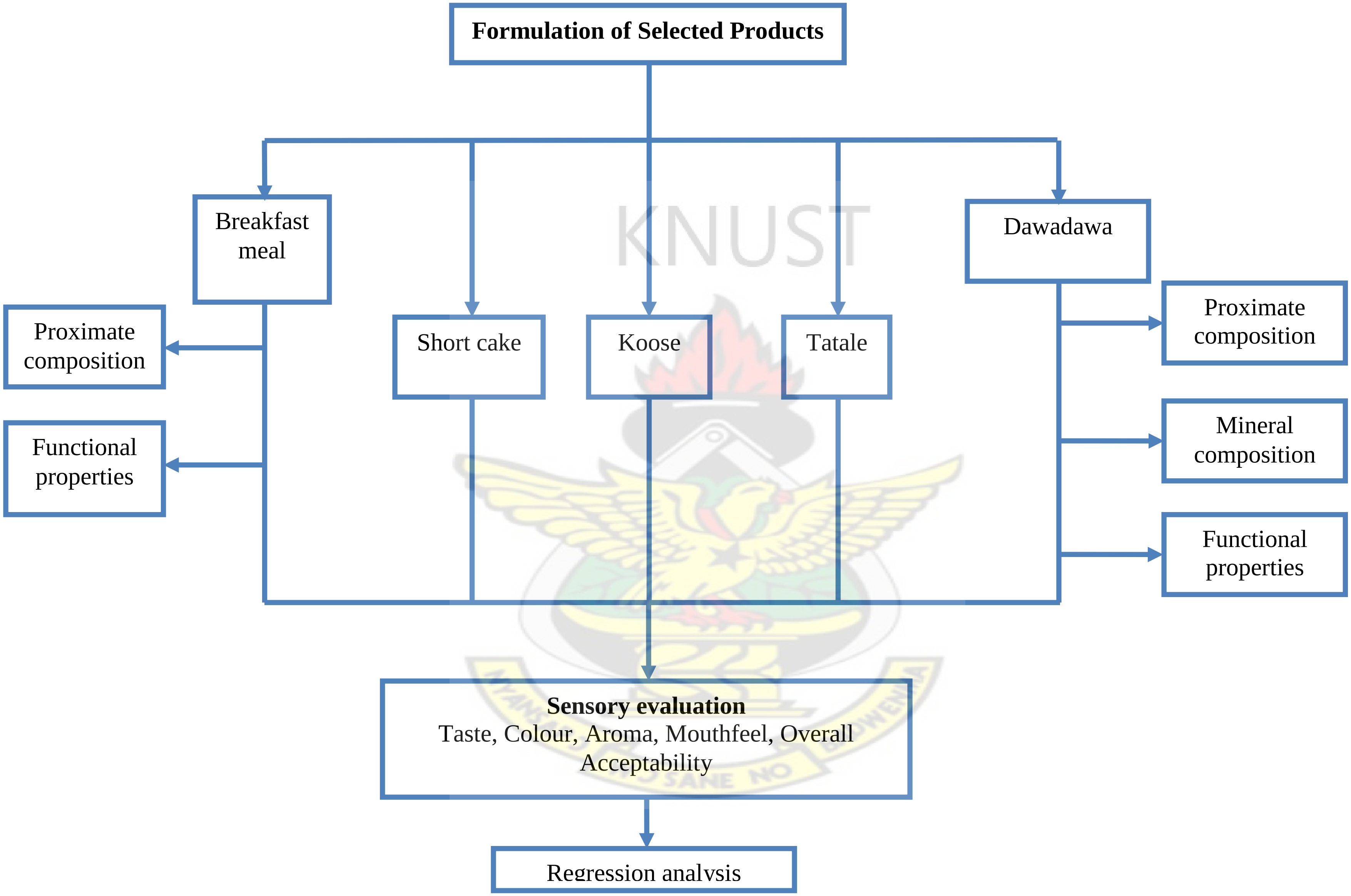

Figure 1-2: Flow diagram for product formulation

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 ARTOCARPUS ALTILIS

2.1.1 Origin and Botanic Description

Artocarpus altilis is commonly called breadfruit. In Ghana it is known as D-Ball. It is native to Polynesia. According to Kerr (2009), Bligh in 1793 successfully carried breadfruit plants to St. Vincent and Jamaica. The Plant has since spread throughout the tropics .

According to Orwa *et al.* (2009), *Artocarpus altilis* is a large, evergreen tree growing as high as 15-20 m. It has light coloured smooth bark and a trunk of up to 1.2 m in diameter. It grows up to a height of 4 m before branching and has 2 large stipules enclosing the terminal bud, up to 30 cm long at maturity, yellowing and falling when leaves fold or inflorescence emerges. The leaves of *A. altilis* are thick, leathery with dark green top with an elevated midrib and main veins. The juvenile leaves on young trees and new shoots of mature trees are usually larger. The leaves are sometimes smooth but often with few to many pale to reddish hairs, especially on the midrib and veins.

The fruit is a highly specialized structure and is composed of 1500-2000 flowers attached to the fruit axis or core. The fruit is globose to oblong, 12-20 x 12 cm with light green, yellowish-green or yellow rind when mature. The pulp is creamy white or pale yellow. It is usually seedless, although there are seeded forms. The seeds have thin, dark-brown outer skin about 0.5 mm thick and an inner, fragile, paper-like membrane that surrounds the fleshy, white edible portion of the seed (ICRAF, 2010).

2.1.2 Biology

Artocarpus altilis trees are monoecious with the male and female flowers occuring separately on the same tree. Male inflorescence emerges before the female. Pollen is shed 10-15 days after the emergence of the male inflorescence, for a period of about 4 days. Female flowers are receptive 3 days after the emergence of the female inflorescence from the bracts and open in successive stages, with basal flowers opening first (Ragone, 1997). *Artocarpus altilis* is cross-pollinated. According to Ragone (1991) *A. altilis* can be asexually propagated. According to the author, *A. altilis* trees start fruiting in 3-6 years.

2.1.3 Ecology

Artocarpus altilis is a crop for the hot, humid, tropical lowlands. It prefers rainfall of fairly equal distribution but is quite tolerant of short dry periods. *A. altilis* grows best in equatorial lowlands; it is occasionally found in the highlands, but yield and fruit quality suffer in cooler conditions (Harvey, 1999). Good drainage is essential, and the trees may shed their fruit when the soil is excessively wet.

2.1.4 Biophysical Limits

It grows at altitudes of 0-1550m above sea level with mean annual temperature of 21-32^{o}C and mean annual rainfall of 1500-2500mm (Janic and Paull, 2008). It can be grown on a species of soils and thrives on alluvial and coastal soils. They do best in deep, fertile, well drained sandy loam or clay loam soils. Some cultivars, especially inter specific hybrids, have adapted to shallow, calcareous soils and appear to tolerate high saline conditions (ICRAF, 2010).

2.1.5 Products

In West Africa *A. altilis* has many uses (Baccus-Taylor and Akingbala, 2007). It is versatile and can be cooked and eaten at all stages of its development. It can be eaten raw, boiled, steamed or roasted. Very small fruits, 2-6 cm or larger in diameter, can be boiled. *Artocarpus altilis* can also be pickled and marinated. The most common method of preservation is by preparing the fermented, pit-preserved breadfruit called ma, masi, mahr, furo or bwiru by Pacific Islanders (Cox, 1980). In many areas, the male inflorescence is pickled or candied.

2.1.6 Nutritional Composition and Importance

Compared with other staple starchy crops, breadfruit is a better source of protein than is cassava; it is comparable to sweet potato and banana. It is a relatively good source of iron, calcium, potassium and riboflavin (ICRAF, 2010). The seeds are low in fat, compared with tree nuts such as almond, Brazil nut and macadamia nut, which contain 50-70% fat.

Nelson-Quartey *et al.* (2007) reported a protein content of 6.19% for *Artocarpus altilis* flour whereas Oduro *et al.* (2007) reported 3.28%. Crude fat content reported for *A. altilis* were 2.26% and 2.82% by Nelson-Quartey *et al.* (2007) and Oduro *et al.* (2007), respectively. Carbohydrate content reported for *A. altilis* pulp flour are 81.70% (Nelson-Quartey *et al*., 2007) and 82.84% (Oduro *et al*., 2007).

The leaves are eaten by livestock and can be fed to cattle, goats, pigs and horses. Over riped breadfruit cores and other breadfruit waste are fed to pigs and other animals.

2.1.7 Maturity and Quality Indices of *Artocarpus altilis*

Fully mature fruits are dark-green and their segments are more rounded and smoother than less mature fruits. Latex stains may be present on the skin of mature fruits. Yellowing of the skin indicates over-maturity (Kader, 2012). According to the author, good quality breadfruits are mature-green, firm, with intact stem, and free from defects (such as blemishes, sunscald, cracking, bruising, and insect damage) and decay. Uniformity of shape, size, and weight are also important quality factors. Breadfruit pulp (edible portion) contains 25-30% (fresh weight basis) carbohydrates, half of which is starch (Kader, 2012).

2.1.8 Processing of *Artocarpus altilis*

Consumer-acceptable, drum-dried and cabinet-dried, protein-enriched breakfast foods using uncooked or cooked breadfruit as the main ingredient have been developed. For instance, Nelson-Quartey *et al.* (2007) produced an infant formulation while Oduro *et al*. (2007) produced a breakfast meal using *A. altilis* pulp flour. Sliced breadfruit has been canned in 1.5% brine (Baccus-Taylor and Akingbala, 2007).

2.2 ARTOCARPUS CAMANSI (BREADNUT)

The preferred scientific name is *Artocarpus camansi* Blanco and it belongs to the family Moraceae. It is commonly known as breadnut. *Artocarpus camansi* is a wild ancestor of *Artocarpus altilis* and they are distinctly different (NTBG, 2010)

2.2.1 Origin and Distribution

According to Ragone (2006a) *Artocarpus camansi* has often been confused for *A. altilis*. However, *A. altilis* is a separate species that originated from its wild seeded ancestor, *A. camansi*. *Artocarpus camansi* is native to New Guinea, Indonesia and the Philippines. In New Guinea, it is a dominant member of alluvial forests in lowland areas and is one of the first species to appear on the tops of frequently flooded banks of rivers. The trees grow widely scattered in the forest and are dispersed by birds, flying foxes, and arboreal mammals that feed on the flesh and drop the large seeds (Ragone, 2006a).

While breadnut is uncommon in the Pacific islands, it has long been cultivated and used in other tropical regions. *Artocarpus camansi* is now widespread in the Caribbean and South America, Southeast Asia, and parts of Africa, especially coastal West Africa including Ghana (Gamedoagbao and Bennett-Lartey, 2007).

2.2.2 Biophysical Limits

Artocarpus camansi grows best in equatorial lowlands below 600–650 m and rainfall of 1300–3800 mm (Janic *and* Paull, 2008). However, it has the capacity to adapt to a wide range of conditions. It thrives in lowlands, mixed alluvial forests, in cultivation, as well as in association with a wide species of domesticated plants. It grows well in deep fertile and well drained soils.

2.2.3 Botanical Description

The tree grows to heights of 10–15 m with trunk girth of 1 m or larger. Branching begin at a height of 5 m. The tree produces sticky, white, and milky latex in all parts of the tree. The canopy diameter generally measures about half of the tree height. *Artocarpus camansi* is a single-trunked tree with a spreading evergreen canopy. Buttresses are found at the base of the trunk. It has a more open branching structure than *A. altilis* (NTBG, 2010). Flowering is monoecious with male and female flowers on the same tree at the ends of branches, with the male inflorescence appearing first (Ragone, 2006b). Unlike *A. altilis*, the individual flowers do not fuse together along their length. The leaves are large (40-60 cm), alternate, dissected with 4–6 pairs of lobes and have sinuses cut half way to the midrib. They are densely pubescent, with many white or reddish-white hairs on upper and lower veins, lower leaf surface, and petiole. Blade is dull green with green veins (Orwa *et al*., 2009).

According to Ragone (2006b) the fruit is a large fleshy syncarp, oval or ovoid, 13–20 cm long and 7–12 cm in diameter, weighing approximately 800 g. The skin is dull green to green-yellow when ripe with a spiny texture from the pointed, flexible, 5–12 mm long tips of individual flowers. The fruit pulp is yellow-whitish when ripe with a sweet aroma and taste. The fruit is not as solid or dense as *A. altilis* because the individual flowers forming the fruit are fused together only at their bases. The fruit contains numerous seeds, from 12 to as many as 150, each weighing an average of 7–10 g, comprising 30–

50% or more of the total fruit weight. The seeds are rounded or flattened by compression and about 2.5 cm long. They have a thin, light-brown outer seed coat that is patterned with darker veins. In contrast, the seeds of breadfruit usually have a dark-brown, shiny seed coat. The seeds have little or no endosperm, no period of dormancy, germinate immediately, and are unable to withstand desiccation (Ragone, 2006b)

2.2.4 Nutritional composition, Uses and Products of *Artocarpus camansi*

Willams and Badrie (2005) reported that fresh breadnut seeds contain 6.92% protein, 3.65% fat, 3.62% ash, 10.99% total fiber and 25.67% carbohydrate. In their study they observed that the predominant mineral was potassium (599.97 mg/100g) followed by sodium (119.18 mg/100g). Calcium, iron, phosphorus and magnesium were 10.70 mg/100g, 1.24 mg/100g, 4.30 mg/100g, and 44.78 mg/100g respectively. Ragone (2006b) however, reported higher values (Table 2-1) for protein (13.3-19.9%), fat (6.2-29.0%) and carbohydrate (76.2%).

Table 2-1: Nutritional composition of *A. camansi* seeds

Nutritional component	Amount
Protein	13.3–19.9%
Carbohydrate	76.2%
Fat	6.2–29.0%
Calcium	66–70 mg
Potassium	380–1620 mg
Phosphorus	320–360 mg
Iron	8.7 mg
Magnesium	10.0 mg
Niacin	8.3 mg
Sodium	1.6 mg

Source: Ragone (2006b)

Artocarpus camansi is used as staple food. The nutritious fruits are usually consumed when immature, thinly sliced and boiled as a vegetable in soups or stews. The beans nutritious and is a good source of protein. It is low in fat compared to nuts such as almond, Brazil nut, and macadamia nut. The fat extracted from the seed is a light yellow, viscous liquid at room temperature with a characteristic odor similar to that of peanuts. It has a chemical number and physical properties similar to those of olive oil. Its seeds are a good source of minerals and contain more niacin than most other nuts (NTBG, 2010).

The tree is used as timber, fuel wood. The wood is carved into statues, bowls and fishing floats. Dried male flowers can be burned to repel mosquitoes and other flying insects (Elevitch *et al.*, 2006).

2.3 ARTOCARPUS HETEROPHYLLUS

2.3.1 Origin and distribution

Artocarpus heterophyllus Lam similarly belong to the Family Moracea and is native to India, Bangladesh and Nepal (ICUC, 2002). It is commonly called Jackfruit. It is commercially grown and sold in Southeast Asia and Northern Australia. It is also grown in parts of Hawaii, Brazil, Suriname, Madagascar, and in islands of the West Indies such as Jamaica and Trinidad. It is the national fruit of Bangladesh and Indonesia. Archeological findings in India have revealed that jackfruit was cultivated in India 3000 to 6000 years ago. Outside of its countries of origin, fresh jackfruit can be found at Asian food markets. It is also extensively cultivated in the Brazilian coastal region, being commercialized in local markets. It may also be available canned in sugar syrup or frozen. According to Burkill (1997), it is cultivated in some countries in the evergreen forest zone of West Africa. It is found in the south coastal parts of Nigeria (Odoemelam, 2005) and grows wild in Ghana (Leipzig, 1996).

2.3.2 Biophysical Limits

It is well suited to tropical lowlands. In India it is found in the Western coast with high rainfall and sporadic in areas with low rainfall. In Western Ghats it is found at 1500 m above sea level (Muralidharan *et al*., 1997). It is adapted to only humid tropical and near tropical climates (Akinmutimi, 2006).

2.3.3 Botanical Description

The jackfruit is evergreen and produces more yield than any other fruit tree species and bears the largest edible fruit (Alagiapillai *et al*., 1996). The fruits can reach 50 kg in weight (Selvaraj and Pal, 1989) and up to 90 cm long and 50 cm in diameter. The sweet yellow sheaths around the seeds are about 3–5 mm thick and have a taste similar to that of pineapple, but milder and less juicy. Jackfruit is a dicotyledonous compound fruit (Ahmed *et al*., 1986). Samaddar (1985) indicated that jackfruit has wide variability. Rahman *et al*. (1999) reported that jackfruit has two textural forms; in one the perianth becomes soft and pulpy when ripe, while in the other it remains firm.

2.3.4 Uses

Jackfruit can be roasted or boiled to make them edible. The pulp of the ripe jackfruit may be eaten or incorporated into fruit salad (Odoemelam, 2005). According to the author jackfruit is consumed in Nigeria though it is stigmatized as ‘poor man’s food’. Unripe (young) jackfruit can also be eaten whole. Young jackfruit has a mild flavour and distinctive texture. The cuisines of India, Bangladesh, Sri Lanka, Indonesia, Cambodia, and Vietnam use cooked young jackfruit. In many cultures, jackfruit is boiled and used in curries as a food staple (Frei and Becker, 2004). The wood of the tree is used for the production of various musical instruments. It is also widely used in the manufacture of furniture. The heartwood of the jackfruit tree is used by Buddhist forest monastics in Southeast Asia as a dye, giving the robes of the monks in those traditions their traditional off-brown colors (Ariyesako, 1998).

2.3.5 Nutritional Composition

Samaddar (1985) reported that ripe jackfruit flakes contains 18.9% carbohydrates and 0.8% minerals, 30 IU vitamin A and 0.25 mg thiamine per 100 g perianth. The energy per kg-wet weight of ripe perianth is 2 MJ (Ahmed *et al*., 1986).

2.3.6 Digestive Disturbances by Artocarpus heterophyllus

All over the world, there is some resistance to the jackfruit, attributed to the belief that overindulgence in it causes digestive ailments. Burkill (1997) reported that it is the raw, unripe fruit that is astringent and indigestible. The ripe fruit is somewhat laxative; if eaten in excess it will cause diarrhoea.

2.4 *TRECULIA AFRICANA*

Treculia africana also belongs to the family *Moraceae*. Its known species are *Treculia africana* Decne, *Treculia africana* inversa Okafor (Nwabueze and Nwokenna, 2006), and *Treculia africana* Mollis (CAB International, 2006). It is generally called African breadfruit but other synonyms such as African boxwood and wild jackfruit are used. It is known as *afon*, *ediang* or *ekwa* in Nigeria, brebretim in Senegal and Ghana, ezeya in Tanzania and *muzinda* in Uganda. In Ghana another common name for it is *Ototim*.

2.4.1 Geographical Distribution and Environmental Requirements

The African breadfruit is found on the approximate latitude limits of 15 ^{o}N to 20 ^{o}S. It is a fruit tree of riparian forest in tropical Africa. It is usually found near streams or in swampy areas of forests. It is not light demanding and grows in wide species of soils and climatic conditions. It thrives in most tropical regions. *T. africana* has potential to be grown in valleys and riverine areas. It has potential to be domesticated on farmlands or planted as avenue tree. Its canopy is found in the upper storey of forest stands. *T. africana* thrives in altitude range from sea level to 1500 m with mean annual rainfall of 0-1800 mm (Asase and Tetteh, 2010). It performs best with dry season duration of less than 9 months and with a mean annual temperature of 20^{o}C-32^{o}C. It performs well in soils with medium texture, free drainage, and acidic soil reaction.

In East Africa, it is found in Uganda, Sudan, Tanzania, Angola while in West and Central Africa it is found in Benin, Central African Republic, Cote d'Ivoire, Liberia, Gambia, Gabon, Senegal, Sierra Leone, Nigeria, Guinea, Congo DR, Guinea-Bissau, Togo, Niger, Chad, Cameroon, and Ghana. In North Africa, it grows in Tunisia while in Southern Africa it grows in Madagascar, Mozambique, Equitorial Guinea, Malawi, Sao Tome and Principe, Sudan, Tanzania, and Zambia (ICRAF, 2010).

2.4.2 Botany of Treculia africana

T. africana is an evergreen tree 10-30 m in height (maximum of 50 m) with a dense spreading crown and fluted trunk. The bark is grey, smooth, thick and when cut exudates a white latex which later turns rusty red. Based on detailed field observations 3 species have been recognized: *T. africana var africana*, *T. africana var. inverse* and *T. africana var. mollis.* Their taxonomic differences are based mainly on the size of the fruit head (infructesence) and the hairness of branchlets and leaves.

2.4.3 Silviculture, Management and Uses of *Treculia africana*

Treculia africana tolerates wind and shade and has ability to coppice and be pollarded. It can be propagated with seeds or vegetatively by cuttings and grafting. *Treculia africana* is used for agroforestry, soil improvement, soil conservation, erosion control, shelterbelts, windbreaks, amenity and ornamental. Leipzig (1996) reported that *T. africana* has medicinal uses and is used as such in Ghana.

2.4.4 Nutritional Composition

T. africana seed is a rich source of vegetable oil (10%), protein (17%) and carbohydrates (40%), as well as several minerals and vitamins (Enibe *et al.*, 2002). The 10% oil yield compares very well with that of sunflower, cotton and palm kernel cakes (http://www.troikaindia.com/solvent-extraction-plant.html). The fat and oil content makes it a potential commercial raw material for the production of vegetable oil, in pharmaceuticals, soaps, perfumes and paints (Chukwuone and Chukwuemeka, 2008). In Nigeria, Runsewe-Abiodun *et al.* (2001) prepared porridge from *Treculia africana* and after feeding to malnourished children observed an improvement in their conditions without any adverse reactions.

2.5 FLOUR PRODUCTION

2.5.1 Pre-Drying Operations

Harvesting and handling procedures prior to drying are very important in achieving good quality products. According to Brenndorfer *et al*. (1985), pre-drying procedures may include hygiene, cleaning, grading and sizing, peeling, (coring, pitting, trimming), cutting (slicing), blanching, use of additives, sulphuring, salting or sugaring. The sequence and specific procedures depends on the crop to be dried.

2.5.2 Drying Operations

There are two basic phenomena involved in drying operations, namely: evaporation of moisture from the surface and migration of moisture from the interior of a particle to the surface. The rate of evaporation is proportional to the difference between the saturated vapour pressure of water at the surface temperature, and the partial vapour pressure of the water in the adjacent air. The vapour pressure increases with increase in air temperature at constant humidity whereas the partial vapour pressure of the adjacent air increases with humidity at any fixed temperature. In practical terms the warmer the air the greater the difference between saturated vapour pressure (Ps)- actual vapour pressure (Pa) and hence the greater the rate of evaporation; the more humid the air the smaller the Ps-Pa and hence a lower rate of evaporation (Brenndorfer *et al*., 1985). Drying can be done by various means including the use of solar and oven dryers.

2.5.3 Quality Indicators of Flour

In the culinary sense, flour is a powder made from cereal grains, other seeds, or roots. It is the main ingredient of bread, which is a staple food for many civilizations, and other products. Wheat flour is one of the most important foods in European, North American, Middle Eastern and North African cultures, and is the defining ingredient in most of their styles of breads and pastries. Higher gluten content produces lighter and softer baked products by embedding small gas bubbles. Jackfruit seed flour has high carbohydrate, especially fibre and other nutritional content (Jinshui *et al*., 2002). The seeds are thus blended into flour and mix with other flours in baking (Verheij, 1991). The amount of protein (gluten) in flour is an indicator of bread-baking quality for plain white flour (http://home.earthlink.net/~ggda/flour_summary.htm).

2.5.4 Composite Flours

Composite flours have become important mainly due to the rising demand and cost of importing wheat flour to countries where the climate is not suitable for growing wheat. Attempts have been made to replace wheat flours with flour from vegetable sources for food product development. Although vegetable flour has been successfully used for food products, the substitutes have usually been in combination with wheat in order to produce products of desirable characteristics. Different types of flours are sometimes blended together to enhance specific quality attributes (Dendy, 1993). For instance Liener (1981), indicated that the relatively high protein content of soybean along with its relatively high lysine, trptophan and minerals grant soybeans the potential for use to supplement maize and other flours. According to Seibel (2012), composite flours vary in their use and includethe production of bread, pasta and pastries. According to the author, composite flours for bread and baked products could have as much as 30% of wheat substituted by other vegetable flours such as cassava, maize and soy.

2.6 FUNCTIONAL PROPERTIES

2.6.1 Bulk Density

Bulk density is defined as the ratio of weight of flour to flour volume in grammes per centimeter cube, (Subramanian and Viswanathan, 2007). It is a measure of heaviness of a flour sample. Bulk density is directly proportional to starch content of flour (Oti and Akobundu, 2007) and increases with increase in starch content (Bhattachrya and Prakash, 1994). Therefore, in the food processing industries, knowledge of bulk density provides an idea of the amount of starch in the food material and also how the individual particles of the flour can arrange themselves in a compact manner. Bulk density helps in determining suitable packaging requirements of the flours as it relates to the load the sample could carry if allowed to rest directly on one another. It gives a measure of the mass relative to the space occupied by the food substance. High values are indicative of high cost of packaging (Oluwatooyin *et al*., 2002) as more materials would be required. Bulk density also relates to mouth feel and flavor of food. Bulk density is affected by moisture and it reflects particle size distribution of the flour (Etudaiye *et al.*, 2009).

2.6.2 Water Absorption Capacity

Water absorption capacity of flour is defined as the differences in weight of the flour before and after water absorption, (Abbey and Ibeh, 1988). It describes flour–water association ability under limited water supply. Imbibition of water is an important functional trait in foods such as sausages, custards and doughs (Adebowale *et al*., 2005).

Depending on a protein side chain (number of charged and polar group), a protein may bind varying amount of water (Vaclavik and Christian, 2003). The interaction of proteins with water is important to properties such as hydration, swelling, solubility and gelation.

Water absorption capacity is specific for each type of starch, and it depends on several factors such as amylose:amylopectin ratio, intra and inter molecular forces and size of granules, (Rahman *et al.*, 1999). The smaller the size of the granules, the higher the absorption capacity (Singh *et al.*, 1991). Water absorption capacity varies with protein source, composition, previous processing, such as heating and alkali processing (Ikegwu and Ekumankana, 2010). It is a function of ionic strength, pH, temperature, size and shape of the protein molecules. According to Etudaiye *et al*. (2009) gelatinization of carbohydrates and swelling of crude fiber may also occur during heating, leading to increased water absorption. The water absorption capacity of flour is an indication of the amount of water available for gelatinization (Edema *et al*., 2005). It is a useful indication of whether protein can be incorporated with aqueous food formulations, especially those involving dough handling such as processed cheese, sausages and bread dough (Osungbaro *et al*., 2010).

High water absorption capacity of flours suggests the possibility of presence of some hydrophilic proteins or polar amino acid residue in the flour (Odoemelam, 2000). Similarly, Kaur and Singh (2005) indicated that flours with high water absorption have more hydrophilic constituents, such as polysaccharides. Increase in water absorption capacity may be due to effect of water adsorption via existing polar binding sites distributed over the protein surface, and molecular rearrangement leading to the exposure of more polar binding sites. High water absorption may also be due to the nature of the starch and possible contribution to water absorption by the cell wall materials (Sathe and Salunkhe, 1981a; 1981b). Sanni *et al.* (2006) reported that high water absorption capacity is attributed to lose structure of the starch polymers while low value indicates the compactness of the molecular structure.

2.6.3 Oil Absorption Capacity

Oil absorption capacity is defined as the difference in weight of flour before and after oil absorption (Giami *et al.*, 1994). Oil absorption capacity is an important property in food formulations. Oils improve flavor and increase the mouth feel of the food. Oil absorption capacity aids food formulations (Odoemelam, 2000) and gives an indication of flavor-retaining capacity of flour (Narayana and Narasimga, 1982). Moreover, it is useful in structure interaction in food including extension of shelf life particularly in bakery or meat products (Adebowale and Lawal 2003a). Hydrophobic proteins show superior binding of lipids, implying that non-polar amino acid side chains bind the paraffin chains of fats (Adejuyitan *et al*., 2009; Kaur and Singh, 2005).

2.6.4 Swelling power

Swelling power is defined as the ratio of weight of paste to the weight of dry flour (Crosbie, 1991). Swelling power is an indication of the water absorption index of the granules during heating (Loos *et al*., 1981). Dengate (1984) stated that swelling power is seen as mainly the result of granule swelling permitting the exudation of amylose. Swelling of starch granules is the first stage in the initiation changes in hydration related properties (McComick, *et al*. 1991). When an aqueous suspension of starch granules is heated, these structures are hydrated and swelling takes place. King (2005) and June *et al*. (1991) reported that starch granules in suspension swell when heated, as the temperature is raised, hydrogen bonds continue to be disrupted, water molecules become attached to liberated hydroxyl groups and the granules continue to swell. Usually the higher the swelling power, the more soluble the flour is in a solution. Moorthy and Ramanujam (1986) suggested that the swelling power of granules reflected the extent of the associative forces within the granule.

Accordign to Galvez and Resurreccion (1993), starches have been classified as high swelling, moderate swelling, restricted swelling, or highly restricted swelling. High-swelling starches have swelling power of approximately 30% or higher at 95°C. Their granules swell enormously and the internal bonds become fragile toward shear when the starch is cooked in water. Restricted-swelling starches have swelling power in the range of 16-20% at 95°C. The cross-linkages in their granules reduce swelling and stabilize them against shearing during cooking in water (Galvez and Resurreccion, 1993).

Adebowale *et al*. (2005) reported that differences in swelling indicate differences in molecular organization within the starch granules. Swelling power has been related to the associative binding within the starch granule, and apparently, the strength and character of the micellar network is related to the amylose content of the starch, low amylose content, produces high swelling power (Duke and Alan, 1986). On the other hand, Tester and Morrison (1990) reported that swelling behavior of cereal starches are due to the property of their amylopectin. However, amylose acts both as diluents and inhibitor of swelling especially in the presence of lipids. Ayenor (1985) has indicated that high swelling capacity of starches might be due to weak internal bonding between starch granules.

Iwe (2003) reported that swelling is often affected by processing time. Doublier *et al* (1987) and Shamekh *et al.* (1994) demonstrated that lipid removal from oat starch resulted in reduction of swelling power. According to Shimelis *et al*. (2006) the presence of starch and protein could lead to attraction of their opposite charges and form inclusion complexes during gelatinization restricting swelling. Similarly, it has been reported by Zeleznak and Hoseney (1987) that amylose acts both as diluents and inhibitor of swelling, especially in the presence of lipids which can form insoluble complexes with some of the amylose during swelling and gelatinization. Pomeranz (1991) indicated that the formation of protein-amylose complex in native starches and flours may be the cause of decrease in swelling power.

2.6.5 Solubility

Solubility is indicative of water penetration ability into starch granules of flours. Modification of starches could be important to absorption and retention of water to increase swelling powers of starches required in the manufacture of confectionery goods (Ikegwu and Ekumankana, 2010). The increased leaching of solubilized amylose molecules from swelled starch granules results in increased solubility (Tumaalii and Wooton, 1988). On the other hand, Doublier *et al.* (1987) and Shamekh *et al.* (1994) demonstrated that lipid removal from oat starch resulted in increased solubility.

The swelling power and solubility of flour indicates the existence of strong bonding forces probably due to high amount of protein and fat that might form inclusion complexes with amylose (Pomeranz, 1991).

In food preparations where maximum solubility of protein is desired, as in aqueous emulsions and gel food preparations flours with good nitrogen solubility are useful (Akinyele *et al*., 1986).

Low swelling accompanied by the high solubility is indicative of the weak associative forces in the starch granules in these species (Aryee *et al.*, 2006). Swelling power and solubility have been used to provide evidence for associative binding force within the granules.

2.6.6 Foaming Capacity (FC) and Foam Stability (FS)

Foam capacity is the ability of a substance, in this case flour, in a solution to produce foam after shaking vigorously or stirring while foam stability is defined as the volume of foam that would remain one hour after shaking of a solution, which is then expressed as a percentage of the initial foam volume (Narayana and Narasimga, 1982).

Proteins foam when whipped because they are surface active. According to Adebowale and Lawal (2003b), increase in concentration of proteins enhances greater protein–protein interaction, which increases viscosity and facilitates formation of a multilayer cohesive protein film at the interface. Increase in concentration could again lead to formation of thicker films, which limits the effect of drainage of protein from films.

Foam stability is important since the usefulness of whipping agents depends on their ability to maintain the whip foam as long as possible (Lin *et al*., 1974). Foam stability is governed by the ability of the film formed around the entrapped air bubbles to remain intact without draining, it follows that stable foams can only be formed by highly surface-active solutes (Cherry and McWatters, 1981).

According to Nunoo (2009) increase in foaming capacity (FC) may be due, in part, to higher diffusion of the unfolded and fragmented proteins towards an air-water interface. Increased unfolding and fragmentation of protein may enable the formation of more continuous phases of thin liquid layers which trap air bubbles, resulting in increased foaming capacity.

Flours with high foam capacity and stability such as cowpea is useful as aerating agents in food systems such as *akara* and *moi –moi* which requires the production of stable foam volumes when whipped (Akinyele *et al*., 1986).

2.6.7 Least gelation concentration

Least gelation concentration (LGC) is an index of gelation. According to Circle *et al.* (1964) gels are characterized by their viscosity, plasticity and elasticity. Sathe *et al.* (1982) indicated that the variation in gel formation of flours could be incidental on the relative ratios of proteins, carbohydrates and lipids. Low LGC is related to amylopectin and oxidized amylose. The gel strength of amylopectin is attributed to the rigidity provided by its crystalline nature (Ikegwu *et al*., 2009). Lawal *et al*. (2004) reported that these crystalline areas, both within the swollen granules and in the aqueous solution between the granules, improve the strength and rigidity of starch gel.

High gelation properties may be due to the enhanced interaction that occurs among the binding forces as the concentration increased (Ikegwu *et al*., 2009). Visser and Thomas (1987) reported that rate of gelling and gel firmness depends on temperature, time of heating and protein concentration. Physical competition for water between protein and starch for gelation and gelatinization respectively influences the least gelation concentration (Singh, 2001).

2.7 PASTING PROPERTIES

2.7.1 Meaning of pasting properties

Pasting is the result of a combination of processes that follow gelatinization from granule rupture to subsequent polymer alignment due to mechanical sheer during the heating and cooling of starch (Otegbayo *et al*., 2006).

Since flours are cooked into paste before consumption, determination of pasting characteristics of flours are important in predicting quality index and the behavior of paste during and after cooking (Etudaiye *et al*., 2009).

2.7.2 Gelatinization

When starch is heated in the presence of sufficient water, its granules swell, and the crystalline organization in starch decomposes (Donovan, 1979) to form amorphous regions. This molecular disordering is called gelatinization and is manifested by irreversible changes in properties (Rojas-Molina *et al.*, 2007). Several changes may occur upon heating a starch-water system, including enormous swelling, increased viscosity, translucency and solubility. These changes are defined as gelatinization (Ikegwu and Ekumankana., 2010).

Jenkins and Donald (1998) indicated that water first enters the amorphous growth rings, causing these regions to swell. After a significant amount of water enters the amorphous regions, a large amount of swelling occurs, providing sufficient stress through connectivity of molecules from the amorphous growth ring to the semi-crystalline lamellae, resulting in the disruption of starch crystallites, which is evidenced by the loss of crystallinity. Huang *et al.* (2007) however, reported that amylopectin molecules are involved.

Gelation of protein also occurs in flour pastes and is very important for the preparation of puddings, jams and sauces that require thickening and jelling. Some kinds of proteins form gels through interactions with polysaccharide gelling agents such as starch and gelatin (Nunoo, 2009).

2.7.3 Role of starch

According to Adebowale *et al*. (2005) starches are the principal food reserve polysaccharides in plants and are of both nutrition and economic benefit in human diets. Starches with their wide applications have generated demand in the food industry. Starch is convertible to many useful materials by chemical and biochemical techniques (Eliasson and Gudmundsson, 1996). It plays an important role in food industries because it affects the physical properties of many foods and it has many uses such as thickeneing, water binding, emulsion stabilizing and gelling. Starches from various plant sources have their own unique properties that enable them to tolerate a wide range of processing techniques as well as various distribution, storage and final preparation conditions (Daniel and Weaver, 2000; David and William, 1999; Buleon *et al*., 1998).

Hoover *et al*. (1991) reported that starch granule can be separated into 2 distinctly different components, amylose and amylopectin. The molecular arrangement in a starch granule can be altered by various physical treatments. According to Adebowale *et al*. (2005) physical treats can change certain starch properties.

Starch characteristics such as swelling power and solubility pattern, pasting behaviour and physico-chemical properties are important for improved quality of food products and could be utilized for the development of composite blends from small scale industry level as value-added products (Ikegwu and Ekumankana, 2010).

2.7.4 Importance of pasting properties

From the consumers' point of view, the pasting properties of a product are critical to their acceptance (Zhou *et al*., 1998). Pasting characteristics of starches have been associated with cooking quality and texture of various food products (Moorthy, 1994, 2002; Kim *et al*., 1995). Pasting characteristics play an important role in the selection of a crop species for use in the industry as thickeners, binders or for any other use (Aryee *et al.* 2006).

According to Aryee *et al*. (2006) food flours with high gelatinization temperatures cannot be used directly as brewery adjunct since their gelatinization temperatures do not fall within the range for barley malt. They will have to be either pre-gelatinized or processed further into glucose syrup before they can be used as adjuncts.

For use as thickeners, the paste formed should not retrograde and should also have high paste stability, when cold or hot (Aryee *et al*., 2006). Generally for starches, high viscosity is desirable for industrial uses, for which a high thickening power at high temperatures is required (Kim *et al*., 1995).

2.7.5 Classification of viscosity pattern and use of each type of starch

Classification of viscosity pattern is important to categorize starches for end product recommendation (Shimelis *et al*.,. 2006) A restricted type of swelling is mostly desired for the starch extracts for the manufacture of value added products such as noodles. Composite blends with cereals importantly require that the starch granules swell sufficiently and remain intact and stable against sheering during the process (Galvez and Resurreccion, 1993).

2.7.6 Factors affecting pasting properties

Pasting characteristics are determined predominantly by the content and nature of starch and beta-glucan fractions ameliorated by the lipid, protein and other non-starch polysaccharides (Zhou *et al*., 1999). Pasting properties are known to be affected by amylose, lipid and phosphorous content as well as starch granule size (Peroni *et al*., 2006). Zhou *et al*. (1998) have also reported that important factors affecting pasting properties include starch granule size, starch composition, processing ingredients and chemical pretreatment.

The intrinsic viscosity of oat starch amylose has been reported to be negatively correlated with protein content of the parent flour Zhou *et al*., 1998). On the other hand, the intrinsic viscosity of starch amylopectins decreased as the flour protein decreased. Amylose and starch lipid contents were positively correlated with the onset of gelatinization of oat starches (Harunian-Sowa and White, 1992; Wang and White, 1994).

Gibinski *et al.* (1993) reported that lipid removal from oat starch decreased peak viscosity, setback and gelatinization temperature.

On the order hand, Virtanen *et al.* (1993) in their work observed that acid modification (which could happen with fermentation) of oat starch granules caused substantial changes in the pasting behavior and decreased viscosity of oat starch.

2.7.7 Significance of pasting properties

2.7.7.1 Pasting/Gelatinization temperature

Pasting temperature is the temperature it takes for the paste to gel during cooking. It provides an indication of the minimum temperature required for sample cooking, energy costs involved and other components stability (Shimelis *et al*., 2006). It has implications on the stability and other components in a formula and also indicates energy loss (Etudaiye *et al.*, 2009). Gelatinization temperature has been known to depend on the size of the starch granule; small granules are more resistant to rupture and loss of molecular order (Rincon and Padilla, 2004).

High gelatinization temperature of starches indicates that the starch granules resist swelling. According to Cooke and Gidley (1992) higher pasting temperatures reflects stronger crystalline structures or more molecular orders. Higher pasting temperatures may be related to the presence of stronger bonding forces with the granule interior (Opata *et al*, 2007). Ikegwu *et al*. (2009) attributed high pasting temperature to amylopectin's high crystalline nature which is known to resist gelatinization compared with amorphous amylase.

2.7.7.2 Peak/Maximum viscosity

Peak viscosity is the highest viscosity achievable during cooking of flour pastes. It is the maximum viscosity developed by a starch-water suspension during heating (Adebowale *et al*., 2005). It gives an indication of the ability of starch to swell freely before their physical breakdown. It is an important distinguishing factor of a given starch from given species (Rincon and Padilla*l*., 2004). Variation in the peak viscosity could be as a result of the amylose contents of the starches (Oledinma *et al.*, 2009). Relatively high peak viscosities of starches are indicative that the starches may be suitable for products requiring high gel strength and elasticity (Ikegwu and Ekumankana, 2010). Peak viscosity is linked to the ease of cooking and indicative of the strength of pastes which are from gelatinization during processing in food applications (Opata *et al.*, 2007).

Jacobs *et al.* (1995) indicated that the formation of tightly packed array of swollen and deformable granules and the leaching of amylose can contribute to viscosity development in starch paste during heating. According to the authors, rigidity of granule increase due to insufficient gelatinization giving higher viscosity to paste due to the fact that rigid granules are more resistant to shearing. Increases in swelling power and solubility lead to viscosity increment since better dispersion of starch in aqueous systems and water absorption are obtained due to hydrophilic substituting groups that allow the retention of water molecules because of their ability to form hydrogen bonds (Acona *et al.*, 1997).

Increase in viscosity with rising temperature may be attributed to the removal of water from the exuded amylose by the granules as they swell (Ghiasi *et al.*, 1982). Low peak viscosity might be due to the action of fat and protein stabilizers, preventing water from getting access to the granules resulting in a decrease in starch granule swelling (Opata *et al*., 2007). On the other hand higher peak viscosity of pastes implies ability to form thicker pastes on cooking due to higher swelling power of starches (Otegbayo *et al*., 2006). Sandhu and Singh (2007) showed that there is a significant negative correlation (r = -0.86) between protein content and peak viscosity of corn flour. Amylopectin increases peak viscosity due to high water binding capacity of the starch granules while oxidized amylose result in low peak viscosity indicating low water binding capacity of the starch (Ikegwu *et al*., 2009)

2.7.7.3 Setback

Setback value is the difference between final viscosity and hot paste viscosity or trough. It is a measure of the stability of paste after cooking. It is the phase where during cooling of the mixture, a re-association between the starch molecules occurs to a greater or lesser degree. Setback viscosity gives an indication of retrogradation or reordering of starch molecules during heating.

It, therefore affects retrogradation or re-ordering of the starch molecules. It is also associated with syneresis. Low set back values indicate high stability (Etudaiye *et al.*, 2009) of paste and greater resistance to retrogradation (Sanni *et al.*, 2004) and syneris. Retrogradation is a general term for the behaviour of recrystallization of gelatinized starches on cooling and storage, and is accompanied by gel hardening and the leakage of water (syneresis) from the starch gel (Nunoo, 2009).

Peroni *et al*. (2006) indicated that flours with low setback may possess low values of amylose of high molecular weight. Decrease in viscosity on cooling indicates the absence of retrogradation or setback (Aryee *et al.*, 2006). A low setback value indicates that flour gives a non-cohesive paste (Kim *et al*., 1995). This means that such starches cannot be used for products in which starch stability is required at low temperatures, such as adhesives. Bajner (2002) observed that the addition of stearic acid to maize starch resulted in reduced viscosity on cooling due to setback.

Increase in setback may be attributable to higher starch concentrations encouraging the formation of a more ordered structure, which in turn trapped enough water, forming stronger gels with higher viscosities. This phenomenon may increase the tendencies for retrogradation accompanied by syneresis (Nunoo, 2009). The higher the setback value, the lower the retrogradation during cooling of the products made from the flour (Ikegwu and Ekumankana., 2010).

Setback viscosity is an important factor for starch used as a food ingredient in processing and preservation, because the quality of the food's texture and physical properties deteriorate due to retrogradation as time passes.

Kim *et al*. (1995) has indicated the association of setback values with cohesiveness of paste in potato. Oladele and Aina (2007) have attributed low setback and breakdown (i.e. good stability to heating and mechanical shear) viscosities of tiger nuts to their high fat contents (32.13%-35.43%).

2.7.7.4 Hot paste viscosity

The hot paste viscosity at 95^{o}C is indicative of additional breakdown of granules due to stirring, reflecting the stability of the hot paste (Carnali and Zhou, 1996). It gives a measure of the tendency of the paste to breakdown during cooking.

Hot paste viscosity has been attributed to the mixed effect of swollen starch granules, granule fragments, dispersed colloidal starch molecules, molecularly dispersed starch molecules, rate of amylose exudation, and competition between exuded amylose and remaining free water (Gebrie-Mariam *et al*., 1998).

High paste stability is an indication of very weak cross-linking within the starch granules. This means that such starches cannot be used for products where starch stability is required at very high temperatures, because they will breakdown (Aryee *et al.,* 2006). Lower breakdown of hot paste is attributable to a starch maintaining its structural integrity under shear and heat implying such starch could be used in food products that require continuous heating like those for children and the elderly (Gebrie-Mariam *et al*., 1998)

2.7.7.5 Cold paste

According to Carnali and Zhou (1996) the cold paste viscosity at 50^{o}C is an indicator of stability of the cold paste. Increase in cold paste viscosity indicates the association of the elements present in the paste as the temperature of the paste decreases.

Rincon and Padilla (2004) reported that the extent of increase in viscosity on cooling hot starchy paste is governed by the starch retrogradation tendency and is mainly determined by the affinity of hydroxyl groups of one molecule for another. Amylose molecules being randomly dispersed can orient themselves in parallel fashion to form aggregates of low solubility leading to gel formation. Increase in viscosity on cooling is attributable to high retrogradation tendency of the amylose fraction (Rincon and Padilla., 2004).

2.7.7.6 Breakdown

Low breakdown is indicative of good paste stability. The smaller tendencies to retrograde are an advantage in food products such as soups and sauces, which undergo loss of viscosity and precipitation as a result of retrogradation (Adebowale and Lawal, 2003a).

Higher breakdown values of pastes imply that there is less granule rupture in a starch implying stability of paste (Farhat *et al*., 1999). Oduro *et al.* (2000) explained that starches with low paste stability or breakdown show weak cross-linking among the granules. The higher the breakdown in viscosity, the lower the ability of the sample to withstand heating and shear stress during cooking (Ikegwu *et al*., 2009)

2.7.7.7 Final viscosity

The final viscosity is the change in the viscosity after holding cooked starch at 50°C. It gives an idea of the ability of a material to form gel after cooking. Final viscosity is used to define the particular quality of starch and indicate the stability of the cooked paste in actual use. It also indicates the ability to form paste or gel after cooling (Ikegwu *and* Ekumankana, 2010). Final viscosity is the most commonly used parameter to determine a particular starch-based sample quality (Sanni *et al*., 2006).

Increased final viscosity on cooling is indicative of a starch forming firm gel after cooking and cooling. It can be an important parameter in predicting and defining the final textural quality of pounded yam in terms of its springiness (Otegbayo *et al*., 2006). Variation in the final viscosity might be as a result of modification of the native amylose (Ikegwu *et al*., 2009).

Starches with high final viscosities might be used as thickening and stabilizing agents in products such as baked products (Ikegwu *et al*., 2009).

2.7.7.8 Peak time (Time taken to reach peak viscosity)

Peak time is the time at which the peak viscosity occurs (Lawal *et al*., 2004). It is the time it takes for the pastes to gel during cooking.

2.7.8 Instruments and measurement of pasting properties

Determination of gelatinization properties of starch, indicated by the viscosity of flour-water suspension during heating is done by Amylograph. Amylograph has been used traditionally for wheat and rye flours. However, it has found use in other flours (ICC, 1992).

The amylograph viscosity is the resistance, measured in Brabender Units (BU) of a flour-water suspension heated in a Brabender Amylograph at a constant rate of increase of temperature and with the bowl rotating at a specified, constant rotational speed (Brabender, 2010; Stanojeka and Sokoloski, 2012).

According to Zhou *et al*. (1998), three main instruments, the amylograph, the Ottawa Starch Viscometer (OSV) and the Rapid ViscoAnalyser (RVA) have been the main instruments used. However, rheometer is also in use. (. According to Zhou *et al*. (1998) the RVA is characterized by faster and stronger mixing action than the OSV, which in turn has a stronger mixing action than the amylograph. Deffenbaugh and Walker (1989) indicated that when the heating rate was controlled to 1.5^{o}C/min, the results obtained on the RVA (using wheat flour) were similar to those obtained on the Amylograph, with correlation coefficients of the order 0.90.

The Brabender Visco-Amylograph is the most common instrument used for determining pasting characteristics of flours and characterization of starches all over the world (Balagopalan *et al*., 1988). It is a rotational instrument which allows a continuous determination of viscosity (in arbitrary Brabender units) at either a constant temperature or constant increasing or decreasing temperature. The rotating sample bowl contains a number of fixed vertical pins and is driven at constant speed by a synchronous motor. A circular metal disc with several pins projecting downwards into the sample serves as the sensory element. When the viscosity of the sample increases, the force exerted by the sensory element is dynamically balanced by a calibrated tension spring. Attached to the spring is a pen by means of which the changes in viscosity of the paste are recorded on a chart of the strip type. It has means for controlling the temperature rise so that it occurs at the constant rate of 1.5^{o}C/min. The heating rate of 1.5°C/min corresponds with the temperature increase of bread during baking. The Brabender requires 90 minutes to complete the amylogram.

When the paste is heated the starch granules gelatinize and swell. It absorbs a great deal of the available water which causes the viscosity to rise. The temperature at which the viscosity begins to rise is termed the pasting temperature (Naruenartwongsakul *et al*., 2004).. It is not the same as the gelation temperature since considerable granule swelling must occur before a viscosity increase is reached. Difference in pasting temperature could be due to the effect of gelation temperature of hydrocolloids (Naruenartwongsakul *et al*., 2004).

As heating continues, granule rupture increases and viscosity gradually decreases. The drop in viscosity when holding at 95^{o}C reduces the stability of the paste. On cooling the paste to 50^{o}C the viscosity usually increases. The extent of this increase reflects the retrogradation tendency of the starch which is greater with rising amylose content (Tan, 2003).

A graph or amylograph obtained contains six significant points (Zobel, 1988; Whistler and BeMiller, 1996)

- Pasting temperature: initiation of paste formation
- Peak viscosity:
- Viscosity at 95^{o}C which in relation with the peak viscosity gives an idea of cooking of starch
- Viscosity of the paste at 95^{o}C for a certain period reflects the stability or breakdown of the paste
- Viscosity of the paste after cooling to 50^{o}C is a measure of the setback produced by cooling
- Final viscosity after stirring for a definite period at 50^{o}C indicates the stability or breakdown of the paste.

The amylograph gives a graph consisting of four distinct phases namely, pre-gelatinization, gelatinization peak, drop-off (as stirring – enzymes if present-degrade the structure of the gelatinized starch) and setback (the increases in viscosity that follows cooling) (Zhou *et al*., 1998).

2.8 DIGESTIBILITY OF FOOD

According to Bender (2005) digestibility is defined as the proportion of food absorbed by the digestive tract into the bloodstream. It is measured as the difference between food intake and feacal output. This is known as ‘apparent’ digestibility. When an allowance is made for that part of the feaces that is not derived from undigested food residues (shed cells of the intestinal tract, bacteria, residues of undigested juices) it is known as ‘true’ digestibility.

The digestibility of food is influenced by many factors including the type of feed, extent of starch protein interaction, inhibitors or anti-nutrients such as tannin (Rooney and Pflugfelder, 1986) and cell wall composition (fiber composition) (Jung and Allen, 1995). They have been reported to either interfere in digestion or inhibit the absorption of nutrients (Elhag *et al*., 2002).

2.8.1 Tannins

Allelochemicals such as tannins are chemical compounds produced by plants as adaptations for self defence (Aletor, 1993). When tannins form complexes with protein enzymes it results in reduced digestion and absorption (Osuntogun *et al*., 1987). Tannins have been reported to bind Fe making it unavailable (Brune *et al*., 1991). They are also known to cleave DNA in the presence of copper ions (Shirahata *et al*., 1989).

According to Akindahunsi *et al*. (1999) cassava contains 0.19% tannin. Fagbemi *et al.* (2005) reported that breadnut contain tannin content of 9.2 g/100g, whereas cashew nut and fluted pumpkin seed flour contain 19.1 g/100g. The authors reported *invitro* protein digestibility of 71.3%, 72.0% and 74.3% for breadnut, fluted pumpkin and cashew nut seed flours respectively. On the other hand, *T. africana* has been reported not to contain tannin (Akinmutimi, 2006).

2.8.2 Crude fiber

Total dietary fibre is defined as the polysaccharides and lignin in food resistant to mammalian digestive enzymes (van Soest *et al*., 1991). Legumes are second to cereals as important sources of dietary fibre (Perez-Hidalgo *et al*., 1997). Intake of dietary fibre has potential to protect against cardiovascular diseases, diabetes, obesity, colon cancer and other diverticular diseases (McPherson, 1992).

According to Morse and Sedivic (1990) fiber analysis helps nutritionists to estimate feed intake, digestibility of feed, energy content and expected animal performance. Fiber analyses are similarly used to analyze human food (Johnson and Marlett, 1986).

Important fiber components include neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL). The fiber concentration of forage and animal feeds are routinely established using the NDF, ADF and ADL tests (Richards *et al*., 2005). Sequential analysis of fiber helps provide estimates of hemicelluloses and cellulose contents in food (Openwetware, 2011). Belyea and Ricketts (1993) indicated that the detergent fiber analysis method separates a forage into 2 parts namely, cell soluble and detergent fiber. Cell soluble include starches, proteins, sugars and other highly digestible components. On the other hand, detergent fiber provides structural support for plants and is not as digestible as cell soluble. Detergent fiber values are important in ration formulation because they reflect the amount of forage the animal can consume (Schroeder, 1994).

2.8.3 Nuetral Detergent Fiber (NDF)

Insoluble fiber in feed includes the cross-linked matrix of plant cell wall. It is measured conveniently as NDF (van Soest *et al*., 1991). NDF contains all the fiber being hemicelluloses, cellulose and lignin (van Soest *et al*., 1991). It accounts for belly fill. As NDF percentages increase, dry matter intake generally decreases (Schroeder 1994). NDF is determined by boiling a food sample with detergent at pH of 7 (Belyea and Ricketts, 1993). NDF is used to estimate cell wall carbohydrates. Since there are differences in NDF rumen degradation and its influence on animal performance, the knowledge of NDF is critical for effective feeding (Oba and Allen, 1999). Ahmad and Wilman (2001) indicated that incomplete degradation of cell walls is a major factor limiting the value of animal feed. Lignin is the primary component responsible for limiting the digestion of forages (van Soest, 1994; Traxler *et al*., 1998). van Soest (1994) indicated that forage digestibility in ruminants is constrained by the extent of cell wall (NDF) digestion.

2.8.4 Acid Detergent Fiber (ADF)

According to Schroeder (1994) ADF refers to the cell wall portions of the forage that are made up of cellulose and lignin which relate to the ability of an animal to digest forage. The author indicated that as ADF increases, digestibility of forage usually decreases.

ADF is analysed at pH=2. The procedure dissolves away hemicelluloses and cell soluble. It is related to Digestible dry matter (DMD). The digestibility of ADF is between 20 and 80% (Belyea and Ricketts, 1993)

2.8.5 Acid Detergent Lignin (ADL)

ADL is measured by further treating ADF with strong acid (Belyea and Ricketts, 1993) which dissolves away cellulose or with permanganate which oxidizes or removes lignin. Nousiainen *et al*. (2004) indicated that indigestible NDF is the most important factor affecting the total diet organic matter digestibility. ADL is the single most important predictor of indigestible NDF content of forages and crops (Janick *et al.*, 2008; Traxler *et al*., 1998; Huhtanen *et al*., 2006). Their reports indicate that higher ADL values result in lower invivo organic matter digestibility. According to Belyea and Ricketts (1993) the digestibility of ADL ranges between 0% and 30%.

2.8.6 Dry matter digestibility (DMD), Net Energy for Lactation (NEL) and Relative Feed Value (RFV)

DMD is an estimate of the digestibility (Schroeder, 1994). According to Belyea and Ricketts (1993) the test for DMD simulates digestibility in the cow at the laboratory and it is less expensive and less time consuming. As the percent ADF increases, the estimated digestibility and net energy available for production in an animal/man decreases (Schroeder, 1994). Schroeder (1994) indicated that relative feed value (RFV) is an index that combines the important nutritional factors of intake and digestibility. According to the author it has no units, but the index allows comparisons of legumes, grass, and legume-grass forages. Forage with ADF of 41 percent and NDF of 53 percent has an index of 100. Other forages can then be compared against this value. As percentage ADF and NDF decrease, the RFV increases.

2.9 SUMMARY AND GAP IN KNOWLEDGE

2.9.1 Functional Properties Of Breadfruits

Akubor *et al*. (2000) reported that *T. africana* had bulk density of 0.74 g/cm^3. Odoemelan (2005) reported on the functional properties of *Artocarpus heterophyllus* found in Nigeria. The author observed water absorption capacity of 2.3 and oil absorption capacity of 2.8 ml/g, whereas bulk density was 0.61 g/ml and foam capacity of 7.1 g/ml.Work done by Adebowale *et al*. (2005) showed that native starch of *A. altilis* was a better gelating food material than its modified derivatives.

The pasting behavior of *A. altilis* pulp starch was characterised by Rincorn and Padilla (2004). According to them the peak viscosity of *A. altilis* starch (3509 BU) is higher than both wheat (1704 BU) and maize (1523 BU). Similarly it had higher final viscosity (3971 BU) than wheat (2550 BU) and maize (1874 BU).

2.9.2 Sensory attributes of products formulated using breadfruits

Onweluzo and Nwakalor (2009) produced consumer acceptable vegetable milk from *T. africana* seeds. Giami and Amasisi (2003) successfully produced bread by replacing 10% of wheat flour with *T. africana*. The bread had crust colour, crumb colour, crumb texture, loaf height and loaf volume which were similar to that produced with 100% wheat flour. Similarly Esuoso and Bamiro (1995) produced acceptable bread by replacing 10% of wheat flour with *A. altilis* pulp flour. Nochera and Caldwell (1992) reported that *A. altilis* could be used to replace 10% wheat flour for biscuit production without adverse effects. Nwabueze and Atuonwu (2007) in a study of substituting *T. africana* for wheat flour indicated that *T. africana* could replace 20% of wheat for biscuit production. Runsewe-Abiodun *et al*. (2001) indicated that *T. africana* could be useful in the nutritional rehabilitation of children with mild to moderate protein-energy malnutrition. Nelson-Quartey *et al*. (2007) produced an infant food based on *A. altilis* and *A. camansi*. Baccus-Taylor and Akingbala (2007) reported that consumer acceptable canned sliced *A. altilis* in Trinidad.

2.9.3 Inter-relationships between physico-chemical properties *T. africana*

Nwabuenze and Nwokenna (2006) reported on the relationships between some physico-chemical properties of *T. africana* seeds. According to them seed size was more correlated with cooking time than swelling and hydration properties. They further reported that amylose content of *T. africana* was accounted for its water absorption and hydration properties which also influenced cooking time.

Conclusion

This review has clearly revealed that breadfruit species (*A. heterophyllus*, *A. altilis*, *A. camansi* and *T. africana*) fruits are used as food and have played important food security roles in the countries where they are found. Even though the species have been well characterized in terms of their botany, traditional food uses and proximate composition, there is insufficient information on their functional properties including pasting characteristics. Available literature did not provide sufficient information about their potential for modern food and industrial uses. Again, the relationship among their physico-chemical properties have not been sufficient ly reported. No information has also been reported on the use of their chemical composition to predict their digestibility. Research into these untapped areas would bridge the knowledge gap and make sufficient information available to Food Scientists as well as Nutritionists to make informed decisions about their uses. Invariably, if the knowledge gap is bridged breadfruits will find expanded uses, would help in combating of malnutrition, play better roles in ensuring food security and potentially be a good source of livelihood for those engaged in it.

CHAPTER THREE

MATERIALS AND METHODS

3.1 SURVEY/BASELINE STUDY

A survey was conducted in six regions (Western, Volta, Eastern, Central, Ashanti and Brong Ahafo) of Ghana. Purposive sampling was used in the selection of regions and communities. The selection of the regions was based on natural ecological habitats of breadfruits being, forest zones with altitude of up to 1500m, mean annual rainfall of 1250-3000mm and mean annual temperature of 22-35^{o}C (Orwa *et al.*, 2009; Ragone, 2006a; Ragone, 2006b). On the other hand, the communities were selected based on referred leads by staff of the Forestry Commission of Ghana as well as the general public based on their familiarity with the species. Structured questionnaires were administered to inhabitants (273; 153 for *Artocarpus* spp. and 120 for *Treculia africana*) of identified communities (Appendix A1). Information generated during survey included known species of breadfruits, traditional uses and processing methods, fruiting period and known adverse effects after consumption. Field visits were also carried out to confirm responses from the respondents.

3.2 EXPERIMENTAL LOCATIONS

All proximate determinations were carried out at the Biochemistry Department of the Crops Research Institute of the Centre for Scientific and Industrial Research at Fumesua. Functional properties were determined at the laboratories of Department of Food Science and Technology as well as the Postharvest Technology Section of the Department of Horticulture, Kwame Nkrumah University of Science and Technology

(KNUST), Kumasi. Pasting characteristics were determined at the Food Research Institute of the Centre for Scientific and Industrial Research (FRI-CSIR), Accra, Ghana. Mineral analysis was carried out at the Biochemistry laboratory of School of Medical Sciences, KNUST, Kumasi and FRI-CSIR.

3.3 SAMPLE COLLECTION AND PREPARATION

Artocarpus altilis and *Artocarpus heterophyllus* fruits were collected from Kwame Nkrumah University of Science and Technology, Kumasi while *Artocarpus camansi* fruits were from New Tafo-Akim in the Eastern Region of Ghana. *Treculia africana* fruits were obtained from Twifo Praso in the Central Region, Ghana.

Fresh firm and mature *A. altilis* fruits were harvested washed with clean water and transported immediately to laboratory for analyses. Mature ripe fruits of *A. heterophyllus*, *A. camansi* and *T. africana* were harvested and allowed to ferment for 5 days for easy seed extraction. Seeds were extracted from the fibrous pulp, washed and air-dried for 30 minutes prior to analyses.

3.4 PRODUCTION OF BREADFRUIT FLOURS

Figures 3-1 shows the flow diagram for the production of *Artocarpus altilis* pulp flour while Figure 3-2 shows that for *Artocarpus camansi*, *Artocarpus heterophyllus* and *Treculia africana*.

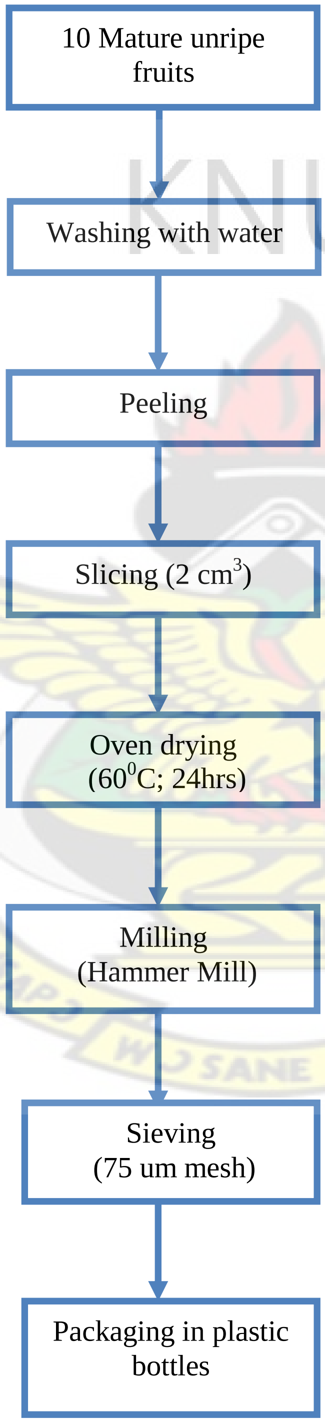

Figure 3-1. *A. altilis* pulp flour production

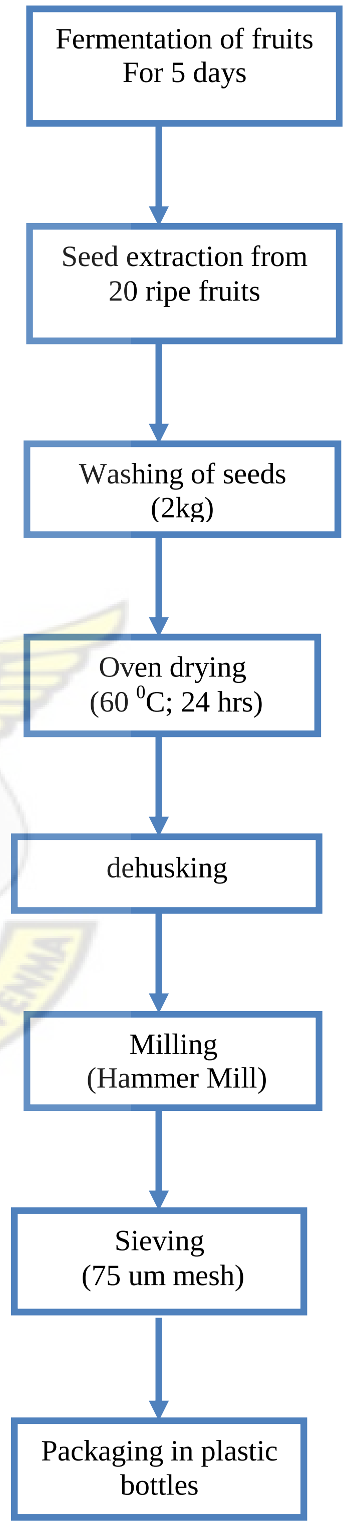

Figure 3-2. *A. camansi*, *T. africana*, *A. heterophyllus* seed flour production

3.4.1 Artocarpus altilis

Ten (10) fresh mature unripe fruits of *Artocarpus altilis* were harvested, washed with clean water, peeled and sliced into cubes (about 2 cm^3) under running tap water. Five kilograms (5kg) of the sliced cubes were immediately placed in an oven (Wagtech-Model GP120SSE300HYD) and dried at 60°C for 24 hours till crisp (moisture content of 9.0%) based on preliminary investigation. Dried slices were cooled and milled in hammer mill and sieved through 75 µm mesh.

3.4.2 Artocarpus camansi, Artocarpus heteropyllus *and* Treculia africana

Seeds were extracted by hand from twenty (20) fruits each of over-ripe *Artocarpus camansi, A. heterophyllus* and *T. africana.* Two kilograms (2 kg) of the extracted seeds were washed in clean fresh water and dried at 60°C in an oven (Wagtech-Model GP120SSE300HYD) for 24 hours (Odoemelam, 2005) to facilitate dehusking (endosperm removal). The dried seeds were milled in a hammer mill and sieved using 75 µm mesh to obtain the flours. The flours were packaged in air-tight plastic bottles prior to analyses.

3.5 PARAMETERS STUDIED

3.5.1 Nutritional Analysis

3.5.1.1 Proximate composition

Determination of moisture content, ash, crude protein, and crude fiber were carried out using methods described by AOAC (1990). Crude fat was extracted using the Soxhlet procedure with petroleum ether (60-80°C). Carbohydrate content was determined by difference (Kirk and Sawyer, 1991).

3.5.1.2 Mineral Analysis

Sample preparation

Two (2) grams of dried milled samples was ashed in previously ignited and weighed crucible. The crucible and content were then placed in Muffle furnace (size 2, England) for 2 hrs at 600^{o}C. The samples were then allowed to cool in an oven to 100^{o}C for 30 minutes, cooled to ambient temperature (28 ^{o}C) in a desicator and weighed. Ash was calculated and expressed as percentage of the original weight. Two milliliters of concentrated hydrochloric acid (HCl) was poured on selected ashed samples to dissolve ash in crucible. Dissolved ash was filtered through Whatmans filter paper no. 540 into dilution tubes. Double distilled water was used to wash left over ash in crucible and poured into dilution tube. This was made up to 25 ml mark using distilled water prior to analysis (AOAC, 1990).

Calcium was determined by O-cresolphthalein complexone method using Optima SP-300 spectrophotometer (Tietz, 1995). Iron cotent was determined by the 1, 10-phenanthtoline method using Optima SP-300 spectrophotometer (Harris, 2003). Phosphorus was determined by Ascorbic acid molybdate method using spectrophotometer (Optima SP-300) (Tietz, 1995). Potassium and sodium were determined by the method of Taffouo *et al.* (2008).) using Jenway Flame photometer. The Calmagite method was used in the determination of Magnesium content and Optima SP-300 spectrophotometer used at 520 nm (Tietz, 1995).

3.5.2 Physical Property

3.5.2.1 Bulk density

The method used by Oladele and Aina (2007) was utilized. A 50 g flour sample was put into 100 ml measuring cylinder. The cylinder was tapped continuously until a constant volume was obtained. The bulk density (g/cm^3) was calculated as weight of flour (g) divided by flour volume (cm^3).

3.5.3 Functional Properties

The following functional properties were studied were; bulk density, water and oil absorption capacity, solubility, swelling power, foam capacity and stability and least gelation concentration.

3.5.3.1 Water and oil absorption capacities

Water and oil absorption capacities of the flour samples were determined as decribed by Abbey and Ibey (1988) with slight modification. One gram of flour sample mixed with 10ml of distilled water or oil was placed in a centrifuge tube. The suspension was agitated for one hour on a griffin flask shaker after which it was centrifuged for 15 min at 2200 rpm. The volume of water or oil on the sediment water was measured. Water and oil absorption capacities were calculated as ml of water or oil absorbed per gram of flour respectively.

3.5.3.2 Swelling power and solubility

This was determined by the methoddescribed by Oladele and Aina (2007). One gram of the flour was mixed with 10 ml distilled water in a centrifuge tube and heated at 80^{o}C for 30 minutes. This was continuously shaken during the heating period. The tube was removed from the bath, wiped dry, cooled to room temperature (28 ^{o}C) and centrifuged for 15 mins at 2200 rpm. The supernatant was evaporated, and the dried residue weighed to determine the solubility. The swollen sample (paste) obtained from decanting supernatant was also weighed to determine the swelling power. Swelling power was calculated as weight of the paste/weight of dry sample.

3.5.3.3 Foaming capacity and stability

Foam capacity was determined using Narayana and Narasimga (1982) method. Two grams of the flour sample was added to 50 ml distilled water at 30±2^{o}C in a 100ml measuring cylinder. The suspension was mixed and shaken to foam and the foam volume after 30 seconds was recorded. The foam capacity was expressed as percentage increase in volume. The foam volume was recorded 30 minutes and 60 minutes after whipping to determine the foam stability as a percentage of the initial foam volume. The volume increase (%) was calculated using the formula:

$$VI (\%) = (A-B)/B \times 100$$

where, VI = Volume increase

A = Volume after shaking (ml)

B = Volume before shaking (ml)

3.5.3.4 Least gelation concentration

Least gelation concentrations for the various flour samples were determined using the method of Abbey and Ibeh (1988). Samples were mixed with 5 ml distilled water in test tubes to obtain suspensions of 2-20% (w/v) concentration. The test tubes were heated for 1 hour in a boiling water bath, cooled rapidly under running tap water and further cooled for 2 hrs in a refrigerator at 4^oC. The least gelation concentration was regarded as that concentration at which the sample from the inverted test tube did not fall or slip.

3.5.3.2 Pasting characteristics

The pasting characteristics of the Breadfruit flour samples (moisture content ranging between 7.12 and 9.56 and corrected to 14%) were determined in triplicates using American Association of Cereal Chemists Approved Method 22.10 (AACC, 1983) with slight modifications. A Brabender viscoamylograph (Viscograph PT-100) from Food Research Institute, Accra was used to study all the pasting properties of the flour at 75 rpm and a torque of 700 g equivalent to 100 Brabender units (BU) (Demiate *et al.*, 2001). The slurry was heated from 25–95^oC at a uniform rate of 1.5^oC/min under a constant stirring speed. The torque was continuously monitored. It was followed by cooling at a controlled rate of 1.5C/min (Damardjati and Luh 1987) to 50^oC. The cooked paste viscosity of 14% sluries in 420 ml water were measured. Pasting parameters including beginning of gelatinization, maximum/peak viscosity, end of final holding, break down and set back were recorded and expressed as Brabender Units (BU) (Demiate *et al.*, 2001).

3.5.4 Food Products Formulation

After the assessment of the physicochemical properties of the flours of the various breadfruit species, selected products were developed based on their functional properties and assessed for their acceptability. The following food products were developed:

breakfast meal, shortcakes, *tatale*, *koose* and condiment. Each product and sample was assigned a unique identification number with a prefix (P-porridge; S-shortcake; T-talale; K-koose and C-condiment) followed by a number.

3.5.1 Food Products

3.5.1.1 Breakfast meal

Twenty (20) ripe fruits of *Treculia africana* of approximately equal dimensions were collected and seeds extracted by hand. The seeds were crushed and dried in an oven at 60^{o}C for 24 hours till crisp dry. After drying, the crushed seeds were dehulled and roasted in a gas oven at 120^{o}C for 20 minutes (Nelson-Quartey *et al.*, 2007). The dehulled roasted seeds were then milled using a hammer mill and sieved with 75µm mesh to obtain the flour. Similarly, Glycine max (soyabeans) beans were sorted and roasted at 130 ^{o}C for 25 min in a gas oven. Roasted beans were allowed to cool and milled with a hammer mill, and sieved through 75 µm mesh. Composite flours of roasted *T. africana* and soybeans were formulated as indicated in Table 3-1. The flour blends were used to prepare breakfast meal (porridge). Porridge was prepared with each product blend by boiling 1:4 (v/v) flour to water dispersion at 100 °C for 10 min. The products were evaluated for aroma, taste, colour, mouthfeel and overall acceptability by a 60 member panel on a 5 point hedonic scale (Onweluzo and Nnamuch, 2009).The most consumer-accepted composite was prepared into an instant meal. One kilogram of flour was kneaded with 500ml distilled water. The dough was divided into 2 equal halves and baked in an oven at 120^{o}C for 1 hr (Oduro *et al.*, 2007), cooled to 28 ^{o}C and milled in a hammer mill and sieved with 75 µm mesh to obtain the instant breakfast meal.

Table 3-1: Composite flour composition

Blend	*T. africana* flour (%)	Soybean flour (%)
P301	100	0
P133	80	20
P834	60	40
P592	40	60
P677	20	80
P218	0	100

3.5.1.2 Short cakes

Based on the functional properties of the different breadfruit flours *Treculia africana* flour was identified to be appropriate for production of pastries. Different composite flours of unfermented *T. africana,* and wheat flours were used in shortcake production. Blends were kneaded with Blueband margarine. Samples were made from wheat flour at substitution level of 0, 20, 40, 60, 80 and 100 % breadfruit flour. One hundred grams (100 g) margarine and 50 g sugar were thoroughly mixed. Two whole eggs and 3 tablespoon milk were mixed into it; 0.2 g salt, 2 g baking powder and 0.2 g vanilla were slowly added and kneaded into dough. The dough was rolled and 7 cm diameter circular cuts were made. The dough cuts were baked at 160^{o}C for 15 min. The shortcakes were cooled and sensory evaluated.

3.5.1.3 Tatale

Four (4) over-ripe plantains (800 g) and 1 medium sized (800 g) ripe *A. altilis* were peeled and mashed with flour (wheat and fermented *A. altilis*) composites. Two small onions (15g each) were chopped and mixed together with an egg, 5 ml palm oil, 1 g of salt and 1 g of chilli powder mixed into the mashed plantain or *A. altilis*. The mixtures were allowed to stand for 20 min to allow it to partially set and also for soluble ingredients to dissolve. One hundred milliliters (100 ml) of palm oil was heated in a pan and dessert spoon used to scoop paste into the heated oil. The pastes were fried in batches for 3-4 min until golden brown, turning once (Grant, 1995). The fried tatale were cooled to 30 ^{o}C and sensory evaluation carried out.

3.5.1.4 Cowpea fritters (*Koose*)

The procedure described by Nagai (2008) was used to prepare cowpea fritters (*koose*) with little modification. *Koose* was prepared using dried fermented *A camansi* at different levels of substitution (0 %, 20 %, 40 %, 60 %, 80 % and 100 %) for cowpea. One kilogram of each composite meal was kneaded with 1000 ml water and allowed to stand for 20 minutes for the meals to reconstitute. Eight hundred grammes (800 g) of onion was grinded and mixed into the kneaded meal together with 15 g pepper, 2 medium sized eggs and 15 g salt and whisked into paste. The resultant pastes were scooped using ladle into 1 litre hot frytol oil and deep fried till brown. The *koose* (approximately 1.5 inches diameter length) was cooled and sensory evaluation carried out.

3.5.1.5 Condiment production

Six hundred grams (600 g) each of cowpea, soyabean and *Treculia africana* seeds were used. They were divided into 300 g halves. Each 300 g cowpea and soyabean was soaked in 1 litre tap water for 12 hrs (overnight) to make boiling easier. They were then boiled in excess water (1:3w/v) for 1 hr and water drained. *Treculia africana* seeds were not soaked (because preliminary investigations showed it cooked much faster than cowpea) but boiled in distilled water for 1 hr. They were then allowed to cool to 30 ^oC. Twenty grams (20 g) of charcoal ash was added to one half (300 g) cowpea, soyabean and *Treculia africana* seeds and thoroughly mixed. The other halves were not treated with wood ash. They were then placed in low density polyethelene (LDPE) bags, covered and allowed to ferment for 2 days as is traditionally done (Personal Observation) and solar dried for 4 hrs and then moulded into balls (approximately 3 inches diameter) and stored in a refrigerator at 8^oC from which samples were taken for analysis. Proximate and mineral analyses were carried out on samples.

3.5.2 Sensory evaluation of food products

Fresh samples of prepared products bearing different codes were placed on white disposable plates in a cool dry well lit and ventilated room. Each product was put in a different plate. After evaluating each coded sample the evaluators were asked to rinse their mouths with water before evaluating another. Five different (breakfast meal, shortcake, tatale, koose and *T. africana* condiment) products and stew prepared with *T. africana* condiment were evaluated. Each food product was evaluated on different days. A 5-point hedonic scale was used in scoring the products [(Appendix A3; 1–Like very much; 2– Like slightly; 3– Neither like nor dislike; 4– Dislike slightly and 5– Dislike very much) (Chinma and Gernah, 2007)]. Parameters assessed were colour, texture, taste, aroma and overall acceptability. Sixty untrained students of the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana constituted the sensory panel. The sensory panel was composed of 30 males and 30 females who were familiar with the consumption of the food items produced (Nwabuenze and Atuonwu, 2007).

3.6 DETERMINATION OF DIGESTIBILITY COEFFICIENTS

Samples of the breadfruit flours were analysed for neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL). NDF, ADF and ADL were determined according to the methods of van Soest *et al*. (1967). Hemicellulose was calculated as NDF-ADF and cellulose as ADF-ADL (Rinne *et al*., 1997). Cell solubles were determined as 100-NDF (Belyea and Ricketts, 1993). Lignin was estimated as ADL-Mineral Ash (Richards *et al*., 2005). Tannin content was estimated using the modified vanillin hydrochloride in methanol method described by Price *et al.* (1978). Routine procedures were used for the determination of Net energy for production (NEL) Digestible dry matter (DDM), dry matter intake (DMI), and relative food/feed value (RFV). Net energy for production (NEL) was estimated as 1.044-0.0123*ADF as recommended by Cooperative Resources International (2006). Digestible dry matter (DDM), dry matter intake (DMI), and relative feed value (RFV) were estimated as 88.9-0.779*ADF, 120/NDF and DDM*DMI/1.29 respectively as suggested by Schroeder (1994). NDF, ADF, ADL, hemicelluloses, cellulose and DDM were expressed as percentages (1 to 100), DMI as percent body weight, while NEL were expressed as Mcal/lb. Tannin was reported as mg/100 g.

3.7 DATA ANALYSIS

Physico-chemical, functional and sensory parameters were analysed with Statistix 9 statistical Package. Data obtained for all parameters were reported as mean scores of triplicates. Differences among sample means were separated using least significant difference (LSD) test at $p \leq 0.01$ (Snedecor & Cochran, 1976). Differences at $p \leq 0.01$ between means of seed-derived and pulp derived (*A. altilis*) flours were determined using Student t-test. Correlation analysis was carried out on parameters studied. Empirical relationships among parameters studied were established using regression analysis among sensory attributes. Similarly, regression analysis was also carried out to establish predictive models for predicting digestibility, net energy for production, as well as relative food/feed value.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents results and discusses the important findings of the study on expanding the food uses of breadfruit species. Indigenous knowledge on the use of breadfruit species in Ghana has been presented. The use of breadfruit species as food indicates that they are edible and that studies into expanding their food uses is important. In this respect, the proximate and mineral composition of the breadfruit species were determined and also presented. Furthermore, results of selected functional properties, which dictate the suitability of the breadfruit flours for different food uses, are also discussed. Important relationships between the various physico-chemical properties were established. Selected products developed and their sensory attributes are also presented in this chapter. Predictive models for predicting digestibility of breadfruits were developed. The digestibility and energy coefficients and anti-nutrient (tannin) content have also been discussed. Important predictive equations established in this study have been reported.

4.2 AVAILABILITY OF AND INDIGENOUS KNOWLEDGE ON BREADFRUITS IN GHANA

Results on availability and agro-ecological as well as indigenous knowledge on breadfruits in Ghana have been presented in Tables 4-1 and 4-2. Breadfruit species were found to be available in Western, Ashanti, Volta, Eastern, Brong Ahafo, and Western Regions of Ghana (Appendix A2). Plates 4-1 to 4-12 show representative photos (trees, fruits, pulp and beans) of breadfruit species in Ghana.

Table 4-1 Agro-ecological information on breadfruits in Ghana

Description		*Artocarpus* spp.		*T. africana*	
		No. of respondents	%	No. of respondents	%
No. of respondents		153		120	
Familiarity with breadfruits	Yes	141	92.16	106	88.33
	No	12	7.84	14	11.67
Common species	One	138	2.13	106	100
	Two	3	97.87		0
Ecological zones	Forest Zones	120	85.11	106	100
	Cocoa plantations	9	6.38	96	90.57
	Fields	12	8.51	0	0
Fruiting season	Nov- Feb	70	49.65	86	81.13
	Mar- June	28	19.86	10	9.43
	July- Oct	43	30.49	5	4.72
	Not Sure			5	4.72
Yield (Fruits/tree/season)	0-99	78	55.32	87	82.07
	100-199	52	36.88	11	10.38
	200-300	11	7.80	8	7.55
Susceptibility to pest diseases	Yes	3	2.13	0	0
	No	138	97.87	100	95.28
	Unknown	0	0	6	5.66

4.2.1 Artocarpus spp.

Over ninety percent (92.16%; Table 4-1) of the respondents indicated that they were familiar with *Artocarpus* spp. According to the respondents there were two main species namely *A. altilis* and *A. camansi*. *Artocarpus heterophyllus* however was not common and was mostly found in national parks, botanical gardens and agricultural research institutions. The respondents (85.11%) indicated that *Artocarpus spp.* were found mainly within forest zones and used as agroforestry plants on cocoa plantations. Fruiting was mostly reported to be between November and February (49.65%) though fruits could be available in smaller quantities throughout the year.

Plate 4-1 *Artocarpus altilis* tree

Plate 4-2 *Artocarpus altilis* fruit

Plate 4-3 Cross section of *Artocarpus altilis* fruit showing pulp

The respondents (92.2%) (Table 4-1) indicated that each tree could yield up to about 200 fruits per season and that fruits persist for 2-3 months when in season. *Artocarpus* spp. were used mainly as food (95.74%) (Table 4-2). The beans and pulp of *A. camansi* and *A. altilis* respectively are the parts consumed as food and are either boiled or roasted and used *Artocarpus camansi* and *Artocarpus altilis* were reported to be a source of income for both farmers and retailers who sold them. Plate 4-13 shows *Artocarpus camansi* on sale at Nkonya in the Volta Region of Ghana. At Bameanko in the Western Region traders were found with bag loads of *A. camansi* beans ready to be transported to Takoradi the regional capital for sale.

Plate 4-4 *Artocarpus camansi* tree(Source: Ragone, 2006)

Plate 4-5 *Artocarpus camansi* fruits

Plate 4-6 *Artocarpus camansi* seeds

Plate 4-7 *Artocarpus heterophyllus* tree

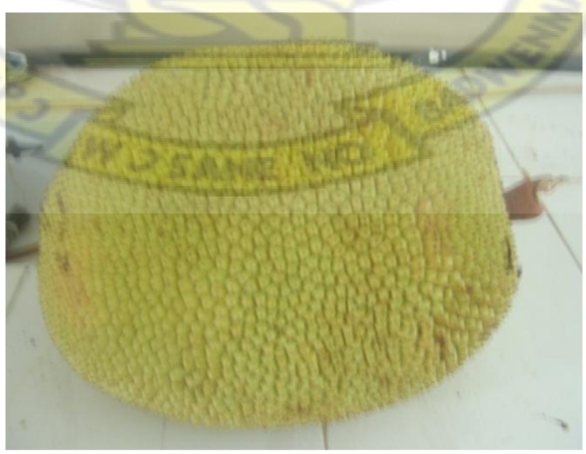

Plate 4-8 *Artocarpus heterophyllus* fruit

Plate 4-9 *Artocarpus heterophyllus* seeds

4.2.2 Treculia africana

Treculia africana similar to *Artocarpus* spp. were known to majority of the respondents (88.33%) (Table 4-1). However, *T. africana* was less popular than *Artocarpus* spp. Only one species was reported. Similar to *Artocarpus* spp. *T. africana* was found in forest zones. They were found both on cocoa farms and in the forests. Fruiting season was found to be between November and February (81.13%). Each tree was reported to produce about 100 fruits per season. Unlike *Artocarpus* spp, *T. africana* is not used commonly as food but rather used for its medicinal properties (97.17%) (Table 4-2).

Plate 4-10 *Treculia africana* tree (Source: Wikipedia, 2010)

Plate 4-11 *Treculia africana* fruit

Plate 4-12 *Treculia africana* seeds

The major seasons was said to be between November and February for all the species. *T. africana* was not a source of income. Livestock, snails, rats and porcupines also relished on the fruits. The fruits also attracted many animals and therefore their sites served as suitable sites for hunting and gathering.

Plate 4-13. *Artocrapus camansi* nuts on sale in the Volta Region

Table 4-2 Indigenous knowledge of respondents on breadfruits in Ghana

Description		*Artocarpus* spp.		*T. Africana*	
		No. of respondents	%	No. of respondents	%
Sold	Yes	82	58.17	0	0
	No	59	41.84	106	100
Indigenous use of fruit	Food	135	95.74	3	2.83
	Oil Production	0	0	0	0
	Rituals	3	2.13	0	0
	Medicinal	3	2.13	103	97.17
Part of fruit eaten	Seeds	138	97.87	3	2.83
	Fibrous Pulp	3	2.13	0	0
	Not sure			103	97.17
Shelflife (days)	1-7	132	93.62	0	0
	8-14	9	6.38	0	0
	≥ 14	0	0	3	2.83
	> 2 Week	0	0	103	97.17
Processing	Cooking	141	100	0	0
	Roasting	141	100	3	2.83
	Frying	0	0	0	0
	Others				97.17
Known adverse effects after consumption	Flatulence	34	24.11	0	0
	Constipation	23	16.31	0	0
	Thirst	18	12.77	0	0
	Unknown	75	53.19	106	100
Other uses of tree	Agroforestry	108	76.60	54	50.94
	Fuel wood	24	17.02	17	16.04
	Ornamental	4	2.84	0	0
	Animal Feed	5	3.54	35	33.02

4.2.3 Traditional processing of breadfruits

The traditional processing procedures for the breadfruit species from the survey are presented in Figure 4-1 *Artocarpus altilis* was harvested at the mature but unripe stage while *Artocarpus camansi* and *Treuclia africana* are collected ripe. *Artocarpus altilis* was peeled and pulp of fruit sliced. Sliced pulp were either boiled or roasted. On the other hand, seeds from *Artocarpus camansi* and *T. africana* fruits were extracted from ripe fruits, partially dried in air and either boiled or roasted. After cooking testa of seed were removed and seeds eaten as a snack or milled for future use in soups.

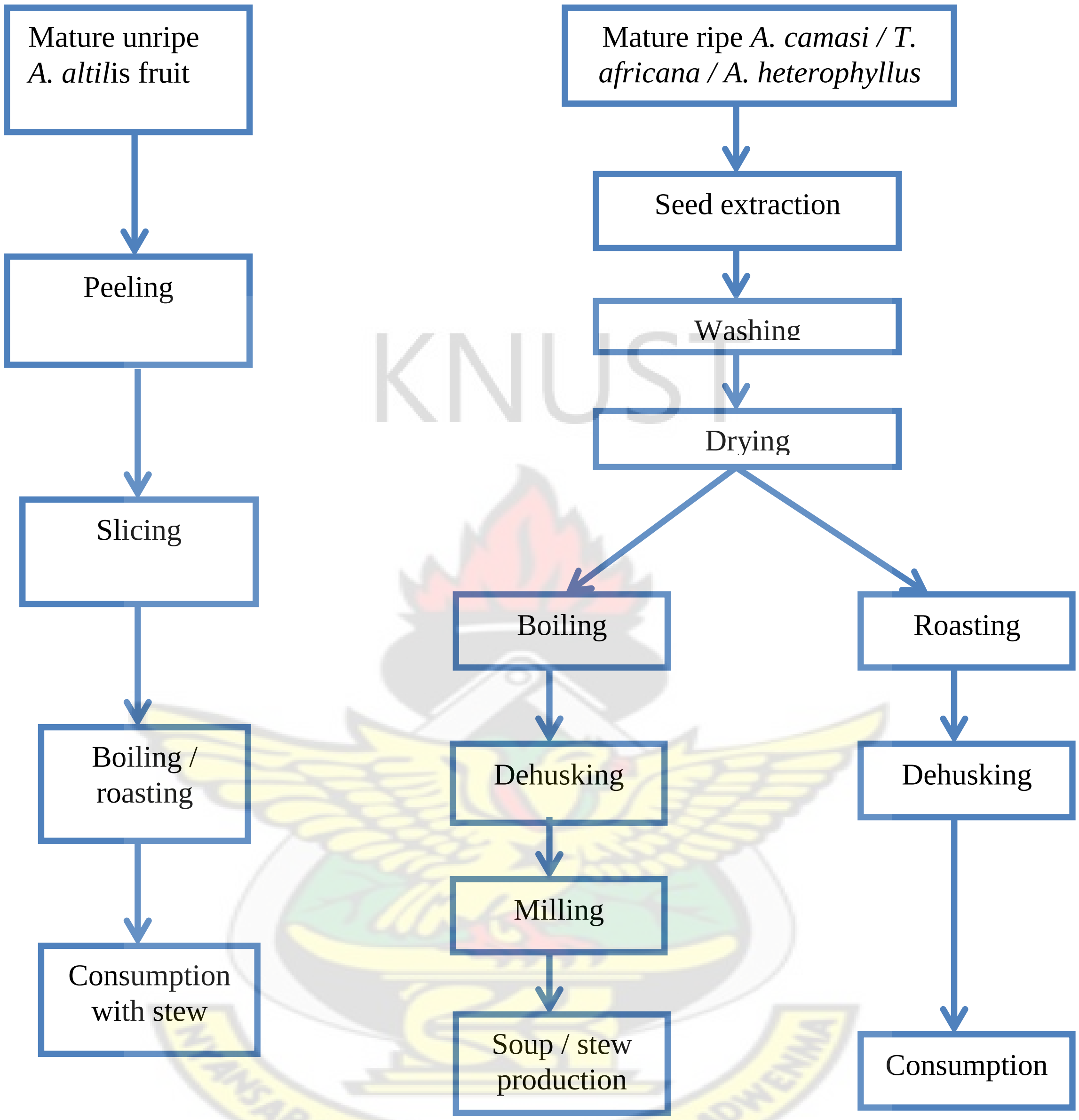

Figure 4-1: Flow diagram showing the traditional processing procedure for *A. altilis, A. camansi* and *T. africana* (Source: Survey, 2010)

4.3 PROXIMATE COMPOSITION OF NUTS-DERIVED FLOURS OF BREADFRUITS

4.3.1 Moisture Content

The moisture content of the nut-derived flours (*Artocarpus camansi*, *Artocarpus heterophyllus* and *T. africana*) varied between 7.20% and 10.81% (Table 4-3). The moisture content of *T. africana* was the highest and was significantly ($P<0.01$) different from the others. The least moisture content was from *A. camansi*. The values obtained in this study are lower than the range (10-14%) recommended by Butt *et al.* (2004) for flours. The lower moisture levels in this study are suggestive of longer shelf life for the breadfruit flours. Generally, increased moisture levels in flours are known to encourage the growth of micro-organisms and consequently microbial spoilage (Oduro *et al.*, 2009) depending on packaging that will exclude atmospheric moisture uptake.

4.3.2. Protein Content

The crude protein content of the seed-based breadfruit species ranged between 12.23% and 17.72% (Table 4-3). *A. camansi* (17.72%) had similar crude protein content as *T. africana* (17.57%) which was significantly higher ($P<0.01$) than *A. heterophyllus* (12.23%). The protein content of the flours was within range (12-15%) for grains and legumes (Ihekoronye and Ngoddy, 1985). Whereas this study reported 17.57% for *T. africana*, Adu (2006) and Giami *et al.* (2000) reported 13.96% and 20.1% respectively. These differences could be due to geographical location or soil nutrient levels since soil nitrogen level could influence protein levels (Blumenthal *et al.*, 2008).

Proximate composition of flours of *Artocarpus heterophyllus*, *Artocarpus camansi* and *Treculia africana*

Parameter	*A. heteropyllus*	*T. africana*	*A. camansi*	$LSD_{0.01}$
Moisture (%)	7.69±0.53	10.81±0.43	7.20±0.05	0.730
Crude protein (%)	12.23±0.12	17.57±0.45	17.72±0.62	1.357
Crude fat (%)	5.57±0.08	9.08±0.14	6.33±0.30	0.655
Crude fibre (%)	2.22±0.09	2.91±0.08	1.67±0.10	0.268
Ash (%)	2.13±0.02	2.64±0.02	2.90±0.05	0.121
Carbohydrates (%)	70.15±0.78	57.00±0.33	64.18±0.70	1.917

Generally, the protein content of flour gives an indication of the nutrient quality of the flour. Flours are usually fortified with high protein flours to provide needed nutrition (Zhao *et al.*, 2004). Proteins are increasingly being utilized to perform functional roles in food formulations. Therefore, the protein content of the flours in this study suggest that they may be useful in food systems where protein functionality are needed, and also contribute to the recommended daily intake of proteins for adults (34-56 g/day) and children (13-19 g/day) (Food and Nutrition Board, 2002).

4.3.3 Crude Fat Content

Significant differences ($P<0.01$) were observed between the species with respect to their fat content (Table 4-3). *T. africana* had the highest crude fat content (9.08%), which was 1.6 times higher than the least (5.57%) found in *A. heterophyllus*. Nelson-Quartey *et al.*

(2007) reported fat content of 6.68 – 7.69% for *A. camansi* and 1.96% – 2.26% for *A. altilis* pulp. However, in this study fat content of *A. camansi* was 6.33%. Differences in fat content of flours may be varietal (Moorthy *et al.*, 1996). Fats are essential in diets as they increase the palatability of foods by absorbing and retaining their flavours (Aiyesanmi and Oguntokun, 1996), in addition to being vital in the structural and biological functioning of cells and in the transport of nutritionally essential fat-soluble vitamins. Diets high in fat contribute significantly to the energy requirement for humans. Consequently, the high fat content of *T. africana* would make it a better source of fat than *A. camansi* and *A. heterophyllus* in food formulations and could be a better flavor enhancer.

4.3.4 Crude Fiber Content

T. africana flour had the highest crude fibre content (2.91%), which was 1.74 times higher than the least 1.67% in *A. camansi* (Table 4-3). Nelson-Quartey *et al.* (2007) recorded crude fiber content of 1.30% for *A. camansi* bean flour. Crude fiber is the insoluble polymeric material of plant cell walls such as cellulose, hemicelluloses, pectin and lignin that constitute the major part of dietary fiber (Johnston and Oliver, 1982). High fiber intake has been linked with decreased chances of colon cancer and associated with reducing constipation. Codex Alimentarius Commission (2000) indicated that the crude fiber content for weaning foods should not be greater than 5%. Consequently, the low crude fiber content of the flours in this study suggest they could be suitable in infant formulations.

4.3.5 Ash Content

Generally, the ash content of the flours ranged between 2.12 and 2.90% (Table 4-3). The strong positive correlation (r=0.78) between potassium content and ash content was indicative of the contribution of potassium to ash content. The ash content of *A. camansi* (2.9%) was lower than the 3.1% reported by Nelson-Quartey *et al.* (2007). In contrast, the ash content for *A. heterophyllus* and *A. camansi* in this study was lower than the 3.6% reported by Singh *et al.* (1991). The ash content of the flours was within range (2.6-3.1) reported for lentils (a legume) but lower than cowpea (Appiah *et al*., 2011a). The flours of the breadfruit nuts would therefore be a better source of ash than lentils.

4.3.6 Carbohydrate Content

The carbohydrate content of the flours of the breadfruit species varied from 57.01% to 70.15%. *A. heterophyllus* had the highest carbohydrate content (70.15%), which was 1.23 times greater than the least in *T. africana* (57.01%) (Table 4-3). The carbohydrate content of the flours was comparable to maize (66.0 to 75.9 %; Ortega, 1986). According to Brown (1991), carbohydrates are good sources of energy and that a high concentration of it is desirable in breakfast meals and weaning formulas. In this regard therefore, the high carbohydrates content of the flours would make them good sources of energy in breakfast formulations.

4.4 MINERAL CONTENT OF NUTS-DERIVED BREADFRUITS FLOURS

4.4.1 Calcium Content

The calcium content of the nut-derived flours of the breadfruit varied between 65.00mg/100g in *A. heterophyllus* and 127.50 mg/100g in *T. africana* (Table 4-4).

However, the calcium content of the flours was lower than for cassava (615 mg/100g; Akindahunsi *et al*, 1999) and *Prospis africana* (362.5 mg/100g; Aremu *et al.* (2006). The National Academy of Sciences (2004) recommends calcium intake of between 500 mg/day and 800 mg/day for children (1-8 years old) and 1000 mg/day to 1300 mg/day for adults. From the results of this study, consuming 400 g/day of *T. africana* flour can provide the complete daily requirement of calcium for children less than eight years of age. Calcium intake is important as it is known to reduce demineralization of bones (Greenberg, 1995).

4.4.2 Iron Content

The iron content of the breadfruit flours ranged between 2.20 mg/100g and 9.38 mg/100g (Table 4-4). Iron content was highest in *A. heterophyllus* flour and least *A. camansi* flour. The iron content of *A. heterophyllus* (9.38 mg/100g) was higher than that reported for lentil (7.1 mg/100g), kidney beans (6.4 mg/100g) and chickpea (6.8 mg/100g) by Cabrera *et al*. (2003). However, *T. africana* (3.75 mg/100g) and *A. camansi* (2.20 mg/100g) were found to have be lower than those values (6.4 and 6.9 mg/100g).

According to the National Academy of Science (2004) the recommended daily allowance for iron is between 8 mg/day for adult males and 18 mg/day for females. *A. heterophyllus* flour could therefore be a better source of iron than *A. camansi* and *T. africana*. The results showed that consuming 100 g of *A. heterophyllus* bean flour could be sufficient in meeting the minimum requirement for male adults. Iron is known to be an important constituent of hemoglobin found in blood and contributes to the combat of anaemia (de Villota *et al*., 1981).

4.4.3 Magnesium Content

The magnesium content of the breadfruit bean flours varied widely from 10.17 mg/100g to 167.71 mg/100g (Table 4-4). The magnesium content of *T. africana* bean flour (167.71 mg/100g) was 16 times greater than the least in *A. camansi* (10.17 mg/100g). The magnesium levels, however, were lower than for cowpea (233 mg/100g) as reported by; Falade *et al*. (2003). Magnesium is essential in enzyme systems and helps maintain electrical potential in nerves (Ferrao *et al.*, 1987). Nutritionally, *T. africana* flour can be considered as a superior source of magnesium than *A. heterophyllus* and *A. camansi* and as such could be used as a supplement in providing the daily requirement of magnesium for adults (265-350 mg) as reported by Food and Nutrition Board (1997).

4.4.4 Potassium Content

The content of potassium was the highest among all the minerals and therefore considered as the most predominant mineral in the flours of the 3 breadfruit species (Table 4-4). *A. camansi* flour had the highest potassium content (1313.3 mg/100g), which was 2.3 times higher than in the least in *T. africana* (533.95 mg/100g). The potassium content of *T. africana* in this study agrees with the 587 mg/100g reported by Osabor *et al.* (2009). In comparative terms the potassium content of the breadfruit flours was higher than tiger nut (216 mg/100g; Oladele and Aina, 2007) flours. The levels of potassium recorded in this study were not surprising as NTBG (2009) reported that breadfruit cultivars are good sources of potassium. Potassium is an important mineral which helps maintain electrolyte balance in humans and is important in amelioration of hypertension (Whelton *et al.*, 1997).

Table 4-4: Mineral composition of flours of *Artocarpus heterophyllus*, *Artocarpus camansi* and *Treculia africana* nuts

Mineral content	*A. heterophyllus*	*T. Africana*	*A. camansi*	$LSD_{0.01}$
Ca (mg/100g)	65.00±0.50	127.5±0.05	93.00±0.00	30.945
Fe (mg/100g)	9.38±0.78	3.75±0.05	2.20±0.10	1.383
Mg(mg/100g)	92.71±0.61	167.71±0.06	10.18±0.29	8.933
K (mg/100g)	588.76±0.01	533.95±0.05	1313.3±0.05	21.377
Na (mg/100g)	53.00±0.00	54.00±0.00	38.00±0.00	0.874
P (mg/100g)	226.00±0.00	440.00±0.00	201.60±1.0	1.748
Ca/P ratio	0.29±0.03 (1/3.5)	0.29±0.03 (1/3.5)	0.46±0.00 (1/2)	0.109
K/Na ratio	11.11±0.04 (11:1)	9.88±0.07 (10:11)	35.02±0.25 (35:1)	0.458

4.4.5 Sodium Content

The sodium content in the flours of the breadfruit species varied between 38.00 mg/100g flour and 54.00 mg/100g flour sample (Table 4-4). *T. africana* had the highest sodium content (54.00 mg/100g) significantly higher (P<0.01) than both *A. heterophyllus* (53.00 mg/100g) and *A. camansi* (37.5 mg/100g). The sodium content of the flours, in this study, were lower than *P.africana* (110.7 mg/100g) reported by Aremu *et al*. (2006). Sodium generally imparts flavor and enhances preservation of foods, but very high levels pose serious health risks. The National Academy of Science (2004) recommends sodium intake of between 1.2 g/day and 1.5 g/day being equivalent to between 2.5-3.5 kg of breadfruit flour/day. Since breadfruit flour is not consumed in such large quantities daily, breadfruit flour could be incorporated in the diet without exposing the consumer to sodium-related health risk.

4.4.6 Phosphorus Content

The flour of the breadfruit cultivars had phosphorus content ranging from 201.6mg/100g to 440mg/100g (Table 4-4). *T. africana* had the highest (440.0 mg/100g), which was 2.2 fold greater than the least in *A. camansi* (201.6 mg/100g). Comparatively, the phosphorus content of the *A. camansi*, *A. heterophullus* and *T. africana* flours were higher than *P.africana* (196.4mg/100g) reported by Aremu *et al.* (2006) but similar to Tiger nut (216 mg/100g) reported by Oladele and Aina (2007). Vitabase (2009) indicated that phosphorus is essential for the process of bone mineralization and maintenance of bone structure. Phosphorus also makes up the structure of cellular membranes, nucleic acids and nucleotides, including adenosine triphosphate. In relation to the recommended daily intake, (700–1250 mg/day), the breadfruit flours could be regarded as average source of phosphorus which could be utilized as food supplement.

4.4.7 Calcium - Phosphorus (Ca:P) Ratio

The Ca:P ratio of the flours of the breadfruit cultivars were between 1:3.5 and 1:2 (Table 4-4). In good health, the ratio of calcium to phosphorus in the blood is 10:4 (http://www.health-science-spirit.com/calcium.html, 2011). If there is a glandular imbalance, the ratio will be maintained at a different level, causing long-term health deterioration. Calcium-phosphorus ratio is also affected by food choices. Foods high in phosphorus and low in calcium, tends to make the body overacid, depletes it of calcium and other minerals and increases the tendency towards inflammations. These effects can be minimized by selecting suitable foods (http://www.health-science-spirit.com/calcium.html, 2011). According to Green *et al.* (1991) the recommended Ca:P ratio is 1:1. However, since the Ca:P ratios are lower than 1, meals based solely on the breadfruit flours would have to be supplemented with Calcium to avoid mineral and osmotic imbalance (Fasasi *et al*., 2004).

4.4.8 Potassium to Sodium (K:Na) Ratio

The K:Na ratio of the flours ranged between 9:1 and 35:1 (Table 4-4). The ratio of potassium to sodium was highest in *A. camansi* (35:1) with fermented *T. africana* being the least (10:1). For normal retention of protein during growth and for balancing metabolic fluid, a K/Na ratio of 1 is recommended (Helsper *et al.*, 1993). On the contrary, Wilhelmi (2010) indicated that the critical ratio for K:Na is greater than 4:1 or the result would be increase of blood pressure and the other related chronic metabolic diseases. The high K: Na ratio obtained for the different flour suggest their suitability for normal protein retention (Akinyede and Amoo, 2009). Since the breadfruit flours had higher K:Na ratio than the minimum the flours could be consumed without much apprehension relating to health risks. Diet high in K:Na ratio help maintain electrolyte balance, ensure efficient electrical conductivity in the body and improve mental alertness and heart performance. This was suggestive that fermented products from *T. africana* such as *T. africana* condiment, produced in this study, could be of great health benefit as it was observed that the condiment had high levels of potassium.

4.5 PHYSICAL PROPERTY

4.5.1 Bulk Density

The bulk density of the breadfruit flours ranged between 0.53 g/cm^3 and 0.76 g/cm^3 (Table 4-5). The bulk density of *A. heterophyllus* (0.76 g/cm^3) was significantly (P<0.01) greater than the other flour treatments and 1.4 times greater than the least *T. africana* (0.53 g/cm^3). The bulk densities of the flours compared favourably with 0.55-0.55 g/cm^3 obtained for tigernut (Akubor and Badifu, 2004) as well as 0.53 for *P.africana* flour and 0.55 g/cm^3 for fermented maize flour (Mbata *et al*., 2009). Bulk density is a measure of the heaviness of a flour sample (Oladele and Aina, 2007).

Table 4-5: Bulk densities of seed flours of *Artocarpus heterophyllus*, *Artocarpus camansi* and *Treculia africana*

SpeciesSpecies	BD (g/cm^3)
A.heteropyllus	0.76±0.00
T. africana	0.53±0.01
A. camansi	0.68±0.01
$LSD_{0.01}$	0.040

BD – Bulk density

Higher bulk density is desirable in that it offers greater packaging advantage as greater quantity of flour may be packed within a constant volume (Ijarotimi and Ashipa, 2005). Mbata *et al.* (2009) indicated that a weaning food should have low bulk density and low water absorption capacity in order to produce a more nutritious and suitable weaning food. In this regard *T. africana* could be most suitable for use in weaning formulations.

Since *A. heterophyllus* flour was observed to be heavier than all the flours it could be more convenient to package and transport since it occupies lesser volume per unit weight. The flours of both *T. africana* and *A. camansi* have the potential for use as breakfast meal ingredient (Mbata *et al*., 2009) since they had lower bulk densities.

Bulk density was positively correlated with carbohydrate (r=0.82; Appendix C1) but negatively with fat content (r=-0.65; Appendix C1) content. The higher bulk density of *A. heterophyllus* may be attributable therefore to the higher carbohydrate content (68.37%-70.15%) compared to the rest. According to Bhattacharya and Prakash (1994) higher carbohydrate content results in higher bulk densities as observed in this study.

4.6 FUNCTIONAL PROPERTIES OF NUT-DERIVED BREADFRUIT FLOURS

The results of the functional properties of *A. camansi*, *A. heterophyllus* and *T. africana* flours are presented in Table 4-6.

4.6.1 Water Absorption Capacity

The water absorption capacity (WAC) of breadfruit flours varied from 2.0 ml/g (200%) to 2.83 g/g (283%) (Table 4-6). The water absorption capacities of the flours were comparable to that for millet (1.89) reported by Onweluzo and Nwabugwu (2009) and unfermented *A. altilis* (2.19) reported by Nelson Quartey (2007). Odoemelam, (2005) reported that *A. heterophyllus* flour has water absorption capacity of 230%, higher than was found in this study (208%). According to Elmoneim *et al*. (2005) water absorption capacity gives an indication of the amount of water available for gelatinization. Low water absorption capacity is desirable for making thinner gruels. Desikachar (1980) indicated that a high water absorption capacity of flours increase its viscosity (consistency) when mixed with water, resulting in a thick paste but does not allow free-flow of the meal (Mosha and Lorri 1987). This may therefore limit the caloric intake when such meals are served to young children. In this study, among the different species, the flour *A. heterophyllus* which had higher water absorption capacity (2.08 g/g) also had higher viscosities (Table 4-6). However, the reverse was true for *T. africana*. The variation probably could be due to the nature of the starches present in each species. According to Nelson-Quartey *et al.* (2007) the presence of fat in appreciable amounts, reduce the water binding capacity of the particular substance by limiting the absorption of water.

In this study water absorption capacity correlated positively (r=0.90; Appendix C1) with swelling power similar to the observation of Etudaiye *et al*. (2009). The observed correlation is to be expected as swelling power is known to be positively influenced by water absorption capacity.

4.6.2 Oil Absorption Capacity

The breadfruit flours had oil absorption capacity (OAC) ranging between 0.50 ml/g (0.38 g/g) to 1.25 ml/g (1.13 g/g) flour (Table 4-6). Comparatively, the oil absorption capacity of *A. heterophyllus* flour in this study, was lower than that (2.8 ml/g) of Odoemelam (2005) for the same breadfruit species. Furthermore, all the flours of the *Artocarpus spp.* had higheroil absorption capacities than mucuna bean (2.2g/g) reported by Udensi and Okoronkwo (2006). *A. heterophyllus* and *A. camansi* flours may have lower flavour-retaining ability than the other flours (Oladele and Aina, 2007) due to their lower oil absorption capacities (0.50 ml/g). Depending on the usage of the flour, the potentially high flavour-retaining ability of the *T. africana* could be a desirable characteristic in food product formulation. The lower oil absorption capacity of *A. heterophyllus* could be due to low hydrophobic proteins which show superior binding of lipids (Adejuyitan *et al.*, 2009). The relatively high oil absorption capacity of *T. africana* flour suggesedt that it could be useful in food formulation where oil holding capacity is needed such as in sausage making, soups and cakes (Aremu *et al.*, 2006).

There was a negative association (r=-0.80; Appendix C1) between oil absorption capacity and carbohydrate content. According to Debnath *et al*. (2003), decrease in solids content (carbohydrate) results in increased oil absorption in chickpea flour. This may have accounted for the observed correlation. This observation however, was at variance with Osundahunsi (2009) who observed decreased oil absorption with decreased carbohydrate content in ripe plantain.

4.6.3 Solubility

The solubility of the flours in distlled water ranged between 8.01% and 11.9%. The observed differences were statistically insignificant ($P<0.01$) with *A. camansi* (11.29%) being 1.41 times higher than *T. africana* (8.01%). Nelson-Quartey *et al.* (2007) reported solubility of 16.97% for *A. camansi* in contrast to the 11.29% observed in this work while Oduro *et al*. (2007) reported 9.54% solubility for *A. altilis* flour. According to Johnson *et al*. (2001), higher solubility would permit better digestibility. It was therefore expected that the digestibility of *A. camansi* would be higher than the rest. However, contrary results were obtained suggesting other factors could be at play (Appendix F4, Table 2).

There was a positive association (r=0.52; Appendix C1) between water absorption capacity and solubility of the flours. This trend was expected and may be traced to the significant positive correlation (r=0.90; Appendix C1) between water absorption capacity and swelling power observed in this study.

There was however, an inverse association (r=-0.58) between solubility and oil absorption capacity as well as foam stability (r=-0.52, 30 minutes; r=-0.72, 60 minutes and r=-0.56, 90 minutes). Nelson-Quartey *et al.* (2007) reported that the presence of lipids could result in reduced water absorption capacity of flours which may lead to reduced swelling and consequently reduced solubility as depicted by the observed negative correlation between oil absorption and solubility.

4.6.4 Swelling Power

The swelling power of the flours of the breadfruit cultivars varied between 4.84 and 6.23. The observed values were higher than tigernut (2.47) reported by Oladele and Aina (2007). The recorded values were lower than for cereal starches (24 to 42) reported by Tester and Morrison (1990). The gelatinization and swelling power test provided suitable predictive method for identifying noodle-quality flours (Morris *et al*., 1997; McComick *et al*., 1991). Li and Yeh (2000) reported that potato and tapioca have high swelling powers while corn and rice are low. The results suggested that the breadfruit cultivars have poor swelling power and might not be suitable for noodle production.

The association (r=0.90; Appendix C1) between swelling power and water absorption capacity of the flours was strong and positive as expected (Etudaiye *et al*., 2009). This suggested that as the water absorption capacity increased the swelling power also increases in the flours leading to improved solubility.

4.6.5 Foam Capacity and stability

The foam capacities of the flours of the breadfruit cultivars were between 5.83% and 25.00% as shown in Figure 4-6. *Artocarpus heterophyllus* had the highest foam capacity. According to Nunoo (2009) increased unfolding and fragmentation of protein may enable the formation of more continuous phases of thin liquid layers which trap air bubbles, resulting in increased foaming capacity. Akintayo *et al*. (2002) recorded 27.05% foam capacity for *Bilphia sapida* flour.

The foam capacities of the flours were higher than that of *P.africana* (3.9%) reported by Aremu *et al*. (2006). While *A. heterophyllus* had higher foam capacity (25%) than cowpea, *A. camansi* (19.2%) was within the range (10-21%) (Appiah *et al*., 2011a). According to Narayana and Narayasimga (1982), foam capacity is attributable to protein content and solubility since foamability is a function of solubilized proteins. Nwokolo (1985) reported that the amount of polar and non-polar lipids in a sample affects foam capacity of a sample.

Table 4-6: Functional properties of flours of *Artocarpus heterophyllus*, *Artocarpus camansi* and *Treculia africana*

Parameter	*A.heteropyllus*	*T. africana*	*A. camansi*	$LSD_{0.01}$
WAC(g/g)	2.08±0.14	2.00±0.01	2.83±0.01	0.564
OAC (ml/g)	0.50±0.00	1.25±0.00	0.50±0.01	0.586
Solubility (%)	10.6±0.30	8.01±0.06	11.29±0.1.99	3.526
Swelling power	5.33±0.09	4.84±0.06	6.23±0.02	0.532
Foam capacity (%)	25.00±0.14	5.83±0.14	19.17±0.14	0.564

WAC – Water absorption capacity; OAC – Oil absorption capacity.

As regards the foam stability, *Artocarpus heterophyllus* had significantly higher foam levels up to 30 minutes of holding. However, at 60 and 90 minutes of holding the differences in the foam level of the various species were not significant (P>0.01).

Table 4-7 Foam stability of of flours of *Artocarpus heterophyllus*, *Artocarpus camansi* and *Treculia africana*

Species	FC (0 minute)	30 minutes	60 minutes	90 minutes
A. heterophyllus	25.00±0.14	10.00±2.50	3.33±0.32	1.67±0.44
A. camansi	19.17±0.14	2.50±0.00	2.50±0.00	1.50±0.29
T. africana	5.83±0.14	0.00±0.00	0.00±0.00	0.00±0.00
$Lsd_{0.01}$	5.641	4.369	6.674	3.422

FC – Foam capacity

In contrast, *T. africana* did not record any foam over 90 minutes of holding (Table 4-7). According to Lin and Zayas (1987) foam stability is important since the usefulness of whipping agents depend on their ability to maintain the whip as long as possible (Cherry and McWatters, 1981). *A. heterophyllus* and *A. camansi* which had relatively higher foam levels at 90-minutes could be useful as whipping agent and used for *koose* production.

Foam capacity was positively correlated (r=0.70) with carbohydrate content and swelling power (r=0.62) but negatively with fat (r=-0.80) and crude fiber (r=-0.62) (Appendix C1) in this study. The presence of lipids could result in reduced diffusion of unfolded and fragmented proteins towards air/water interface. As a result reduced diffusion of unfolded and fragmented protein may therefore disable the formation of more continuous phases of thin liquid layers which trap air bubbles, hence the progressive decrease in foaming capacity as more oil was imbibed. This observation was similar to that of Mepba *et al*. (2008) who indicated that poor foaming may be due to the presence of lipids. As swelling power increases solubility generally increases and therefore unfolded and fragmented protein move more freely to air-water interfaces resulting in increased foaming as indicated by the positive association of foaming with swelling power.

4.6.6 Least Gelation Concentration (LGC)

The results on least gelation concentration of the *A. heterophyllus, A. camansi* and *T. africana* flours have been presented in Table 4-8. The flour of *A. heterophyllus* and *A. camansi* had the same least gelation concentration of 8% and was marginally higher than *T. africana* (6%). These were within the range reported for pigeon pea (5-10%) reported by Onweluzo and Nwabugu, 2009). According to Udensi *et al*. (2001) gelation is an important property which influences the texture of food such as *moi- moi* and soup. As starch granules are heated in water they swell and form gel when the amorphous region becomes hydrated (Adebowale *et al*., 2005). High least gelation concentration might be attributed to high quantity of the amorphous phase during heating in the presence of water. According to Onweluzo and Nwabugu (2009) high amorphous phase results from induced transformation of the inter-crystalline and crystalline regions of starch causing increased readiness to changes in least gelation concentration.

Ezeji and Ojimelukwe (1993) indicated that flours with low least gelation concentration when used in infant formulation would need a lot of dilution since they thickened easily with low flour concentrations thus reducing energy density per unit volume of porridge prepared using flours with low least gelation concentrations. However, since the differences between the species were not significant (P>0.01) they could impart similar texture when used in food formulation (Udensi *et al*., 2001). Aremu *et al*. (2006) on the other hand indicated that the ability of protein to form gels and provide a structural matrix for holding water, flavours, sugars and food ingredients is useful in food application and new product development. Since *T. africana* had lower least gelation concentration it could be useful as a glazing agent. Least gelation concentration had positive correlation with solubility (r=0.71; Appendix C1). Xiong and Brekke (1989) as well as Singh *et al*. (2010) also reported similar correlation between solubility and gelation capacity.

Table 4-8: Gelation concentration of *A.hetrophyllus, A. camansi* and *T. africana* flours

Concentration (%)	*A. heterophyllus*	*A. camansi*	*T. africana*	$LSD_{0.01}$
2	NV	NV	NV	
4	NV	NV	V	
6	V	V	Gel	
8	Gel	Gel	Gel	
10	Gel	Gel	Gel	
12	Gel	Gel	Gel	
14	Gel	Gel	Gel	
16	Gel	Gel	Gel	
18	Gel	Gel	Gel	
20	Gel	Gel	Gel	
LGC	8±0.2	8±0.5	6±0.2	6.054

Key: LGC – Least gelation concentration V – Viscous NV – Not Viscous

4.7 PASTING PROPERTIES OF NUTS-DERIVED BREADFRUIT FLOURS

4.7.1 Pasting Temperature

The pasting behaviour of the breadfruit species have been presented in Figures 4-2 to 4-4. The pasting temperature of the flours of the breadfruit cultivars varied between 69.4 ^{o}C and 94.60 ^{o}C as indicated in Table 4-9. The highest pasting temperature was recorded by *A. camansi* while *T. africana* flour had the lowest. *A. heterophyllus* had similar pasting temperature as tiger nut (82.85 ^{o}C) reported by Oladele and Aina (2007).

Table 4.9: Pasting temperature of flours of *Artocarpus heterophyllus*, *Artocarpus camansi* and *Treculia africana*

Species	Onset temperature (^oC)
A. heterophyllus	81.87±0.10
A. camansi	94.6±0.30
T. africana	69.4±0.30
$LSD_{0.01}$	3.019

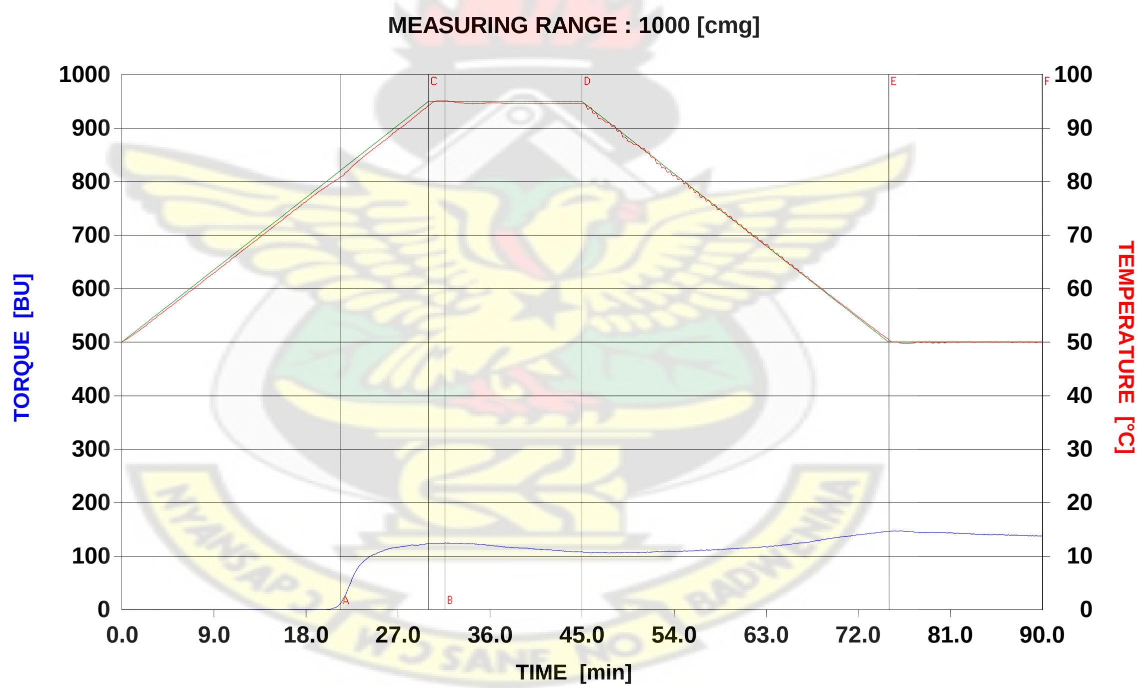

Figure 4-2 Typical pasting profiles for *A. heterophyllus* flour

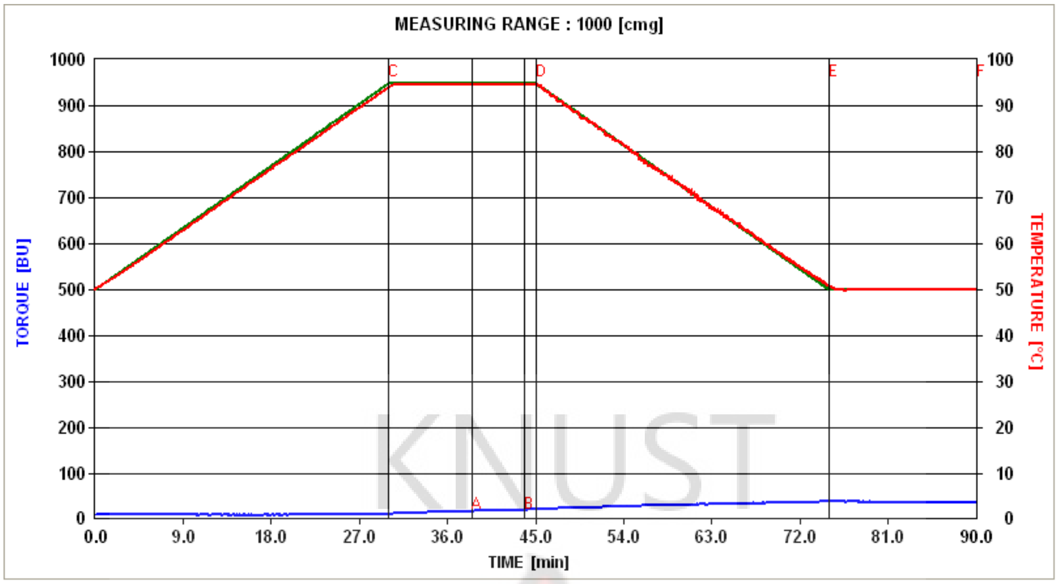

Figure 4-3 Typical pasting profiles for *A. camansi* flour

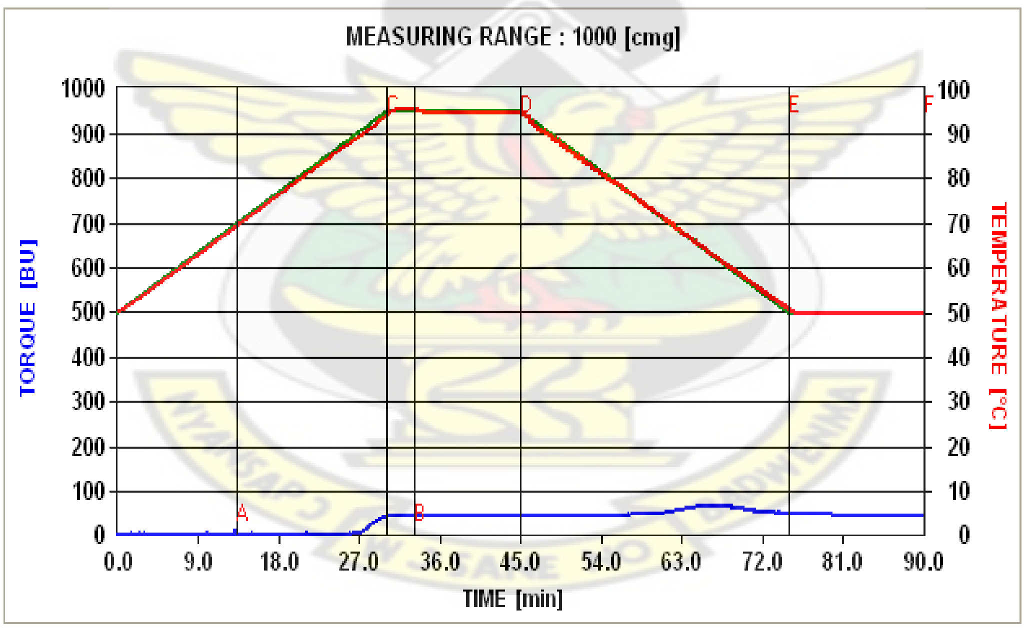

Figure 4-4 Typical pasting profiles for *T. africana* flour

According to Mira *et al.* (2005), higher pasting temperatures would result from delayed or restricted swelling and amylose leaching. Otegbayo *et al.* (2006) reported that lower gelatinization temperature is indicative of lower cooking temperature and shorter cooking time. Flours with shorter cooking time would need lesser time for cooking which is advantageous and might reduce energy consumption as well as reduce cost of processing. Since *T. africana* had the least pasting temperature of 69.4^{o}C it suggests it cooks at lower temperature than the *A. heterophyllus* and *A. camansi*. On the other hand, the high gelatinization temperature of *A. camansi* might be related to the presence of stronger bonding forces within the starch granules of its flour (Opata *et al.*, 2007). Pastes that cook at higher temperatures would need frequent stirring during cooking to avoid scorching (Zhou *et al*., 1999a). Since the *A. camansi* flour had the highest pasting temperature it would require more regular stirring than the other flours during cooking.

4.7.2 Maximum (Peak) Viscosity

As indicated on Table 4-10, the peak viscosity of the flours ranged between 21 BU and 125 BU. *A. heterophyllus* recorded the highest peak viscosity which was 6 times greater than the least *A. camansi*. The peak viscosity of *A. camansi* (21 BU) and *T. africana* (40 BU) were lower than that reported for mothbean (108 BU; Singh and Nath, 2009). The low peak viscosity of *A. camansi* flour might be due the formation of starch-lipid complexes making water inaccessible to the starch in the flour (Eliasson, 1985).

Table 4.10: Pasting properties of *Artocarpus* heterophyllus, *Artocarpus camansi*. and *Treculia africana* flours

Species	PV	FV	SB	BD	TTPV (sec)
A. heterophyllus	125.00±0.00	138.00±0.00	38.00±0.00	17.00±0.00	2008.3±222.8
A. camansi	21.00±0.00	160.00±0.00	17.00±0.00	0.00±0.00	2630.0±0.00
T. Africana	40.00±0.00	40.00±0.00	7.67±0.58	2.00±2.08	2080.0±0.00
$LSD_{0.01}$	7.206	7.206	1.009	1.009	389.36

PV - Peak Viscosity; FV- Final viscosity; SB- Setback; BD – Breakdown; SHP - Stability of hot paste; SCP - Stability of cold paste; TTPV – Time taken to reach peak viscosity

According to Adebowale *et al.* (2005), peak viscosity is an important feature of starch flour. Peak viscosity is an indication of the ability of flour to form thick paste on cooking because of the swelling power of its starch. Peak viscosity is influenced by molecular weight, granular composition, pH and electrolyte concentration of the paste (Aurand *et al.*, 1987). Higher peak viscosity indicates ease of swelling of the starches (Opata *et al*., 2007). Starch with high viscosity is desirable as thickening agents in industry and in food systems (Kim *et al.*, 1995). High viscosity has been reported as indicator of starch quality.

4.7.3 Setback

There was a wide variation in setback values (7.67BU to 38.0 BU; Table 4-10) for the various breadfruit vaieties. *A. heterophyllus* recorded the highest (38 BU) which was 4.9 times higher than the least, *T. africana* (7.6 BU);*T. africana*). Setback is a measure of retrogradation (Oladele and Aina, 2007). Lower setback values indicate lower starch retrogradation (Adebowale *et al.*, 2005). Flours with smaller tendencies to retrograde are an advantage in food products such as soups and sauces, which undergo loss of viscosity and precipitation as a result of retrogradation (Adebowale and Lawal, 2003a). *T. africana* had the least setback (7.67 BU) and therefore more resistant to retrogradation and could be useful soup ingredient. This is not surprising as some respondents indicated they used *T. africana* beans to prepare soups. According *to* Leelavathi *et al.* (1987) soluble amylose is largely responsible for retrogradation during setback. Breakdown correlated positively with pasting temperature (r=0.67) and peak viscosity (r=0.86).

4.7.4 End of Final Holding (Final Viscosity)

The final viscosities of flours varied between 40 BU and 160 BU (Table 4-10). *A. camansi* however, had similar final viscosity (160BU) as defatted bambara beans (160BU; Mensah, 2011).The final viscosities observed in this study were lower than values reported for raw maize flour (990 BU) reported by Sefa-Dedeh(2004) and bread flour (813 BU) as well cake flour (607 BU) reported by Deffenbaugh and Walker(1989). However the final viscosity for *T. africana* showed a decrease from peak viscosity to final viscosity. According to Mensah (2011) variation in the final viscosity might be due to the simple kinetic effect of cooling on viscosity and the re-association of starch molecules. Otegbayo *et al.* (2006) indicated that the final viscosity is an important parameter in predicting the final textural quality of food. It gives an indication of the consistency at which the product will be consumed (Zhou *et al.*, 1999a).The high final viscosity of *A. camansi* suggested it would have thicker eating-consistency at 50 ^{o}C.

4.7.5 Breakdown

The breakdown values for the breadfruit flours ranged between 0.00 BU to 17.00 BU for the flours of the breadfruit cultivars (Table 4-10). Breakdown is the difference between peak viscosity and minimum viscosity. It shows the degree of drop during heating and the extent of starch granule disintegration. Adebowale *et al.* (2005) indicated that higher breakdown in viscosity suggests lower ability of sample to withstand heating and shear stress during cooking. Hence starch sample with lower breakdown will have better ability to withstand heating and shear stress. This implies flours with lower breakdown values give more stable cooked paste suggesting good bonding forces with the starch granules (Zobel, 1984). This is similar to the report of Oduro *et al.* (2000) who indicated that starches with low stability show very weak cross–linking among granules. *A. heterophyllus* with highest breakdown (17.00 BU) would form less stable paste while *A. camansi* (0.00 BU) would be most stable. Breakdown had positive association with stability of cold paste (r=0.94) as well as hot paste stability (r=0.93; Appendix C1) as expected and may be due to less granule rapture for starch (Farhat *et al*., 1999).

4.7.6 Time Taken to Reach Peak Viscosity (TTPV)

The time taken to reach peak viscosity for the flours varied from 2008.3 seconds (31.33) minutes to 2630 seconds (43.83 min). Table 4-10 shows the time taken to reach peak viscosity. *A. camansi* flour took the longest period to attain peak viscosity (2080 seconds or 43.83minutes) which was 1.3 times longer than the least in *A. heterophyllus* (33.48 min). Deffenbaugh and Walker (1989) reported that the time taken to reach peak viscosity of bread and cake flour were 38.8 min and 40.1 min respectively. According to Adebowale *et al*. (2005b) the time to reach peak viscosity is indicative of time required for cooking. Cooking time is dependent on pasting temperature; lower pasting temperature implies shorter cooking time. There was a positive correlation (r=0.51) between TTPV and pasting temperature. This observation is understandable as it takes time to accumulate sufficient heat to initiate gelatinization.

4.8 DIGESTIBILITY OF NUTS OF BREADFRUIT SPECIES

Table 4-11 shows the tannin content and digestibility coefficients of the breadfruit nuts. Significant differences ($P<0.01$) were observed in the digestibility coefficients (Neutral Detergent Fiber - NDF, Acid Detergent fiber - ADF, Acid Detergent Lignin - ADL, hemicelluloses, lignin, cell solubles, Digestible Dry Matter - DDM, Dry Matter Intake - DMI, Net Energy for Production - NEL and Relative Feed Value - RFV). However, the tannin and cellulose content of all the nut species was similar ranging between 47.67 mg/100g-69.67 mg/100g and 4.67%-6.33% respectively. Since the tannin content of the breadfruit nuts were similar it is expected that they would have similar extent of inhibition of digestion and absorption of nutrients present in them.

It was therefore not surprising that tannin content was not found to be a predictor of digestibility in the regression models (Table 4-22). *Treculia africana* had significantly ($P<0.01$) the highest NDF content (69.67%) than *A. heterophyllus* and *A. camansi*. *A. camansi* had the highest lignin content (12.10%) which was 3.4 times higher than the least (*A. heterophyllus*; 3.54%). The high lignin content of *A. camansi* contributed to its low digestibility (70.21%), net energy for production (NEL; 74.88 Mcal/Ib). However, it had higher dry matter intake (DMI; 2.51% per kg body weight) probably as a result of its higher cell soluble content (52.33%) which is known to be more digestible and palatable

(Progressive Nutrition, 2011). This probably resulted in *A. camansi* having higher relative feed value of 137.13 compared to the rest.

Table 4-11:Tannin content and digestibility coefficients of nutrients of breadfruit flours

Parameter	*A. heterophyllus*	*A. camansi*	*T. africana*	$LSD_{0.01}$
Tannin (%)	57.33±1.55	47.67±1.53	69.67±1.53	0.170
NDF (%)	57.33±1.55	47.67±1.53	69.67±1.53	4.281
ADF (%)	14.33±1.16	24.00±1.00	13.33±0.58	2.854
ADL (%)	5.67±0.58	15.00±1.00	7.33±0.58	50.700
Lignin (%)	3.54±0.58	12.10±1.00	4.69±0.58	2.472
HEM (%)	43.00±0.00	23.67±0.58	56.33±0.16	2.472
CELL(%)	6.33±0.58	5.67±0.289	4.67±0.58	1.748
CS (%)	42. 667±1.15	52.33±1.53	30.333±1.53	4.281
DDM (%)	77.73±0.90	70.21±0.78	78.51±0.45	2.223
DMI (%)	2.09±0.04	2.51±0.08	1.72±0.04	0.174
NEL (Mcal/lb)	86.77±0.01	74.88±0.01	88.00±0.01	0.035
RFV	126.18±4.05	137.13±5.95	104.88±2.79	13.486

NDF- Neutral detergent fiber; ADF-Acid detergent fiber; ADL- Acid detergent fiber; HEM- Hemicellulose; CELL-Cellulose; CS- Cell soluble; DDM-Digestible dry matter; DMI- Dry matter intake; NEL- Net energy for lactation; RFV- Relative feed value

4.9 CONCLUSION ON PROXIMATE, MINERAL AND FUNCTIONAL PROPERTIES OF *A. HETEROPHYLLUS*, *A. CAMANSI* AND *T. AFRICANA* BEAN FLOURS

The study has revealed that *A. heterophyllus*, *A. camansi* and *T. africana* bean flours have good proximate and mineral composition as well as functional properties. The high protein and mineral contents would make them suitable in combating malnutrition. On the other hand, their good functional properties suggested that they would be suitable in playing functional roles in food systems and they needed to be exploited for such purposes.

4.10 COMPARATIVE ASSESSMENT OF PHYSICOCHEMICAL AND FUNCTIONAL PROPERTIES OF NUT-DERIVED AND PULP FLOURS OF THE BREADFRUITS SPECIES

The results of a comparative assessment of the physico-chemical and functional properties of the nut and pulp flours of breadfruits have been presented in this section.

4.10.1 Proximate Composition

The proximate composition of the nuts and pulp of breadfruits are presented in Table 4-12. The moisture content of the flours (8.53-9.11%) were similar (P>0.01). The moisture content of the flours was within the recommended range (10-14%) for flours (Butt *et al.*, 2004). Higher moisture content in flours have been reported to enhance spoilage through creating favourable condition for microbial proliferation as well as enhance enzymatic deterioration (Oduro *et al*., 2009). Since the flours had acceptable moisture content they are expected to have good shelf life.

The protein content (15.70%) of the nut-derived flour was generally higher (4.1 times) than for the pulp (3.80%). Nelson-Quartey *et al*. (2007) however, reported a protein content of 6.06% for *A. altilis* pulp. The protein content of the pulp flour was also lower than *Dioscera alata* (water yam; 4.7-15.6%) reported by Treche and Agbor-Egbe (1995) as well the 9.8%; reported by Akubor and Badifu (2004) for wheat flour, (traditionally used in the bakery industry. However the protein content was higher than the 1.7 % reported by Gomez and Valdivieso (1983) for cassava.). Whereas the nut-derived flours can be considered as good source of proteins *A. altilis* pulp flour cannot.

Table 4-12: Proximate composition of *A. altilis* pulp and nut-based flours

	Moisture	Crude protein	Crude fat	Crude fibre	Ash	Carbohydrate
A. altilis Pulp	9.11±0.19a	3.80±0.61b	2.36±0.10b	3.12±0.08a	2.37±0.05a	79.24±0.59a
Nuts	8.53±1.96a	15.70±3.01a	6.93±1.88a	2.27±0.62b	2.56±0.40a	63.97±6.49b
$P_{0.01}$	0.029	0.009	0.003	0.004	0.013	0.004

As regards the fat content, there was significant difference (P<0.01) between the nuts (6.93%) and the pulp (2.36%) with the nuts being 2.9 times higher than the pulp. The breadfruit flours contained higher amounts of fat than *D.alata* (0.09 to 0.20%) reported by Opata *et al*.(2007). However, the low fat content of both the nuts and the pulp suggested they would not be good sources of oil.

The crude fiber content varied significantly (P<0.01) between the nuts and the pulp. The fiber content of the pulp (3.12%) which was 1.37 times higher than the nuts (2.27%). The fiber content of the breadfruits was higher than yam flour (1.65 %) reported by Jimoh and Olatidoye (2009), cassava (1.00 %) reported by Ihekoronye and Ngoddy

(1985) as well as yellow maize (0.66%) reported by Otitoju (2009). Fibre is reported to have beneficial effects on preventing cancer (Shankar and Lanza, 1991). *A. altilis* pulp is thus a better source of fiber than the nuts. *Artocarpus altilis* flour could therefore be used to fortify low-fiber flours such as cassava flour in the bread industry to increase its fiber content.

Both the nuts and pulp of the breadfruit species had similar ash content. The ash content of the pulp 2.37% was higher than cassava (1.0%) reported by Aryee *et al.* (2006) and yam flour (2.03%) reported by Jimoh and Olatdoye(2009) but lower than maize (3.3%) reported by Ihekoronye and Ngoddy (1985). The high ash content of the flours is indicative that they could be good sources of minerals. *A. altilis* pulp flour would therefore be a better source of ash than cassava and yam.

The carbohydrate content of the *A. altilis* pulp flour (79.24%) was higher than the nuts (63.97%) in this study and also *Bilphia sapida* pulp flour (6.53%) recorded by Akintayo *et al*. (2002). The high carbohydrate content of the pulp suggests that *A. altilis* pulp flour could be a good source of energy and explains its use as a staple in the Caribbean (Roberts-Nkrumah, 2005).

4.10.2 Mineral Composition of Breadfruit Pulp and Nut Flour

The mineral composition of the nuts-derived and pulp flours of breadfruits have been presented in Table 4-13. Potassium was found to be the predominant mineral in the breadfruit flours. The potassium content in the pulp (673.5mg/100g) was 2.15 times higher than the nuts (312.02 mg/100g). Generally, the potassium content of both the pulp and nuts flours was higher than in cassava (103.7-554 mg/100g) observed by Charles *et al.* (2005). Potassium has been reported to be an important mineral maintaining electrolyte balance in humans (NTBG, 2009) and its presence in the flours is very useful.

The sodium content of the pulp (69 mg/100g) was statistically similar to the nuts (48.17 mg/100g) in this study. The breadfruit flours had lower sodium content than cassava (437.5 mg/100g) reported by Akindahunsi *et al*. (1999). Morgan (1999) indicated that reducing intake of sodium ameliorates the development of hypertension. Since the sodium content of the breadfruit flours is low they could be used as food without apprehension of health-risks.

Table 4-13: Mineral composition of *A. altilis* pulp and nut-based flours

Treatment	*A. altilis* Pulp	Nuts	P-value
K	673.50±0.20	312.02±2.6	0.000
Na	69.00±0.00	48.17±9.250	0.045
Fe	3.91±0.78	5.11±435.02	0.041
Mg	90.63±0.05	90.19±78.80	0.016
P	140.00±0.00	289.20±131.17	0.002
Ca	60.83±0.43	95.17±31.31	0.175
K:Na	9.76±0.04	18.67±14.17	0.000
Ca:P	0.44±0.05	0.35±0.10	0.483

Statistically, similar amounts of iron were found in the breadfruit nuts and pulp. The iron content of the nuts-derived flour (5.11 mg/100g) was only marginally higher than the pulp (3.91 mg/100g). The iron content of the breadfruit flours was lower than cassava

(32mg/100g) (FAO and IFAD, 2004). Iron is an important constituent of haemoglobin found in blood. de Villota *et al.* (1981) emphasised the importance of iron in oxygen carriage in blood. According to The National Academy of Science (2004) the recommended daily allowance of iron is between 8 mg/day to 18 mg/day. The results of this study suggest that consuming at least 200 g of the breadfruit flours per day could help provide the daily requirement for iron assuming a 100% bioavailability.

The magnesium content in the *A. altilis* pulp flour (90.63 mg/100g) was comparable to the nuts (90.19 mg/100g). The magnesium of the breadfruit flours was higher than have been reported for cassava (36.58-37.71 mg100g) reported by Nassar *et al.*(2003) but lower than maize flour (460mg/100g) reported by Mbata *et al*. (2009) and Osabor *et al.* (2009). Magnesium is essential in enzyme systems and helps maintain electrical potential in nerves (Ferrao *et al.*, 1987). The presence of magnesium suggests they would be useful in enhancing enzyme and nervous system of consumers of breadfruits.

The phosphorous content of the *A. altilis* pulp flour (140 mg/100g) was 2.1 times lower than the nuts (289.20 mg/100g) in this study. The results showed that the phosphorus levels in the breadfruits were higher than in sweet potato (28 mg/100g) reported by; Ihekoronye and Ngoddy (1985) and *B.sapida* pulp (240 mg/100g) recorded by Akintayo *et al.* (2002) but lower than maize; (300mg/100g). The nuts had similar phosphorus content as rice (290mg/100g). According to Vitabase (2009) phosporus is essential for the process of bone mineralization as well as a role in the structure of cellular membranes, nucleic acids and nucleotides, including adenosine triphosphate. The breadfruit species could be a moderate source of phosphorus.

The calcium content of the nuts (95.17 mg/100g) was statistically similar to the pulp (60.83 mg/100g). The calcium levels in the breadfruit flours were however lower than in cassava (615 mg/100g) observed by Akindahunsi *et al.* (1999) and *Prospis africana* (362.5 mg/100g) reported by Aremu *et al.* (2006). The breadfruit flours could, however, be a moderate source of supplementing calcium intake.

There was no significant difference (P<0.01) in K:Na ratio between the pulp (9.67:1) and the nuts (18.67:1) with the pulp being 2.0 times higher. The ratios were higher than the minimum (5.0) reported by Szentmihalyi (1998). According to CIHFI (2008) foods which are naturally higher in potassium than sodium may have a K:Na ratio of 4.0 or more. Dietary changes leading to reduced consumption of potassium than sodium have health implications. Diets with higher K:Na ratio are recommended and these are found usually in whole foods (Arbeit *et al.*, 1992). Whole food refers to the cellular completeness of a food. The high K:Na ratios of the breadfruit flours suggested that the flours could be suitable in helping to ameliorate sodium-related health risk.

The pulp had statistically similar Ca:P ratio (0.44:1) as the nuts (0.35:1). According to Kemi *et al.* (2010) excessive dietary P intake alone can be deleterious to bone through increased parathyroid hormone (PTH) secretion, but adverse effects on bone increase when dietary Ca intake is low The theory is that if there is more phosphorus than calcium in the diet, the body will start to take calcium from its own reserves (the bones) to compensate. Over a period, this may affect dramatically the bones in a negative way prompting nutritionists recommendation for a Ca:P ratio that is at least 1:1 (Patenaude, 2007). According to McDowell (2003) the recommended Ca:P is 1:1 (1.0). However, according to SCSG (2007) a good menu should have a Ca:P ratio over 1. Foods high in phosphorus and low in calcium, tend to make the body overacid, depletes it of calcium and other minerals and increases the tendency towards inflammations (www.health-science-spirit.com/calcium.html). It has been found that when domesticated animals and pets are fed a diet that is low in calcium, but high in phosphorus, they developed bone disorders and dental problems. Since the flours of breadfruit flours recorded a Ca:P ratio of 0.35-0.44, the implication was that diets that were based only on breadfruit flour would need supplementation with calcium to prevent mineral and osmotic imbalance.

4.10.3 Physical Property

4.10.3.1 Bulk density

The bulk density of nut flours (0.65 g/cm^3) (Table 4-14) was not statistically different from the pulp *(*0.57 g/cm^3). The breadfruit flours had lower bulk densities than *D.alata* (0.64-0.76g/cm^3) reported by Udensi *et al*. (2008). Low bulk density of flour is an important component in weaning foods preparation. Bulk density provides an indication of the amount of starch in the breadfruit and also how the individual particles of the flour can arrange themselves in a more compact manner (Bhattachrya and Prakash, 1994). Since the pulp flour and nuts had low bulk densities they could be useful as ingredients in infant formulations. The bulk density of the pulp flours were found to be positively correlated with carbohydrate (r=0.88) (Appendix C2)

Table 4-14 Bulk density of *A. altilis* pulp and nut-based flours

Sample	BD (g/cm^3)
A. altilis Pulp	0.57±0.02
Nuts	0.65±0.12
$P_{0.01}$	0.019

BD – Bulk density

4.10.4 Functional Properties of Breadfruit Pulp and Nut Flours

The functional properties of the flours of the nuts and pulp of breadfruits have been presented in Table 4-15.

Table 4-15: Functional properties of *A. altilis* pulp and nut-based flours

Sample	WAC (g/g)	OAC (ml/g)	SOLB (%)	SP
Pulp	3.67±0.58	1.50±0.2	11.55±2.25	7.02±0.08
Nuts	2.31±0.50	0.75±0.43	9.97±1.7.2	5.50±0.75
$P_{0.01}$	0.387	0.176	0.372	0.012

WAC – Water absorption capacity; OAC – Oil absorption capacity; SOLB – Solubility; SP – Swelling power

4.10.4.1 Water absorption capacity

A. altilis The water absorption capacity of *A. altilis* in this study was higher than the (2.19 g/g) was obtained in an earlier study by Nelson Quartey *et al.* (2007) but lower than the 2.90-3.65 reported by Udensi *et al*. (2008) for cassava. Water absorption capacity is a necessary functional property that predicts the ability of flour to associate with water under conditions where water is limiting. Flours with higher water absorption capacity, according to Desikachar (1980), yield thicker pastes when mixed with water. Odoemelam (2000) explained that flours with high water absorption capacities could possibility contain hydrophilic proteins or polar amino acid residue. Such thick pasty meals therefore limit calorific intake when fed to children. The high water absorption capacity of the pulp flour was suggestive they could be useful in formulation of foods such as soups where thickening is desirable (Olaofe *et al.*, 1994). There was a negative correlation between water absorption capacity and protein (r=-0.90) as well as fiber content (r=-0.81) (Appendix C2) of the pulp flour.

4.10.4.2 Oil absorption capacity

The water absorption capacity of *A. altilis* pulp flour (1.50 g/g) was not significantly (P>0.01) different from the nuts (0.75 g/g). The oil absorption capacity of both the pulp and the nut flours was lower than sorghum (1.7-1.8 g/g) (Elmoneim *et al.*, 2005), *Dioscorea esculenta* (1.9 g/g) (Ukpabi, 2010) and *P.africana* (3.40g/g) (Aremu *et al.*, 2006). The presence of oils in foods improved flavor and improve mouth feel (Odoemelam, 2000). According to Aremu *et al.* (2006) oil absorption capacity was important as oil acts as flavor retainer. Lahl and Braun (1994) had indicated that lipid binding is dependent on the surface availability of hydrophobic amino acids. The nuts probably have higher amounts of hydrophobic amino acids resulting in their lower oil absorption capacity. Since the oil absorption capacity of *A. altilis* pulp flour did not differ from the nuts it was expected that they could all be used with similar results for the preparation of sausage, soups and cakes as flavor retainers (Aremu *et al.*, 2006).

4.10.4.3 Solubility

The solubility of *A. altilis* pulp flour (11.55%) was similar (P>0.01) to the nuts (9.97%). The solubility of the breadfruit flours was however, lower than yam (12.40-13.15%) (Iwuoha, 2004). Nelson-Quartey *et al.* (2007) reported that lipids could hinder the dissolution of flours in water. The observed higher fat content of the nut flours therefore, could have contributed to their lower solubility. The high solubility of the pulp flour suggested it was digestible and therefore could be suitable for use as ingredient in infant food formulations. There was a negative association between solubility and oil absorption capacity (-0.55) (Appendix C2).

4.10.4.4 Swelling power

The swelling power of *A. altilis* flours was 7.02 and was found no to be significant (P>0.01) to the nuts (5.5). The swelling power of both the pulp and the nuts were lower than those of both of yam (9.58) (Jimoh and Olatidoye, 2009) and cassava (7.35-7.38) (Olayinka and Kehinde, 2008). Swelling power is indicative of the solubility of a solute in a solvent. According to Melo *et al*. (2003), higher the swelling powers resulted inhigher solubility of flours (as observed in the present study. Morton (2002) indicated that fiber can be a barrier to swelling of starch. This seemed to have been given credence with the inverse correlation (r= -0.58; Appendix C2) observed in this study.

4.10.4.5 Foam capacity and stability

The foam capacity and stability over a 90 minute holding period of the breadfruit flours have been presented in Table 4-16. The nuts had marginally higher foam capacity (16.67%) than the pulp (9.2%). The foam formed by the pulp was significantly more unstable than the nuts. The foam capacity of the nut flours was within range for cowpea (10-21%) (Appiah *et al*., 2011a). The foam capacity of the breadfruit flours were however, lower than *Biphia sapida* pulp flour (26.62%) (Akintayo *et al*., 2002) but higher than *P.africana* (3.9%) (Aremu *et al.*, 2006) and sorghum flour (0%) (Elmoneim *et al.*, 2005). According to Indrawati *et al.* (2008), foam formation and stability are dependent on pH, viscosity, surface tension and processing methods. Akubor and Chukwu (1999) reported that foams were used to improve the texture and consistency and appearance of foods. The foaming capacity of the flours can be considered as good and therefore the flours could be used as foaming agents in foods requiring foamability such as *koose*. Foam capacity correlated negatively with oil absorption capacity (r=-0.70) (Appendix C2).

Table 4-16 Foam capacity and stability of *A. altilis* pulp and nut-based flours

Species	FC	30 min	60 min	90 min
Nut	16.67±9.83	4.67±5.20	1.94±1.73	1.39±1.27
Pulp	9.17±2.89	0.20±0.10	0.20±0.10	0.20±0.1
$P_{0.01}$	0.079	0.000	0.003	0.006

FC – Foam capacity;

4.10.4.6 Least gelation concentration

The least gelation capacity of *A. altilis* pulp flour (9.4%) was marginally higher than the nuts (6.7%) (Table 4-17). Gelation is an aggregation of denatured molecules. The ability of protein to form gels and provide structural matrix for holding water, flavors, sugars and food ingredients is useful in food application and in new product development

(Aremu *et al*., 2006). Udensi *et al.* (2001) indicated that gelation is a quality indicator influencing the texture of food such as moi–moi, agidi and soup. According to Onweluzo and Nwabuyu (2009) and Ezeji and Ojmelukwe (1993) flours with low least gelation capacity were not suitable for infant formulation since they required more dilution and would result in reduced energy density in relation to volume. Since the pulp flour required significantly (P<0.01) higher concentration of flour to gel they could be more suitable as an ingredient in infant formulation to enhance nutrient density (Ezeji and Ojimelukwe, 1993). The results suggest that breadfruit flours could act similarly as gel-forming or firming agent, and would be useful in food systems such as pudding and snacks which require thickening and gelling. The pulp flour may be marginally more suitable for to providing structure and body in foods such as *Tatale*.

Table 4-17: Least gelation concentration of *A. altilis* pulp and nut-based flours

Species	Least gelation concentration (%)
A. altilis Pulp	9.4±1.15
Nuts	6.7±1.15
$P_{0.01}$	0.500

4.10.7 Comparative Assessment of Pasting Characteristics of Flours of Breadfruit Nuts and Pulp

Figure 4-5 show the pasting behavior of the *A. altilis* pulp flours. The pasting temperatures of the flours were 73.20^{o}C and 81.96^{o}C (Table 4-18) for the pulp and nut flours respectively. There were significant differences (P<0.01) in pasting properties between the flour types.

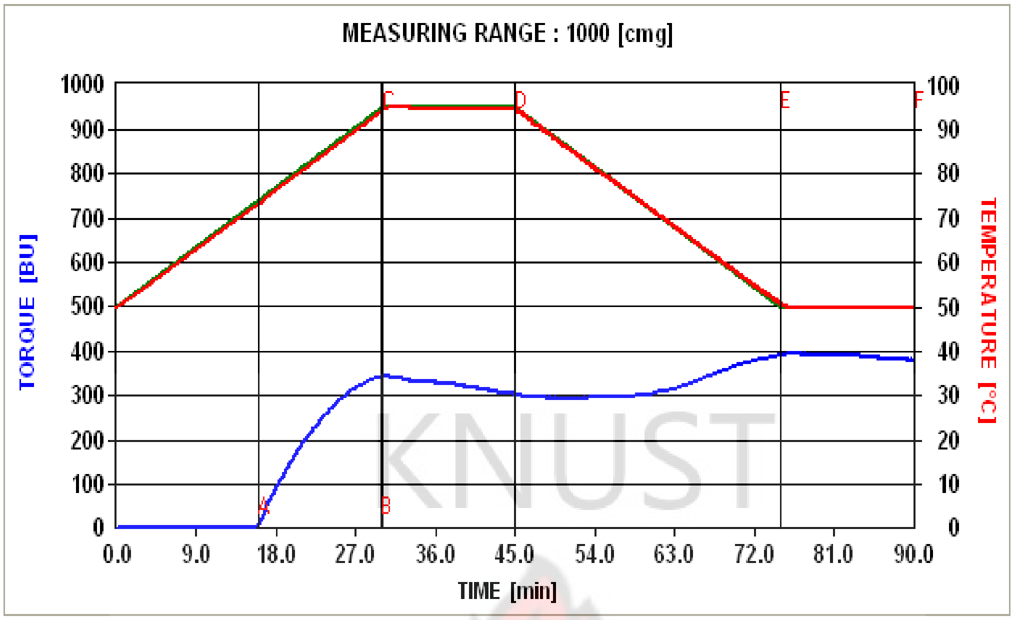

Figure 4-5 Typical pasting profiles for *A. altilis* pulp flour

The pasting temperature of *A. altilis* pulp (73.2°C) was within the range reported by Sefa-Dedeh *et al*. (2004) for maize (69-78°C) but higher than 64.2°C reported for cassava by Dzogbefia *et al.* (2008). Pasting temperature gives an indication of the temperature at which the flour would be cooked. The results showed that the nuts cooked at a higher temperature than the pulp. Cooking the nuts would therefore require more energy than the pulp. Higher pasting temperatures are likely to induce scorching before a paste is well cooked. This highlighted the need for continuous stirring when cooking with flours that have high pasting temperatures. Pasting temperature correlated positively with carbohydrate content (r=0.93), fiber content (r=0.62), bulk density (r=0.98) (Appendix C2).

All the viscosity parameters measured were higher in the *A. altilis* pulp flour compared to the nuts. The peak viscosity was 5.7 times higher in the *A. altilis* pulp (354.33 BU) than the nuts (62.00 BU). The peak viscosity of *A. altilis* was lower than the 488 BU and 426 BU reported by Deffenbaugh and Walker (1989) for bread flour (wheat) and cake flour (wheat) respectively. It was also higher than for cassava starch as 660 BU (Dzogbefia *et al.*, 2008). The results indicate that the pulp flour formed thicker pastes than the nuts. This is attributable to the higher swelling power (7.02) (Table 4-15) observed in pulp flour compared to the 5.50 of the nuts as according to Otegbayo *et al*. (2006) there was a positive correlation between swelling power and paste thickness. Ayenor (1985) indicated that high swelling capacity might be due to weak internal bonding in the starch granule. *A. altilis* probably have weaker internal bonding in its starch than the nuts resulting in higher peak viscosity (Otegbayo *et al*., 2006) which invariably led to granule rupture and alignment due to mechanical shear. The results indicated that the pulp flour could be useful as a thickening agent. According to Mbata *et al*. (2009) a low viscosity food would contain higher concentration of nutrients per unit weight since the volume of the food would be low. The pulp flour had higher viscosity and might be suitable for foods where heavy thickening is required. Peak viscosity was positively associated with protein content (r=0.61) (Appendix C2) while pasting temperature was negatively associated with carbohydrate content (r=-0.92) (Appendix C2).

The higher setback values for the pulp flour (84.00 BU) (Table 4-18) suggest it might be more resistant to breakdown in viscosity than the nuts (20.89 BU). This implies the cooked paste of the pulp flour would be more stable than the nuts (Oduro *et al.*, 2000) and the flour could be used for preparation of thick porridges. Correlation analysis on the *A. altilis* flours showed that setback correlated positively with peak viscosity (r=0.99) (Appendix C2) and protein content (r=0.55) but negatively with carbohydrate content (r=-0.86), fibre content (r=-0.60), oil absorption capacity (r=-0.89) and swelling power (r=-0.93). On the other hand peak viscosity correlated positively (r=0.61) with protein content whiles pasting temperature was positively correlated (r=0.92) to carbohydrate content.

Breakdown was higher in the pulp (43.67 BU) (Table 4-18) than in the nuts (6.33 BU). The results suggest that the pulp flour had lesser granule rapture of its starch suggesting it would have a more stable cooked paste compared to the nuts (Farhat *et al.*,1999). Lower breakdown viscosity during heating was indicative of good stability of starch paste and good bonding forces with the starch granules (Zobel 1984).

Table 4-18: Pasting characteristics of *A. altilis* pulp and nut-based flours

	PT	PV	EFH/FV	SB	BD
Pulp	73.20±0.2	354.33±9.87	395.33±8.39	84.00±6.93	43.67±3.22
Nuts	81.96±12.60	62.00±55.38	76.67±60.18	20.89±15.54	6.33±9.29
$P_{0.01}$	0.000	0.001	0.001	0.003	0.003

Key: ; PT-Pasting temperature (^{o}C); PV–Peak viscosity; EFH/FV-final viscosity; SB-Setback; BD-Breakdown

4.10.8 Digestibility of *A. altilis* pulp and nuts

Table 4-19 shows the tannin content and digestibility coefficients of the breadfruit pulp and nuts. The differences between the averages of the nuts and the pulp (*A. altilis*) were generally not significant (P<0.01) for all the parameters assessed. However, the differences between all the unpooled data of the nuts and the pulp were significant (P<0.01) (Table 4-21).

Table 4-19: Tannin content and digestibility coefficients of *A. altilis* pulp and nut-based flours

Parameter	Pulp	Nuts	$P_{0.01}$
Tannin (%)	4.30±1.20	3.51±0.08	0.32
NDF (%)	45.33±1.53	58.222±11.03	0.12
ADF (%)	16.33±1.53	17.222±5.89	0.81
ADL (%)	6.67±1.15	9.3333±4.98	0.42
Lignin (%)	4.32±1.19	6.7780±4.65	0.42
HEM (%)	29.00±1.00	41.000±16.43	0.28
CELL (%)	9.67±2.08	7.8889±1.64	0.31
CS (%)	54.667±1.53	41.778±11.03	0.12
DDM (%)	76.18±1.19	75.48±4.60	0.81
DMI (%)	2.65± 0.09	2.1120±0.40	0.09
NEL (Mcal/lb)	0.84±0.02	0.83±0.03	0.81
RFV	156.48±7.64	122.73±16.40	0.03

NDF- Neutral detergent fiber; ADF-Acid detergent fiber; ADL- Acid detergent fiber; HEM- Hemicellulose; CELL-Cellulose; CS- Cell soluble; DDM-Digestible dry matter; DMI- Dry matter intake; NEL- Net energy for lactation; RFV- Relative feed value

CONCLUSION

Although *Artocarpus altilis* pulp flour had lower protein content, it had comparable mineral composition and higher carbohydrate content as the nut-derived flours. It was also less heavy than the nut flours. It had higher least gelation concentration and formed thicker pastes with higher viscosity values. The carbohydrate and mineral content make *A. altilis* pulp flour more suitable for providing energy and nourishment for its consumers than the other flours. Its higher pasting viscosities were appropriate for producing meals requiring thicker paste formation during cooking.

4.11 PREDICTING THE DIGESTIBILITY OF NUTRIENTS AND THE ENERGY VALUES OF FOUR BREADFRUIT SPECIES BASED ON CHEMICAL ANALYSIS

4.11.1 Chemical Composition

The results of the chemical analyses are presented in Table 4-20. The crude protein content of the *A. camansi* (17.72 g/100g), *T. africana* (17.57 g/100g), and *A. heterophyllus* (12.23 g/100g) were higher than in *A. altilis* (3.8 g/100g). The results show that consuming 300 g of *A. camansi*, *T. africana* and *A. heterophyllus* per day would provide the recommended daily intake of proteins of (34-56 g/day) for human adults and children (13-19 g/day) (Food and Nutrition Board, 2002). The carbohydrate content of the breadfruit species was comparable to maize (66.0% to 75.9%) (Ortega *et al*.,1986). The high carbohydrate content was indicative that the breadfruits could be good sources of energy (Appiah *et al*., 2011a) in foods.

The tannin content of the different breadfruit species (Table 4-19) were statistically similar and ranged between 3.44 and 4.30 mg/100g. These were lower than the reported 13.3 g/100 and 19.1 g/100g for cashew nut and fluted pumpkin seeds respectively. Tannin has been reported to form complexes with proteins including enzymes resulting in reduced digestion and absorption (Cornel University, 2008; Jansman, 1993). They are also known to bind iron (Fe) making it unavailable (Brune *et al*., 1991) for absorption. In this study no significant ($P<0.05$) correlation was observed between tannin content and DDM of the breadfruit flours ($R= 0.13$) Table 4-21). Again, regression analysis did not identify tannin content as a predictor of digestible dry matter (Table 4-20). The low tannin content and the high digestible dry matter (DDM) content indicated that the breadfruit species can be used as food or feed ingredients without much apprehension about digestibility as well as nutrient availability.

Table 4-20: Chemical composition of breadfruit flours

Species	Crude Protein (g/100g)	Crude fat (g/100g)	Ash (g/100g)	Carbohydrates (g/100g)	Tannin (mg/100g)
A. camansi	17.72±0.62	6.33±0.30	2.90±0.05	64.18±0.70	3.44±0.09
A. heterophyllus	12.23±0.12	5.57±0.08	2.13±0.02	70.15±0.78	3.50±0.02
A. altilis	3.80±0.61	2.36±0.05	2.37±0.05	79.24±0.59	4.30±0.15
T. africana	17.57±0.45	9.08±0.14	2.64±0.02	57.00±0.33	3.59±0.02
$Lsd_{0.01}$	1.351	0.673	0.113	1.705	1.647

The neutral detergent fibre (NDF) content of the different breadfruit flours varied significantly. *T. africana* had highest NDF content (69.67 %) (Table 4-21) which was 154 % higher than the least (*A. altilis*; 45.33 %). *A. altilis* and *A. camansi* had statistically similar (P>0.01) NDF content. According to Johnson and Marlett (1986) NDF represented the insoluble fraction of fiber which is primarily responsible for increasing stool weight, defecation frequency and for decreasing gastrointestinal transit time. *T. africana* could therefore increase stool weight and reduce gastrointestinal transit and therefore reduce constipation more than the others.

The lignin content (Table 4-21), the major component of ADL (Richards *et al*., 2005), was similar for *T. africana*, *A. altilis*, and *A. heterophyllus* but statistically (P<0.01) higher in *A. camansi*. Schroeder (1994) indicated that as lignin increases, digestibility, intake, and animal performance usually decreases. Thus, *A. camansi* had the least dry matter intake (DMI). According to Belyea and Ricketts (1993) lignin ties up cellulose indicating that higher concentrations of lignin results in reduced cellulose digestibility. The low digestible dry matter (DDM) content (70.21%) of *A. camansi* could be attributed to its high lignin content. *Treculia africana* had the highest DDM (78.51%) suggesting that it was more digestible (Schroeder, 1994) than the rest. It was therefore not surprising that it was used in infant formulations particularly in Nigeria (Osuji and Owei, 2010; Amusa *et al*., 2002).

Table 4-21: Digestibility of nutrients of breadfruit flours

Species	NDF (%)	ADF (%)	ADL (%)	Lignin (%)	HEM (%)	CELL (%)	CS (%)	DDM (%)	DMI (%)	NEL (Mcal/lb)	RFV
AC	47.67±1.53	24.00±1.00	15.00±1.00	12.10±1.00	23.67±0.58	5.67±0.289	52.333±1.53	70.21±0.78	2.51±0.08	74.88±0.01	137.13±5.95
AH	57.33±1.55	14.33±0.1.16	5.67±0.58	3.54±0.58	43.00±0.00	6.33±0.58	42.667±1.15	77.73±0.90	2.09±0.04	86.77±0.01	126.18±4.05
AA	45.33±1.53	16.33±0.53	6.67±0.56	4.32±1.15	29.00±0.00	9.67±2.08	54.667±1.53	76.18±1.19	2.65±0.09	84.31±0.02	156.48±7.64
TA	69.67±1.53	13.33±0.58	7.33±0.58	4.69±0.58	56.33±0.16	4.67±0.58	30.333±1.53	78.51±0.45	1.72±0.04	88.00±0.01	104.88±2.79
$Lsd_{0.01}$	3.954	3.063	2.373	2.447	1.768	5.002	3.954	2.386	0.125	3.770	10.221

AC-*Artocarpus camansi*; AH- *Artocarpus heterphyllus*; AA-*Artocarpus altilis*; TA-*Treculia africana*; NDF- Neutral detergent fiber; ADF-Acid detergent fiber; ADL- Acid detergent fiber; HEM- Hemicellulose; CELLU-Cellulose; CS- Cell soluble; DDM-Digestible dry matter; DMI- Dry matter intake; NEL- Net energy for lactation; RFV- Relative feed value

The estimated net energy available for production and growth (NEL) was similar in *T. africana* (88.00 Mcal/lb), *A. heterophyllus* (86.77 Mcal/lb) *and A. altilis* (84.31 Mcal/lb) (Table 4-21). However, *A. camansi* (74.88 Mcal/lb), having the least NEL, differed significantly ($P<0.01$) from the rest. Generally, breadfruit species had high NEL values suggesting they would be useful in providing sufficient energy for growth if consumed. All the species varied significantly ($P<0.01$) from each other with respect to their estimated DMI. *A. altilis* (2.65 %) had highest DMI, 1.5 times higher than the least (*T. africana*; 1.72 %).

There was an inverse association between lignin content and digestible dry matter (DDM) content (R^2=0.99; Table 4-22) for *A. camansi* and *T. africana*. According to van Soest (1994) and Traxlet *et al*. (1998), lignin is responsible for the limited digestion of feed.

Table 4-22: Effect of chemical constituents on digestible dry matter (DDM) for breadfruit flours

Species	Equation No.	Relationship	R^2	P
A. camansi	1	Digestible Dry Matter = 82.00 – 0.76 Lignin	0.99	0.04
T. africana	2	Digestible Dry Matter = 82.07 - 0.76Lignin	0.99	0.00

The variation in dry matter intake (DMI) of both *A. altilis* and *A. camansi* could be explained by their cell soluble content (Table 4-23; equations 4 and 5). Other single predictors of DMI for *A. altilis* was its acid detergent fiber (ADF) content (Equation 3) whereas for *A. camansi*, it was its NDF content (Eqn 6). This observation relating to *A. camansi* was similar to the report of Schroeder (1994), who indicated that forage with high NDF values had less digestible dry matter intake (DMI) values. As regards *A. heterophyllus*, the variability in DMI could be attributed to its lignin (Equation 7) and carbohydrate content (Equation 8).

Table 4-23: Effect of chemical constituents on dry matter intake (DMI) for breadfruit flours

Species	Equation No.	Relationship	R^2	P
A. altilis	3	Dry Matter Intake = 3.59 – 0.06 Acid detergent fiber	0.99	0.01
	4	Dry Matter Intake = -0.51 + 0.08 Cell solubles	0.99	0.01
A. camansi	5	Dry Matter Intake = -0.51 + 0.05 Cell solubles	0.99	0.01
	6	Dry Matter Intake = 5.07 - 0.05 Neutral detergent fiber	0.99	0.01
A. heterophyllus	7	Dry Matter Intake = 83.1 – 1.51Lignin	0.99	0.02
	8	Dry Matter Intake = -1.74 + 0.06 Carbohydrates	0.99	0.02

Net energy for lactation/production (NEL) is the available energy for production in an animal (Schroeder, 1994). NEL was negatively related to lignin content of *A.*

heterophyllus (R^2=0.99; Table 4-24, Equation 10) and *T. africana* (R^2=0.99; Equation 11).

Table 4-24: Effect of chemical constituents on net energy for lactation (NEL) for breadfruit flours

Species	Equation No.	Equation	R^2	P
A. heterophullus	9	Net Energy = -0.41 + 0.02 Carbohydrates	0.99	0.04
	10	Net energy = 0.95 – 0.02 Lignin	0.99	0.02
T. africana	11	Net energy = 0.94 – 0.01Lignin	0.99	0.04

The relative feed value is an index that combines the important nutritional factors of intake and digestibility. Relative Feed Value has been of great value in ranking forages for sale or inventorying and assigning forage to animal groups according to their quality needs (Moore 2002). The relative feed value (RFV) (Table 4-25) of *A. heterophyllus* had a positive relationship with its carbohydrate content (R^2=0.99 Equation 12). According to Schroeder (1994) as percent ADF and NDF decrease the RFV increases similar to what was observed in this study. *A. altilis* (156.48) had higher RFV than *A. camansi* (137.13), *A. heterophyllus* (126.18) and *T. africana* (104.88) (Table 4-21). According to Progressive Nutrition (2011) the higher the RFV in forages, the more digestible and palatable they are. This is because, as the non-digestible fiber (ADF and NDF) increases, the palatability is lowered and the rate of passage through the intestinal tract slows due to its poor fermenting quality. Based on the reported grading by Progressive Nutrition (2011), *A. altilis* would therefore be a prime feed ingredient (RFV>151) while *A.*

camansi and *A. heterophyllus* would be premium ingredients (RFV 125-150) with *T. africana* graded as good (RFV 103-124).

Table 4-25: Effect of chemical constituents on relative feed value (RFV) for *A.heterophyllus* flours

Species	Equation No.	Equation	R^2	P
A. heterophullus	12	Relative Feed Value = -237.57 + 5.19 Carbohydrates	0.99	0.04

CONCLUSION

This study has shown that the breadfruit species had good digestibility and provides equations for predicting the digestibility coefficients of energy and nutrients in breadfruits. The digestibility and energy values of breadfruits could be predicted by using their chemical composition without doing feeding trials. The predictor for digestible dry matter (DDM) was lignin. Dry matter Intake (DMI) was dependent on carbohydrate, acid detergent fiber. The net energy for production (NEL) was predictable from carbohydrate, lignin while relative feed value (RFV) was dependent on the carbohydrate content.

4.12 PRODUCT DEVELOPMENT USING BREADFRUIT FLOURS

After the assessment of the physicochemical properties of flours of the various breadfruit species selected products were developed and assessed for their acceptability. The following products were produced: breakfast meal, pastry, fried pudding (*tatale*), *koose* (fritters) and *T. africana* condiment.

4.12.1 Breakfast Meal

4.12.1.1 Introduction

Breakfast meal was produced using *T. africana* flour. Results from the physico-chemical analysis revealed that the flour of *T. africana* had high protein content (17.57%), high potassium (533.95 mg/100g), low bulk density (0.53 ml/g), low swelling power (4.87), good solubility (8.01), low water absorption capacity (2.0 ml/cm^3), low viscosity (40.00 BU). These properties of *T. africana* flour made it suitable for production of weaning food as well as breakfast meal.

4.12.1.2 Nutritional composition composite flours for breakfast meal

The composite flours of *T. africana* and *Glycine max* (soyabean) were therefore used for the preparation of breakfast meal. Soyabean flour was used to fortify the protein content of *T. africana* flour as well as for improving its flavour. The proximate composition of the composite flours has been presented in Table 4-26.

Crude protein, crude fat, crude fibre and ash contents of the composite flours increased as soya bean level was increased in the composite flours. However, moisture and carbohydrate content decreased.

Table 4-26: Proximate composition of composite flours of *T. africana* and *G.max*

Flour blend (*T. africana*:*G.max*)	Moist. (%)	CP (%)	C.fat (%)	C.fibre (%)	Ash (%)	CHO (%)	Energy (kcal/100g)
P301 (100:0)	8.32	16.42	11.21	2.86	3.13	58.06	398.81
P133 (80:20)	7.85	20.36	12.47	3.44	3.28	52.60	404.07
P834 (60:40)	6.84	24.19	14.54	3.97	3.46	47.00	415.62
P592 (40:60)	7.1	31.08	16.37	4.60	4.06	36.79	418.81
P677 (20:80)	5.6	35.24	18.81	5.12	5.07	30.16	430.89
P218(0:100)	4.62	44.11	20.9	5.76	5.39	19.22	441.42

Key: Moist. – Moisture; CP – Crude Protein; C.Fat – Crude fat; C.Fib – Crude Fibre; CHO-Carbohydrate

The moisture content of the composite flours ranged between 4.62% and 8.32%. The moisture levels in the flours were lower than the 10-14% limits for flours (Butt *et al.*, 2004). According to Oduro *et al.* (2009), lower moisture content in foods enhances the shelf life of foods. The lower moisture contents of the flours suggested that they would have long shelf life.

The crude protein content of the composite flours was high. Flour composite P218 had the highest protein content (44.11%) significantly ($P<0.05$) different from composite P301 (16.42%) which was the least. According to Food and Nutrition Board (2002), the recommended daily protein intake is 34-56 g/day for children and 13-19 g/day for adults. Consuming a breakfast meal produced using 100 g of the flour could help meet the minimum daily protein needs of an adult.

The crude fat content in the composite flours varied between 11.21% and 20.9%. The results of the study showed that the fat content of the flours increased with increasing *Glycine max* content suggesting that palatability could also increase in a similar manner (Aremu *et al.*, 2006).

It was observed that as *G.max* levels increased in the composite flours crude fibre content also increased. The fiber content of the flours ranged between 2.86% and 5.76%. These values were high and suggest that the consumption of meals based on the flours could supply the needed crude fiber requirement. Crude fiber has been reported to be important in prevention of constipation and colon cancer (Shankar and Lanza, 1991). Therefore, the intake of meals based on *T. africana*-*G.max* composite flours could help to reduce the health risk of insufficient fiber intake.

Again, increasing proportions of *G.max* in the flour composites resulted in increased ash content. The ash content of the flours varied between 3.13% and 5.39% suggesting that the mineral content of the flours were high. The flours therefore, could help provide the needed mineral nourishment to consumers who would consume meals based on the composite flours.

The carbohydrate content of the flour blends varied significantly from 19.22% to 58.06% in composite P281 and P301 respectively. Carbohydrates are good sources of energy and help provide bulk and impart the needed pastiness for necessary mouthfeel. The high energy content (398.81-441.42 kcal/100g) of the flour blends suggested that meals based on the blends could help meet the daily energy requirement of the body.

4.12.1.3 Functional properties

Analysis of the functional properties of the flour composites showed that the bulk density of the flour blends ranged between 0.59 g/cm^3 and 0.77 g/cm^3 (Table 4-28). It was observed that as the proportion of *G.max* increased the composite flour also increased in bulk density. This was expected as it was observed that the bulk density of *G.max* (0.77 g/cm^3) was higher than *T. africana* flour (0.59 g/cm^3) used for the flour blends. According to Mbata *et al*. (2009) low bulk densities are important requirement in infant formulas. Therefore the flour composites which gave lower bulk densities could be suitable ingredients for infant foods.

Table 4-27: Functional properties of composite flours of *T. africana* and *G.max*

Functional properties (*T. africana*:*G.max*)	P301 (100:0)	P133 (80:20)	P834 (60:40)	P592 (40:60)	P677 (20:80)	P218 (0:100)
WAC (%)	197.65	205.19	217.17	241.75	267.17	288.16
Solubility (%)	8.56	11.32	16.45	19.48	21.34	26.23
Bulk density (g/cm^3)	0.59	0.63	0.66	0.71	0.74	0.77

Key: WAC - Water Absorption capacity

The water absorption capacity of the composite flours showed that P301 (197.65%) had the lowest while P218 had the highest (288.16%). Water absorption capacity is a hydration property and plays active role in hydration and development of paste. The higher water absorption capacity of *G.max* suggests that they might contain more hydrophilic proteins than *T. africana* (Lawal and Adebowale, 2004). The high water absorption capacity of flour suggested that the flour may have high solubility as observed in this study (Table 4-27).

The solubility of the flour blends were between 8.56% for P301 and 26.23% in P218. The increase in water absorption capacity with increasing *G.max* flour levels explains why the solubility of the flours also increased. Higher solubility has been associated with increased digestibility (Tonheim *et al*., 2007). The meals based on the blends with higher solubility could therefore be appropriate for children and adults since they would be digestible.

4.12.1.4 Sensory evaluation of porridges from *T. africana*-soyabean flour blends

Porridges were prepared from the composite flours and sensory evaluation was carried out. The colour of P301 was appreciated better than the rest, which did not differ significantly (P>0.05) from each other. (Table 4-28). The colour *T. africana* (P301) was lighter and therefore could have contributed to it being preferred.

Porridge from rations P301 and P133 the most acceptable in terms of mouth feel and were similar to each other with a score of 2.2 and 2.3 respectively. It was observed that the acceptability of mouthfeel declined with increasing levels of *G.max*.

Table 4-28: Sensory score for breadfruit porridges (*T. africana*:*G.max*)

Sensory Parameter	P301 (100:0)	P133 (80:20)	P834 (60:40)	P592 (40:60)	P677 (20:80)	P218 (0:100)	$LSD_{0.05}$
Colour	1.7	2.9	2.8	2.6	3.0	3.1	0.464
Mouthfeel	2.2	2.3	3.4	3.4	3.8	3.8	0.318
Taste	2.4	1.3	2.4	3.1	3.1	3.2	0.328
OA	2.2	1.9	2.5	2.6	2.8	2.9	0.193

Key: OA - Overall acceptability ; 1 – like very much; 2- like slightly; 3- neither like nor dislike; 4- dislike slightly; 5- dislike very much;

The taste of P133 was the most acceptable (1.3) compared to the rest. Generally, the breakfast meal produced with *T. africana*:*G.max* ratio of 80:20 (P133) was adjudged the most acceptable with overall acceptability score of 1.9 (Table 4-29). It was followed by blends P301 (2.2), then P834 (2.5) which was similar to P592 (2.6). The results suggested that above 20% level of G.max resulted in reduced acceptability even though none of the products was disliked (overall acceptability ≥3.0).

Regression analysis showed that the taste of the breakfast meal was the single most important variable explaining 53% (R^2=0.53) (Table 4-29)of the variation in overall acceptability. The contribution of taste to overall acceptability was governed by the equation: '*y=1.44+0.40(taste)*'as shown in Table 4-30. Stepwise regression revealed that colour, mouthfeel and taste explained 90% (R^2=0.90) of the variation in overall acceptability with the model: '*y=0.51+0.22(colour) +0.18mouthfeel +0.40(taste)*'.

Table 4-29: Relationship between overall acceptability and sensory variables for breadfruit products

Product	Regression equation	(R^2)	P value
BP	y=1.74+0.28(colour)	0.32	0.000
	y=1.24+0.39(mouthfeel)	0.50	0.000
	y=1.44+0.40(taste)	0.53	0.000
	y=0.92+0.28(taste)+0.26(mouthfeel)	0.71	0.000
	y=0.76+0.39(taste)+0.26(colour)	0.71	0.000
	y=0.51+0.22(colour)+0.18(mouthfeel)+0.31(taste)	0.83	0.000
Shortcake	*y=0.74+0.80(taste)*	0.67	0.000
	y=0.70+0.73(aroma)	0.72	0.000
	y=0.39+0.76(mouthfeel)	0.77	0.000
	y=0.78+0.71(colour)	0.82	0.000
	y=0.29+0.44(colour)+0.40(mouthfeel)	0.91	0.000
	y=0.09+0.42(aroma)+0.49(mouthfeel)	0.91	0.000
	y=0.29+0.44(colour)+0.40(mouthfeel)	0.91	0.000
	y=0.41+0.50(colour)+0.39(taste)	0.91	0.000
	y=0.43+0.47(colour)+0.37(aroma)	0.91	0.000
Koose	*y=0.89+0.77(taste)*	0.70	0.000
	y=0.39+0.76(mouthfeel)	0.72	0.000
	y=0.37+0.67(colour)	0.75	0.000
	y=0.65+0.69(aroma)	0.79	0.000
	y=0.54+0.44(taste)+0.52(mouthfeel)	0.83	0.000
	y=0.20+0.43(aroma)+0.36(colour)	0.89	0.000
	y=0.34+0.46(aroma)+0.47(mouthfeel)+0.37(taste)	0.91	0.000
	y=0.10+0.52(mouthfeel)+0.43(colour)	0.91	0.000
	y=0.12+0.44(colour)+0.46(taste)	0.92	0.000
Tatale	*y=0.90+0.90(mouthfeel)*	0.33	0.000
	y=0.96+0.60(taste)	0.42	0.000
	y=1.07+0.53(colour)	0.71	0.000
	y=1.01+0.52(aroma)	0.71	0.000
	y=0.81+0.31(aroma)+0.32(colour)	0.84	0.000
	y=0.48+0.45(colour)+0.38(taste)	0.85	0.000
Condiment	*y=0.28+0.87(colour)*	0.79	0.000
	y=0.39+087(aroma)	0.84	0.000
Stew	*y=0.76+0.67(aroma)*	0.63	0.000
	y=0.78+065(taste)	0.69	0.000

Key: BP - Breadfruit porridge; RC - Regression coefficient

4.12.2 Shortcake

T. africana flour was used to substitute for conventional wheat flour at varous levels of substitution. Sensory evaluation was conducted to assess the performance of *T. africana* flour in the production of shortcake. *T. africana* flour was selected on the basis of its high oil absorption capacity (1.25 ml/g). According to Aremu *et al*. (2006) flours with high oil absorption capacities could be suitable for the production of sausage, soups and pastries. The sensory performance of shortcake produced using *T. africana* as substitute for wheat flour has been presented on Table 4-30.

Table 4-30: Sensory score for *T. africana* shortcake (Wheat:*T. africana*)

Sensory parameter	S301 (100:0)	S133 (80:20)	S834 (60:40)	S592 (40:60)	S677 (20:80)	S218 (0:100)	$LSD_{0.05}$
Colour	1.3	1.4	1.7	2.6	3.8	4.6	0.320
Mouthfeel	1.4	1.7	2.8	3.4	3.7	4.4	0.337
Aroma	1.3	1.8	1.8	2.9	3.6	4.1	0.372
Taste	1.4	1.4	1.7	2.6	3.1	3.7	0.350
OA	1.4	1.6	2.0	2.9	3.6	4.2	0.182

Key: OA - Overall acceptability ; 1 – like very much; 2- like slightly; 3- neither like nor dislike; 4- dislike slightly; 5- dislike very much;

The colour of the shortcakes S301 (1.3), S133 (1.4) and S834 (1.7) were similarly appreciated and were considered to be better than S592, S677 and S218 which contained higher amounts of *T. africana* flour (≥60%). This might be attributable to the relatively darker colour of the shortcakes produced using 60% or more *T. africana* flour. This was not surprising as colour (R2=0.82) (Table 4-30) was found to be the single most important variable explaining the variation in overall acceptability (Table 4-30).

As regards mouthfeel, shortcake S301 (1.4) and S133 (1.7) containing up to 20% *T. africana* flour were observed to be similar and perceived to be better than the rest (S834, S592 and S677). Shortcakes S301 and S133were generally scored as liked with hedonic scores between 1 and 2.

Generally, the aroma of S301 (Table 4-30) which contained only wheat flour was better appreciated than those containing *T. africana* flour. The aroma of S133 (1.8) was perceived to be similar to S834 (1.8) but significantly ($P<0.05$) better than S592 (2.9), S677 (3.6) and S281 (4.1). It was observed that as the *T. africana* content increased preference for the aroma decreased. The aroma of S677 and S218 were disliked by the panel.

The taste of S301 (1.4), S133 (1.4) and S834 (1.7) were considered to be similar but better than S592 (2.6), S677 (3.1) and S218 (3.7). The results showed that the taste of the shortcakes was adversely affected at ≥60% level of substitution of wheat flour by *T. africana* flour. Generally, it was observed that up to 40% level of substitution of wheat flour by *T. africana* flour, the hedonic scoring for the shortcake was within the like range (≤ 2.0). Colour was the single most important attribute explaining 82% (R^2=0.82) (Table 4-30) of the variation in overall acceptability. This was not surprising as it was observed that as *T. africana* content increased in the composite shortcake flour the colour of the corresponding shortcake became darker.

4.12.3 Tatale

In this study, *A. altilis* flour which had high peak (354.33BU), final viscosities (385.33 BU) (Table 4-18). The low least gelation concentration suggested that small quantities of *A. altilis* flour could gel easily when heated in the presence of water. These property made the flour of *A. altilis* pulp suitable as a binder for use in the production of Tatale, a traditional ripe plantain fritter in Ghana. Table 4-31 shows the results of sensory evaluation carried out on *Tatale* produced using *A. altilis* flour at various levels of substitution for wheat flour.

Table 4-31: Sensory scoring for *Tatale* produced with *A. altilis* and wheat composite fours (Wheat:*A. altilis*)

Sensory Parameter	T301 (100:0)	T133 (80:20)	T834 (60:40)	T592 (40:60)	T677 (20:80)	T218 (0:100)	$LSD_{0.05}$
Colour	1.2	1.3	1.3	2.3	3.3	3.1	0.246
Mouthfeel	1.8	2.1	2.4	2.4	2.6	2.7	0.287
Aroma	1.4	1.3	2.0	2.1	3.2	3.6	0.287
Taste	1.6	1.8	1.9	2.3	2.3	2.4	0.298
OA	1.5	1.6	1.9	2.3	2.9	3.0	0.147

Key: OA - Overall acceptability ; 1 – like very much; 2- like slightly; 3- neither like nor dislike; 4- dislike slightly; 5- dislike very much;

With respect to the colour of *Tatale*, the sensory panel regarded products T301 (1.2), T133 (1.3) and T834 (1.3) as similar. This suggested that substituting up to 40% of wheat flour by *A. altilis* flour did not result in adverse colour change in the *Tatale* produced. The mouthfeel of T301 (1.8) was the most acceptable and was significantly

(P<0.05) different (P<0.01) from the rest. Generally all the products were considered as having satisfactory muthfeel (hedonic score 1 to < 3). The aroma of T301 (1.4) and T133 (1.3) were similar and significantly better than T834 (2.0), T592 (2.1), T677 (3.2) and T218 (3.6). Since up to 60% level of substitution of wheat for *A. altilis* flour did not result in the panel indicating they disliked the products, it suggested that the substitution level of 60% gave agreeable aroma.

As regards the taste, T301 (1.6) was appreciated better than T133 (1.8) which was also similar to T834 (1.9) but better than the rest. Generally, the taste of all the products was regarded as agreeable (hedonic score 1 to < 3). Overall T301 (1.5), T133 (1.6) and T834 (1.9) with up to 40% *A. altilis* pulp flour produced acceptable Tatale and were considered similar to each other. However, they were more acceptable than T592 (2.3), T677 (2.9) and T218 (3.0). From the results it can be concluded that *A. altilis* pulp flour can be used to substitute up to 40% of wheat flour in the production of Tatale. The regression models derived suggested that the aroma and colour were the major contributors to the variation in overall acceptability with each having R^2=0.71 (Table 4-31).

4.12.4 Breadfruit Fritters (Koose)

A. camansi flour was chosen for *Koose* production based on its high foam capacity (19.2%) (Table 4-6) and foam stability (Table 4-7). There were significant differences in the colour (P<0.05)of the *Koose* produced from the different flour composites. The colour of K301 (1.3) (Table 4-32) was more appreciated than K133 (2.3), K834 (3.3) and the rest.

As far as mouthfeel was concerned the panellist assessed K301 (1.2), K133 (1.2) and K834 (1.3) to be similar. However, they were better preferred to K592 (2.6), K677 (2.9) and K218 (3.0) which were produced using more than 60% of *A. camansi* flour. The products with the most preferred aroma was K301 (1.4) and significantly ($P<0.05$) better than the rest. At 60% and higher levels of substitution of *A. camansi* flour for cowpea the aroma of the products were deteriorated and was disliked.

The products with the most preferred taste were K301 (1.2), K133 (1.3) and K834 (1.5) which did not differ significantly ($P<0.05$) from each other and were better than the rest (Table 4-32). The results show that 60% of cowpea used for the production of Koose could be substituted with *A. camansi* without adverse effect on taste.

With respect to overall acceptability K301 (1.3) was more acceptable than the rest. The sensory evaluation results suggested that up to 40% level of substitution by *A. camansi* for cowpea produced acceptable fritter (Koose). Aroma was found to be the single most reliable sensory attribute explaining 79% (R^2=0.79) (Table 4-29) of the variation in overall acceptability. On the other hand, linear multiple regression indicated that colour and taste together explained 91.5% (R^2=0.92) (Table 4-29) of the variation in overall acceptability of the koose produced.

Table 4-32: Sensory scoring for Koose produced with *A. camansi* and cowpea composite flours (Cowpea:*A. camansi*)

Sensory Parameter	K301 (100:0)	K133 (80:20)	K834 (60:40)	K592 (40:60)	K677 (20:80)	K218 (0:100)	$LSD_{0.05}$
Colour	1.3	2.3	3.3	4.1	4.2	4.6	0.290
Mouthfeel	1.2	1.3	1.3	2.6	2.9	3.0	0.276
Aroma	1.4	1.8	2.1	3.4	3.6	4.4	0.343
Taste	1.2	1.3	1.5	2.8	3.2	3.2	0.320
OA	1.3	1.7	2.1	3.2	3.5	3.8	0.158

Key: OA - Overall acceptability ; 1 – like very much; 2- like slightly; 3- neither like nor dislike; 4- dislike slightly; 5- dislike very much;

4.12.5 Nutritional and Functional Properties of Treculia africana Condiment

4.12.5.1 Nutritional composition

Proximate composition

A comparative assessment of the performance of *Treculia africana* in the production of a local condiment (dawadawa) was assessed. Condiments were produced using, *T. africana*, *Glycine max* and *Parkia biglobosa* beans (Plate 4-14). The proximate composition, mineral composition, functional properties and sensory qualities of the condiments were assessed and reported in Tables 4-33 – 4-35.

The moisture content of the condiments ranged between 10.23 and 11.41%. Significant differences ($P<0.01$) were observed between the moisture content of *P.clapertoniana* condiment and *G.max* and *T. africana*. The moisture content recorded in this study were within range (6%-11%) reported by Souane (1985) for *dawadawa*. The low moisture content of the condiments is likely to enhance their shelf life (Oduro *et al*., 2009).

  

A: *P.clapertoniana* condiment B: *G.max* condiment C: *T. africana* condiment

Plate 4-14: Condiments produced using beans from different crops

Parkia biglobosa had the highest protein content (49.69%) which was similar to *G.max* (47.39%) but different from *T. africana* (21.28%). The protein content of *P.biglobosa* and *G.max* was higher than those reported by Souane (1985), Obizoba (1998) and Alabi *et al.* (2005) who reported 37.5%, 27-44% and 34.3% respectively for dawadawa. Although *T. africana* had the least protein content the levels are similar to other sources of plant proteins such as cowpea (Appiah *et al*., 2011b). The high protein content of the condiments make them good meat substitutes and good sources of protein and therefore could be useful in combating protein malnutrition.

The crude fat content of the condiments varied significantly between 17.36% and 26.85% with *T. africana* having the lowest. Fats are kown to be sources of fat-soluble vitamins. The high fat content of *P.calppertoniana* and G.max suggests they could be better sources of fat-soluble vitamins than *T. africana* and flavor enhancers when used for condiment production.

Table 4-33: Proximate composition of condiments

Type of condiment	Moisture (%)	Crude protein (%)	Crude fat (%)	Crude fibre (%)	Ash (%)	Carbohydrate (%)
P.biglobosa	10.23±0.07	49.69±0.04	26.85±0.07	1.49±0.01	4.32±0.04	7.43±0.01
G.max	11.40±0.20	47.39±0.03	19.90±0.08	4.30±0.21	3.70±0.03	16.19±0.20
T. Africana	11.41±0.04	21.28±0.02	17.36±0.09	0.45±0.05	3.14±0.04	45.91±0.30
$LSD_{0.01}$	0.54	2.23	1.40	0.26	0.52	0.97

The crude fiber content of the condiments was low ranging between 0.45% and 1.49%. The observed values were lower compared with some cowpea species (1.92%-3.3%) reported by Chinma *et al.* (2008). The results suggested that the *T. africana* condiment would not be a good source of fiber since it had the least fiber content (0.45%).

The ash content of *Treculia africana* although high (3.14%) was lower than *P.biglobosa* (4.32%) and G.max (3.70%). The ash content of the condiments was higher than the 2.95% reported by Edema *et al.* (2005). Ash content is indicative of the mineral content of the condiment. The high ash content suggested that the condiments would have relatively high mineral content.

The carbohydrate content of the condiments varied widely between the species. *Treculia africana* had the highest (45.91%), which was 6 times higher than the least in *P.biglobosa* (7.43%). These values were lower than the 46.36% reported by Alabi *et al.* (2008). Reduction in carbohydrate content during fermentation of beans as in dawadawa production could be due to utilization of some of the sugars by fermenting organisms for growth and metabolic activities (Chukwu *et al.*, 2010).

Mineral content of condiments

The mineral content of the condiments were generally high. There were significant differences (P<0.01) in potassium content of the condiments varying from 520 mg/100g (Table 4-34) in *T. africana* to 1460 mg/100g in *G.max*. *Treculia africana* condiment therefore could be considered as a good source of potassium. The high potassium content of dawadawa coupled with the low sodium levels seemed to explain the claim by some consumers that it was good for alleviating hypertension.

The condiments had calcium content ranging from 637 mg/100g to2400 mg/100g. *T. africana* had higher (800 mg/100g) calcium content than *P.biglobosa* (637 mg/100g). The high levels of calcium suggested that the condiments could be considered as good sources of calcium.

Treculia africana had higher magnesium content (816 mg/100g) than *G.max* (192mg/100g) and *P.biglobosa* condiments (136 mg/100g). *Treculia africana* would thus, be a better source of magnesium than *G.max* and *P.biglobosa* condiment (Table 4-34) since consuming 50 g of *T. africana* condiment would provide the daily requirement of magnesium for adults (265-350 mg; Food and Nutrition Board, 1997).

Table 4-34: Mineral composition of condiments

Type of condiment	K (mg/100g)	Na (mg/100g)	Ca (mg/100g)	Mg (mg/100g)	P (mg/100g)
P.biglobosa	1322±0.04	28±0.10	637±0.00	136±1.00	375±0.10
G.max	1460±0.00	124±0.04	2400±0.00	192±1.00	388±0.20
T. africana	520±0.02	54±0.00	8000.00	816±0.00	424±0.30
$LSD_{0.01}$	87.54	13.42	65.88	19.22	26.33

The phosphorus content of *T. africana* (424 mg/100g) condiment was significantly higher (P<0.01) than that of *P.biglobosa* (375 mg/100g) and *G.max* (388 mg/100g). The high phosphorus content of *T. africana* condiment suggestd it would be a good food source of phosphorus.

4.12.5.2 Functional properties

The water absorption capacity of the condiments ranged between 0.75ml/g to 1.25ml/g (Table 4-35) for *P.biglobosa* and *G.max* respectively while *T. africana* had 1.0ml/g. However, the differences between the species were not significant (P>0.01). *T. africana* had higher water absorption capacity than *P.biglobosa* and could dissolve more easily into soups and stews. Depending on a protein side chain (number of charged and polar group), a protein may bind varying amount of water (Vaclavik *et al.*, 2003). The water absorption capacity of a flour is an indication of the amount of water that could be absorbed and therefore could be available for gelatinisation (Edema *et al.*, 2005).

The oil absorption capacity of the condiments was 0.45 ml/g, 1.75 ml/g, and 2.17 ml/g for *P.biglobosa*, *T. africana* and *G.max* respectively (Table 4-35). There were significant differences ($P<0.01$) between the condiments produced using the different species. The ability of proteins to bind oil is significant as absorbed oil act as flavour retainer and increase the mouth feel when used in food preparations (Chinma *et al.,* 2008). The oil absorption capacity of *T. africana* condiment was good and indicated that it could be a good flavor retainer and could improve mouthfeel when used in food preparations than *P.biglobosa*. The condiment could therefore be used in food preparation such as soups.

Table 4-35: Water and Oil absorption capacities of condiments

Species	WAC (ml/g)	OAC (ml/g)
P.biglobosa	0.75±0.10	0.45±0.05
G.max	1.25±0.10	2.17±0.05
T. africana	1.00±0.10	1.75±0.04
$LSD_{0.01}$	0.76	0.25

WAC-Water absorption capacity OAC-Oil absorption capacity. Figures bearing different alphabets are significantly different at $p<0.01$

4.12.5.3 Sensory performance of condiments

The results of the sensory evaluation carried out on the condiment showed that *Treculia africana* condiment performed better than *G.max* (2.25) (Table 4-36) with respect to colour but poorly against *P.biglobosa* (1.5) with a hedonic score of 1.8 which fell within the like slightly category. With respect to the aroma of the condiments, *T. africana* (2.35) performed similarly as *Glycine max* (2.1) but poorly against *P.biglobosa* (1.25). Generally, the aroma of all the condiments was liked. As regards the overall acceptability, *T. africana* (2.08) performed similarly as *G.max* (2.18) which is used in commercial production of condiment. The performance of *T. africana* notwithstanding, *P.biglobosa* (1.38) (Table 4-37) was the most accepted.

On the other hand, evaluation of stew prepared using the condiments showed that the taste of *T. africana* stew was liked (2.4) similarly as *G.max* (1.95) (Table 4-37) but better than that with no condiment. However, compared to *P. biglobosa*, *T. africana* was less liked. Similar results were obtained for aroma as in taste. *T. africana* scored poorly against *P.biglobosa* (1.8) and *G.max* (1.8) but better than that with no condiment (2.9). The lower performance notwithstanding, aroma of stew containing *T. africana* (2.5) was within the like slightly and neither-like-nor-dislike range. As regards the overall acceptability *T. africana* stew (2.45) performed better than the stew without condiment (3.00) but poorer than *G.max* (1.88) which was similar to *P.biglobosa* (1.80). On the other hand the score for *T. africana* indicates that its aroma was not as agreeable as *P.biglobosa*. The performance of *T. africana* notwithstanding, the hedonic scoring indicates the aroma was within the range of like slightly and neither like nor dislike. This implies *T. africana* produced a condiment with acceptable aroma.

Table 4-36: Sensory scoring for condiments

Condiment	Colour	Aroma	Overall Acceptability
P.biglobosa	1.50±0.04	1.25±0.12	1.38±0.08
G.max	2.25±0.06	2.10±0.10	2.18±0.08
T. africana	1.80±0.12	2.35±0.16	2.08±0.14
$LSD_{0.01}$	0.43	0.44	0.80

Key: 1 – like very much; 2- like slightly; 3- neither like nor dislike; 4- dislike slightly; 5- dislike very much

The results of overall acceptability of the stews produced with the various condiments showed that *T. africana* performed poorly against *P.biglobosa* but similarly against *G.max* with a score of 2.45. Even though *T. africana* scored better than the stew without condiment, *Parkia biglobosa* was adjudged the best condiment with a mean score of 1.80 similar to *G.max* (Table 4-37).

Table 4-37 Sensory scoring for stew produced with condiments

Condiment	Taste	Aroma	Overall Acceptability
P.biglobosa	1.80±0.09	1.80±0.11	1.80±0.10
G.max	1.95±0.08	1.83±0.20	1.88±0.14
T. africana	2.40±0.07	2.50±0.07	2.45±0.07
No condiment	3.10±0.08	2.90±0.14	3.00±0.11
$LSD_{0.01}$	0.57	0.53	0.41

Key: 1 – like very much; 2- like slightly; 3- neither like nor dislike; 4- dislike slightly; 5- dislike very much

There was a significant (P=0.000) positive association (r=0.64; Appendix C3) among colour and aroma of the condiments. This implied that as the colour of the condiment improved to acceptable levels, the aroma is expected to be better. Regression analysis indicated that aroma was the single most important predictor of overall acceptability (R^2=0.84; Table 4-29).

CONCLUSION ON FOOD PRODUCT FORMULATION

This study has shown that the breadfruit species did not only have good nutritional and functional properties but that they could be used in formulation of different food products where they could replace conventional ingredients. The product produced having breadfruits as ingredients exhibited acceptable sensory attributes as indicated by the sensory panelists.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATION

5.1 CONCLUSION

The study sought to contribute to expanding the use of breadfruit varieities (*Artocarpus altilis*, *Artocarpus camansi*, *Artocarpus heterophyllus* and *Treculia africana*) in Ghana. A systematic evaluation of breadfruit consisting of an audit of available cultivars, their nutritional properties, food properties, industrial potential, and evaluation of their use in selected applications essential towards their development and utilization has been conducted. The roles of indigenous knowledge, physicochemical properties including pasting characteristics, and fermentation were envisaged. Data were presented to show that breadfruit species were common in Ghana, and that they had commendable nutritional composition, functional and pasting properties as well as potential for inclusion of their flours (both unfermented and fermented) in formulation of food products. The study clearly established that the use of breadfruits in Ghana could be expanded and that products of acceptable quality could be produced from them.

Breadfruits were found to be available especially in the rural communities and that they have been used as medicine and food. However, their food use has been limited as they were generally regarded as less important against major and minor foods in Ghana. Fortunately, they are important food security crops and have sustained many during crop failures. Moreover, they are found in forest and transition zones of 6 out of 10 regions) in Ghana.

In Ghana breadfruits are not cultivated on large scale and have not been commercially exploited. Multiple factors have contributed to their non-exploitation. Among the factors are ignorance of their commercial potential, short shelf life, stigmatization as non-important foods, insufficient scientific information on their potential use in food product development as well as their industrial potential.

Artocarpus camansi, *Artocarpus heterophyllus* and *Treculia africana* had high protein content and their inclusion in diets could help alleviate protein-defficiency related conditions such as Kwashiokor. Since the breadfruit species were rich in potassium they could be used in providing the potassium needs of consumers of breadfruits especially in the rural areas where protein undernutrition is high. The good functional properties of the flour make them suitable for use in food systems where they could play functional roles. The low bulk densities and high solubilities of the breadfruit flours suggested they could be used in breakfast meal preparations. The foam capacity of *Artocarpus camansi* and *Artocarpus heterophyllus* suggested they could find application in food systems requiring foamability such as in *koose* production.

As far as the pasting properties were concerned, the breadfruit flours compared favourably with popular food flours and therefore could have application as thickening agents and also find use in soups and stews. Breakfast meal, shortcake, Koose and tatale produced using breadfruit flours were acceptable to consumers with substitution level of conventional flours up to 20% while condiment produced performed favourably with popular condiments.

Based on the survey, physicochemical properties and products developed from the flours, breadfruits in Ghana have huge potential as food ingredient than they are presently used. However, notwithstanding the commendable properties of breadfruit flours, it faces great competition from conventional food flours. Huge industrial opportunities exist in the production of breadfruit flours as products formulated in this study showed good levels of acceptance by consumers. The inclusion of breadfruit flours in food products could reduce the cost of using conventional flours which are expensive. The use of the flours would eventually enhance and expand the use of breadfruits.

This study provides equations for predicting accurately the digestibility coefficients of energy and nutrients in breadfruits. The digestibility and energy values of breadfruits could be predicted by using their chemical composition without doing feeding trials. The predictors for DDM were ADL, lignin, hemicelluloses and NDF. DDI was dependent on carbohydrate, fat ADF, hemicelluloses and NDF contents. On the other hand NEL was predictable from ADL, lignin and hemicelluloses while RFV was dependent on the carbohydrate, fat and NDF content. Thus its incorporation into local food products and its use as agro-forestry trees on cocoa plantation should be exploited. Further research should be done on the cultivation, processing and marketing of breadfruit and its products. Since breadfruits are already popular food security crops with little promotion many more people would consume them and could have good prospects for adoption. In terms of policy, all efforts could be made to promote the planting and consumption of breadfruits at all levels of society.

An important limitation worth mentioning is the stigmatization of breadfruit as food for the poor as well as the notion that it is not suitable for high ranking people in society such as chiefs. These therefore call for systematic education to disabuse the minds of the public from the stigma and rather promote it as good source of food. The breadfruit flours were reported to induce flatulence and this also limits its use. Constraints existing with respect to the utilization of breadfruit include peeling and removal of seeds since their fruits are huge and some of the pulps are slimy hindering seed extraction. Again since breadfruits generally have short shelf life small-scale on-farm processing technologies will have to be promoted. It is necessary to research into the possibility of reducing the height of the breadfruit trees (not compromising yield) since harvesting at height (several meters) is labourious and dangerous considering the bulk of the fruits.

Based on the survey, physicochemical properties, digestibility coefficients and products developed from the flours of breadfruits it is evident that they can be used in the food industry in many more formulations than previously thought.

The empirical relationships established between the physico-chemical properties as well as the digestibility can facilitate the formulation of products using breadfruits at much lower production cost. Overall, the study proved the possibility of producing food products from the breadfruit species (*A. altilis*, *A. camansi*, *T. africana*) other than the present traditional ones. This was possible based on the nutrient, physical, functional including the pasting properties of the flours of the breadfruit species,reported in this study.

5.2 RECOMMENDATIONS

The storage behavior of the flours of the breadfruit species need to be evaluated if it is to become of commercial value such for export. Knowledge of these factors will enable policy makers and planners to advise farmers on the planting of appropriate cultivars as raw materials for food and industrial purposes. The presence or absence of antinutritional factors other than tannin should be investigated and appropriate processing technologies installed for reducing such factors.

It is important that further research be conducted into protein solubility of the flours of the breadfruit species to help identify other food uses of the flours. The development of other food products as well animal feed from the breadfruit species need to be investigated. It is necessary to determine the starch and amylose content of the breadfruit flours.

CONTRIBUTION TO KNOWLEDGE

The study made meaningful contribution to existing knowledge pertaining to parameters studied. The study was successful in establishing the association between proximate, mineral and functional properties of the breadfruit species. The knowledge of the existing associations among the physico-chemical properties of breadfruits would help Food Scientists and Technologists as well as Nutritionists manage their expectation of the association among properties of breadfruits flours. Again the empirical relations established between chemical constituent and digestibility coefficients of the breadfruit species were established. The regression models predicting the various digestibility coefficients are important as they would help eliminate speculations and generalizations in predicting the relationship between physico-chemical parameters.Knowledge of the models would help scientists and practioners in the food and feed industry to predict the digestibility of the flours of breadfruit species when some chemical components are known without carrying out expensive feeding trials. This would facilitate food formulation and development.

This study provides the first report of K:Na and Ca:P ratios of the breadfruit species (*A. heterophyllus*, *A. altilis* and *A. camansi*). These are important information in that they are useful for Nutritionists to make informed decisions on the health benefits of consuming products based on the flours of breadfruit species.

The study has also revealed that the flours of the various breadfruit species could be used to substitute conventional flours used in the formulation of some selected food product with acceptable sensory attributes.Specifically, food products such as ripe plantain fritters (Tatale), cowpea fritters (koose). The predictors of sensory acceptability of the formulated products have been reported. This study has highlighted the potential of *T. africana* in the production of condiment similar to dawadawa which has been conventionally produced using *P.biglobosa* and *G.max.*

Overall, this study has bridged the knowledge gap by providing sufficient physico-chemical information on breadfruit species which can be harnessed by Food Scientists, Nutritionists, Extension Officers as well as policy makers in efforts to combat malnutrition and promote food security using breadfruit species which invariably would facilitate the expansion of the use of breadfruits in Ghana and the sub-region.

References of Published Papers Emanating from Study

- Appiah, F., Oduro, I. and Ellis, W. O. (2011). Pasting properties of *Treculia africana* seed flour in Ghana and the production of a breakfast meal. *Agriculture and Biology Journal of North America* 2 (2): 325-329
- Appiah, F., Oduro, I., and Ellis, W. O. (2011). Proximate and Mineral composition of *Artocarpus altilis* pulp flour as affected by fermentation. *Pakistan Journal of Nutrition* 10 (7): 653-657
- Appiah, F., Oduro, I., and Ellis, W. O. (2011). Functional properties of *Artocarpus altilis* pulp flour as affected by fermentation. *Agriculture and Biology Journal of North America* (5): 773-779.

REFERENCES

Abbey, B. W. and Ibeh, S. O. (1988). Functional properties of raw and heat processed cowpea (*Vigna unguiculata*, walp) flour. *Journal of Food Science*. 53(6): 1775 - 1791.

Acona, D.B., Guerrero, L.C. and Hernndez, E.C. (1997). Acetylation and Characterization of *Canavalia ensiformis* Starch. *Journal of Agricultural and Food Chemistry* 45: 378 382.

Adebowale, K. O. and Lawal, O. S. (2003a). Microstructure, physicochemical properties and retrogradation behavior of Macuna bean (*Macuna pruriens*) starch on heat moisture treatments. *Food Hydrocolloid* 17: 265–272.

Adebowale, K. O. and Lawal, O. S.(2003b) Foaming, gelation and electrophoretic characteristics of macuna bean (*Macuna pruriens*) protein concentrate, *Food Chemistry* 83: 237–246.

Adebowale, K. O., Olu-Owolabi, B. I., Olawumi, E. K. and Lawal, O. S. (2005). Functional properties of native, physically and chemically modified breadfruit (*Artocarpus altilis*) starch. *Industrial Crop Production*, 21, 343–351.

Adebowale, A. A., Sanni, L. O. and Awonorin, S.O. (2005b). Effect of texture modifiers on the physicochemical and sensory properties of dried fufu. *Food Science and Technology International* 11 (5): 373-382.

Adejuyitan, J. A., Otunola, E. T., Akande, E. A., Bolarinwa, I. F. and Oladokun, F. M. (2009). Some physicochemical properties of flour obtained from fermentation of tigernut (*Cyperus esculentus)* sourced from a market in Ogbomoso, Nigeria. *African Journal of Food Science.* Vol 3(2): 51-055.

Adu, G. A. (2006). Production of Spice from *Treculia africana*. An unpublished dissertation submitted to the Department of Biochemistry, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. 40pp.

Ahmad, N. and Wilman D. (2001): The degradation of the cell walls of lucerne, Italian ryegrass and wheat straw when fed to cattle, sheep and rabbits. *Journal of Agricultural Science,* 137, 337-349

Ahmed, K., Malek, M., Jahan, K. and Salamatullah, K. (1986). Nutritive value of Food Stuff 3rd edn. Institutde of Nutrition and Food Science, University of Dhaka, Bangladesh, pp. 16-17.

Aiyesanmi, A. F. and Oguntokun, M. O. (1996). Nutrient composition of *Dioclea reflexa* seed–an underutilized edible legume. *Rivista Italiana delle Sostanze Grasse.* 73:521–523.

Akindahunsi, A. A., Oboh, G. and Oshodi, A. A. (1999). Effect of fermenting cassava with *Rhizopus oryzae* on the chemical composition of is flour and Gari products. United Nations Educational Scientific and Cultural Organization and International Atomic Energy Agency. The Abdus Salam International Centre for theoretical Physics. Miramare-Trieste Italy.

Akinmutimi, A. H. (2006). Nutritive value of Raw and Processed Jackfruit Seeds (*Artocarpus heterophyllus*): *Chemical Analysis. Medwell Agricultural Journal 1(4): 266-271*

Akintayo, E. T., Adebayo, E. A. and Arogundade, L. A. (2002). Chemical composition, physicochemical and functional properties of akee (*Bilphia sapida*) pulp and seed flours. *Food Chemistry* 77: 333-336.

Akinyede, A. I. and Amoo, I. (2009). Chemical and Functional Properties of full Fat and Defatted Cassia fistula Seed flours. *Pakistan Journal of Nutrition* 8(6):765-769

Akinyele, I. O., Onigbinde, A. O., Hussain, M. A. and Omololu, A. (1986). Physico-chemical characteristics of 18 cultivars of Nigerian cowpeas (*V. unguiculata*) and their cooking properties. *Journal of Food Science* 51: 1483-1485

Akubor, P. I., Isolokwu, P. C., Ugbane, O., Onimawo, I. A. (2000). Proximate composition and functional properties of breadfruit kernel and flour blends. *Food Research International* 33:707–712.

Akubor, P. I. and Badifu, G. I. O. (2004). Chemical composition, functional properties and baking potential of African breadfruit kernel and wheat flour blends. *International Journal of Food Science and Technology* 39: 223–229. 2476.

Akubor, P. I. and Chukwu, J. K. (1999). Proximate composition and selected functional properties of fermented and unfermented African oil bean (*Pentaclethra macrophylla*) seed flour. *Plant Foods for Human Nutrition* 54 (3): 227-238.

Alabi, D. A. Akinsulire, O. R. and Sanyaolu, M. A. (2005). Qualitative determination of chemical and nutritional composition of *Parkia biglobosa* (Jacq) Benth. *African Journal of Biotechnology* 4(8): 812-815

Alagiapillai, O. A., Kuttalam, P. S., Subramanian, V. and Jayasekhar, M. (1996). PPI-I Jack: A new high yielding, regular bearing Jack species for Tamil Nadu. *Madras Agricultural Journal*, 83(5), 310–312.

Aletor, VA (1993). Allelochemicals in plant foods and feeding Stuffs. Part I. Nutritional, Biochemical and Physiopathological aspects in animal production. *Vetenary and Human Toxicology* 35(1): 57-67.

American Association of Cereal Chemists (1983). Approved Methods of the AACC, 8th Edition. Method 22-10, approved May 1960, revised October 1982; The Association : St. Paul, MN

Amusa, N. A., Kehinde, I. A. and Ashaye, O. A. (2002). Biodeterioration of breadfruit (*Artocarpus communis*) in storage and its effects on the nutrient composition. *African Journal of Biotechnology* 1 (2): 57-60.

AOAC (1990). Official Methods of Analysis. Association of Official analytical Chemists 15th Edition, Washington D. C.

Appiah, F., Oduro, I. and Ellis, W. O. (2011a). Pasting properties of *Treculia africana* seed flour in Ghana and the production of a breakfast meal. *Agriculture and Biology Journal of North America* 2 (2): 325-329

Appiah, F., Asibuo, J. Y. and Kumah, P. (2011b). Physicochemical and functional properties of bean flours of three cowpea (*Vigna unguiculata* L. Walp) varieties in Ghana. *African Journal of Food Science* 5(2): 100 - 104

Arbeit, M. L., Nicklas, T. A. and Berenson, G. S. (1992). Considerations of dietary sodium/potassium/energy ratios of selected foods *Journal of American College of Nutrition* 11(2):210-22.

Aremu, M. O., Olonisakin, A; Atolaye, B. O and Ogbu, C. F. (2006). Some nutritional and functional studies of *Prosopis africana*. *Electronic Journal of Environmental, Agricultural and Food Chemistry* 5(6):1640-1648.

Ariyesako, B. (1998). The Bhikkhu's Rules: A Guide for Laypeople. The Theravādin Buddhist Monk's Rules. [ftp://ttbc.no-ip.org][Accessed 28th August, 2010]

Aryee, F. N. A., Oduro, I., Ellis, W. O. and Afuakwa, J. J. (2006). The physicochemical properties of flours from the roots of 31 species of cassava. *Food Control* 17 (11): 916-922.

Asase, A. and **Tetteh**, D. A. (2010). The role of complex agroforestry systems in the conservation of forest tree diversity and structure in southeastern Ghana. *Agroforestry Systems* 79 (3): 355-368.

Aurand, L. W., Woods, A. E. and Wells, M. R. (1987). Food Composition and Analysis, van Norstrand Reinhold Int. Co. Ltd. New York, pp. 513 –521.

Ayenor, G. S. (1985). The yam (*Dioscerea*) starches. In G. Osuji (Ed.), Advances in yam research: the biochemistry and technology of the yam tuber. Biochemical Society of Nigeria and Anambra State University of Technology. Enugu, Nigeria pp. 79-88.

Baccus-Taylor, G. S. H. and Akingbala, J. O. (2007). Breadfruit studies at the Food Science and Technology Unit, University of the West Indies, St. Augustine, Trinidad. *Acta Horticulturae* 757: 177-182.

Baccus-Taylor, G. S. H., Akingbala, J. O. and Caldwell, M. (1999). Nutritional evaluation of breadfruit containing composite flours products. *Journal of Food Science* 57: 1420-1451

Bajner, R. E. (2002). Stearic acid addition to maize starch and its influence on pasting viscosity behavior. MSc Thesis. Department of Food Science, Univesity of Pretoria, South Africa. pp83

Balagopalan, C., Padmosa, G., Nanda, S.K. and Moorthy, S.N (1988). Cassava in Food, Feed and Industry. C.R.C. Press Inc. Boca Raton, Florida. pp. 189-196

Belyea, R. L. and Ricketts, R. E. (1993). Forages for cattle: New methods of determining energy content and evaluating heat damage. University of Missouri Extension. G3150. [http://extension.missouri.edu/publications/DisplayPrinterFriendlyPub.aspx?P=G3150][Acceccd 9th august 2011]

Bender, D. A. (2005). *A Dictionary of Food and Nutrition*. Encyclopedia.com. [http://www.encyclopedia.com/doc/1039-digestibility.html][Accessed 1st October 2011]

Beyer, R. (2007). Breadfruit as a candidate for processing. *Acta Horticulturae*. (ISHS) 757: 209–214

Bhattachrya, S. and Prakash, M. (1994). Extrusion blends of rice and chicken pea flours: A response surface analysis. *Journal of Food Engineering* 21: 315 - 330.

Blumenthal, J., Baltensperger, D., Cassman, K. G., Mason, S. and Pavlista, A, (2008). "Importance and Effect of Nitrogen on Crop Quality and Health" . *Agronomy -- Faculty Publications.* Paper 200. [http://digitalcommons.unl.edu/agronomyfacpub/200][Accessed September 1, 2012]

Brabender GmbH and Co. KG (2010). Food Quality Testing with Brabender Test Instruments. **[**http://www.brabender.com/fileadmin/dateien/gb/download/nahrungsmittel/download/broschueren/weitere/Uebersicht_Nahrungsmittel_gb.pdf][Accessed December 15, 2010]

Brenndorfer, B., Kennedy, L., Bateman, O., Trim, D. S., Mrema, G. C. and Brobby, C. W. (1985). *Solar dryers—their role in post-harvest processing*. London: Commonwealth Science Council. pp337

Brown, K. H. (1991). The importance of Dietary Quality versus Quantity for weanlings in the developed countries. A Framework for Discussion. *Food and Nutrition Bulletin.* 13 (2): 86-93.

Brune, M., Hallberg, L. and Skanberg, A. B. (1991). Determination of iron-binding phenolic groups in foods. *Journal of Food Science* 56: 131-137.

Buléon, A., Colonna, P., Planchot, V. and Ball, S. (1998). Starch granules: Structure and biosynthesis, *International Journal of Biological Macromolecules*, 23: 85-112.

Burkill, H. M. (1997). *The Useful Plants of West Tropical Africa*. Vol. 4, 2nd Edn. Royal Botanic Gardens, Kew, pp: 160-161. 960.

Butt, M. S., Nasir, M., Akhtar, S. and Sharif, K. (2004). Effect of moisture and packaging on the shelf life of wheat flour. *International Journal of Food Safety*. 4:1-6

CAB International (2006). *Treculia africana*. Forestry Compendium.available online at: [http://www.cabicompendium.org/NamesLists/FC/Full/TRECAF.htm][Accessed 16th March 2009]

Cabrera, C., Lloris, F. Gimenez, R., Olalla, M. and Loez, C. (2003). Mineral content in legumes and nuts: contribution to the Spanish dietary intake. *The Science of the Total Environment* 308:1-4.

Carnali, J. O. and Zhou, Y. (1996). An examination of the composite model for starch gels. *Journal of Rheology* 40 (2): 221-234

Cavalier-Smith, T. (2003). The excavate protozoan phyla Metamonada Grassé emend (Anaeromonadea, Parabasalia, *Carpediemonas*, Eopharyngia) and Loukozoa emend (Jakobea, *Malawimonas*): their evolutionary affinities and new higher taxa. *International Journal of* Systematic and Evolutionary *Microbiology* 53:1741–58

Charles, A. L., Sriroth, K. and Huang, T-C (2005). Proximate composition, mineral contents, hydrogen cyanide and phytic acid of 5 cassava genotypes *Food Chemistry* 92 (4): 615-620

Cherry, J. P. & McWatters, K. H. (1981). Whippability and aeration. In J. P. Cherry (Ed.), *Protein functionality in foods, ACS symposium series 147*. Washington, DC: American Chemical Society. p. 149

Chinma, C. E. and Gernah, Z. D. I. (2007). Physicochemical and Sensory Properties of Cookies Produced from Cassava/Soyabean/Mango Composite Flours. *Mexiwen Journal of Food Technology* 5 (3): 256-260.

Chinma, C. E., Alemede, I. C., and Emelife, I. G. (2008). Physicochemical and functional properties of some Nigerian cowpea varieties. *Pakistan Journal of Nutrition* 7(1): 186-190.

Chukwu, O., Orhevba, B.A. and Mahmood, B. I. (2010). Influence of Hydrothermal Treatments on Proximate Compositions of Fermented Locust Bean (Dawadawa). *Journal of Food Technology* 8:(3) 99-101

Chukwuone, N. A. and Chukwuemeka, E. O. (2008). Willingness to Pay for Systematic Management of Community Forests for Conservation of Non-Timber Forest Products In Nigeria's Rainforest Region: Implications For Poverty Alleviation. Rob B. Dellink And Arjan Ruijs (Eds.), Economics Of Poverty, Environment And Natural-Resource Use. Pp. 117-137.

CIHFI (2008). Potassium/Sodium Ratio, (K/Na ratio). The Center for the Improvement of Human Functioning International. Wichita, USA [http://biocenterlab.org/tests/urine/kna.shtml][Accessed August 14, 2010).

Circle, S.J., Myer, E. W. and Whiteney, R. (1964): Rheology of Soy protein dispersions. Effect of heat and other factors on gelation. *Cereal Chemistry*, 41: 157-172.

Codex Alimentarius Commission Amendment Regulations (2000). The Processed Cereal-Based Foods and Baby Foods for Infants and Young Children.

Cooke, D. and Gidley, M. J. (1992). Loss of christalline and molecular order during starch gelatinization. Origin of the enthalpy transition. *Carbohydrate Research* 227: 103-112.

Cooperative Resources International (2006). [http://www.Foragetesting.org/lab_procedure/appendix/A/EnergyEstimates.htm][Accessed 17th August 2011]

Cornel University (2008). Tannins: fascinating but sometimes dangerous molecules. In: Plants Poisonous to Livestock. [http://www.ansci.cornell.edu/plants/toxicagents/tannin.html] [Accessed 20th September 2011]

Cox, P. A. (1980). Two samoan technologies for breadfruit and banana preservation. *Economic Botany* Volume 34, Number 2: 181-185

Crosbie, G. B. (1991).The relationship between starch swelling properties, paste viscosity and boiled noodle quality in wheat flours. *Journal of Cereal Science* 13(2): 145-150

Damardjati, D. S. and Luh, B. S. (1987). Physicochemical properties of Extrusion-cooked rice breakfast cereals. Proceeding of the 7th World Congress of Food Science and Technology. Trends in Food Processing 1: Membrane Filtration Technology and Thermal Processing and Quality of Foods. Singapore. October. A. A. Ghee *et al* (Eds.). pp. 251-264.

Daniel, J.R. and Weaver, C.M. (2000). Carbohydrates: Functional properties. In: Christen GL, Smith JS. Eds., *Food chemistry: Principles and applications*. California: Science technology system, pp.63-66.

David, J. and William, A.A. (1999). Starch modifications. Ergan hand book series: Starches. *American Association of Cereal Chemists*, pp.31- 48.

de Villota, D., Ruiz, E. D., Carmona, M. T., Rubio J. J., and de Andrés, S. (1981). Equality of the in-vivo and in-vitro oxygen-binding capacity of haemoglobin in patients with severe respiratory disease. *British Journal of Anaesthesics* 53 (12): 1325–1328.

Debnath, S., Bhat, K. K. and Rastogi, N. K. (2003). Effect of pre-drying on kinetics of moisture loss and oil uptake during deep fat frying of chickpea flour-based snack food. *Lebensmittel-Wissenschaft und-Technologie* 36 (1): 91-98

Deffenbaugh, B. and Walker, C. E. (1989). Comparison of starch pasting properties in the Brabender Viscoamylograph and the Rapid Visco-Analyzer. *Cereal Chemistry* 66 (6): 493-499.

Demiate, I.M., Oetterer, M. and Wosiacki, G. (2001): Characterization of chestnut (castenea sativa, Mill) starch for Industrial Utilization. *Brazilan Archives of Biology and Technology* 44: 1

Dendy, D. A. V. (1993). Review of Composite flour Technology in the Context of Tanzania. Presented at the Workshop: 'Sorghum and Millets Marketing and Utilization'. Arusha, Tanzania. 3-5 May, 1993.

Dengate, H.N. (1984). Swelling pasting and gelling of wheat starch. In: Poneranz, Y. (Ed.), Advances in Cereal Science and Technology, vol. 6. AACC, St. Paul, MN, p. 49.

Desikachar, H. S. R. (1980). Development of weaning foods with high caloric density and low paste viscosity using traditional technologies. *Food and Nutrition Bulletin* 2 (4):221-225.

Donovan, J. W. (1979). Phase transition of the starch-water system. *Biopolymers* 18:263

Doublier, J. C., Paton, D. and Llamas, G. (1987). A rheological investigation of oat starch pastes. *Cereal Chemistry* 64: 21-26

Duke, J. and Alan, A. (1986). *Handbook of proximate analysis tables of higher plants*. CRC Press Inc. Boca de Raton, p. 21

Dzogbefia, V. P., Ofosu, G. A. and Oldham, J. H. (2008). Physicochemical and pasting properties of cassava starch extracted with the aid of pectin enzymes produced from *Saccharomyces cerevisiae* ATCC52712. *Scientific Research and Essay* 3 (9): 406-409.

Edema, M.O., Sanni, L.O. and Sanni, A.I. (2005). Evaluation of maize-soya bean flour blends for sour maize bread production in Nigeria. *African Journal of Biotechnology* 4(9): 911-918.

Elevitch, C. R. E., Isabella, A. Abbott, and Leakey, R. R. B. (2006). Traditional trees of Pacific Islands: their culture, environment, and use. Permanent Agricultural Resources (PAR), Holualoa, Hawaii. pp. 800.

Elhag, M. E., El Tinay, A. H. and Yousif, N. E. (2002). Effect of fermentation on starch, total polyphenols, phytic acid content and in vitro protein digestibility of pearl millet. *Food Chemistry* 77:193-196

Eliasson, A. C. (1985). Starch gelatinization in the presence of emulsifier. A morphological study of wheat starch. *Starch* 37:411-415

Eliasson, A.-C., and Gudmundsson, M. (1996). Starch: Physicochemical and functional aspects. In A.-C. Eliasson (Ed.), *Carbohydrates in food* New York, NY: Marcel Dekker. pp. 431–503

Elmoneim, A., Elkhalifa, O., Schiffler, B. and Bernhardt, R. (2005). Effect of fermentation on the functional properties of sorghum flour. *Food Chemistry* 92: 1-5.

Enibe, S. O. (2001). Design, construction and testing of a breadfruit depulping machine, Landwards, Summer 2001; 16-21.

Enibe, S. O. (2002). Propagation, Early Growth, Nutritional and Engineering Development Project on *Treculia africana* Decne (African Breadfruit). A proposal submitted to AFORNET for funding.

Esuoso, K. O., and F. O. Bamiro. (1995). Studies on the baking properties of non-wheat flours, breadfruit (*Artocarpus altilis*). *International Journal of. Food Science and Nutrition* 46 (3):267-273

Etudaiye, H. A., Nwabueze, T. U. and Sanni, L. O. (2009). Pasting and functional properties of processed cassava from mosaic disease-resistant vaieties cultivated in a high rainfall zone. *Nigeria Food Journal* 27 (2): 185-193

Ezeji, C. and Ojimelukwe, P. C. (1993). Effect of fermentation on the nutritional quality and functional properties of infant food formulations prepared from bambara-groundnut, fluted pumpkin and millet seeds. *Plant Foods for Human Nutrition* 44: 267-276.

Fagbemi, T. N., Oshodi, A. A. and Ipinmoroti, K. O. (2005). Processing effects on some antinutritional factors and *In vitro* Multienzyme Protein Digestibility (IVPD) of three Tropical Seeds: Breadnut (*Artocarpus altilis*), Cashew nut (*Anacardium occidentale*) and Fluted Pumpkin (*Telfaira occidentalis*). *Pakistan Journal of Nutrition* 4 (4): 250-256.

Falade, O. S., Sowunmi, O. R., Oladipo, A., Tubosun, A. and Adewusi, S. R. A. (2003). The level of organic acids in some Nigerian fruits and their effect on mineral availability in composite diets. *Pakistan Journal of Nutrition* 2 (2): 82-88

FAO and IFAD (2004). Cassava for Livestock Feed in Sub-Saharan Africa. [ftp://ftp.fao.org/docrep/fao/007/j1255e/j1255e00.pdf][Accessed 11th August, 2010]

Farhat, I. A, Oguntona, T. and Neale, J. R. (1999). Characterisation of starches from West African yams. *Journal of the Science of Food and Agriculture* 79: 2105–2112

Fasasi, O. S., Eleyinmi, A. R., Fasasi, A. R. and Karim,O. R. (2004). Chemical properties of raw and processed breadfruit (*Treculia africana)* seed flour. *Food, Agriculture and Environment* 2 (1): 65-68.

Ferrao, J. E. M., Ferrao, A. M. B. C. and Anatures, A. M. G. (1987). Garcia deorta, serieda estudes. *Agronomicos* 14 (1 – 2), 35 – 39

Food and Nutrition Board. (1997). Dietary reference intake for calcium, phosphorus, magnesium, vitamin D, and Vitamin F. *Institute of Medicine. National Academy Press.* (KH)*Washington, DC pp190-249*

Food and Nutrition Board. (2002). Dietary reference intake for energy, carbohydrate, fiber, fatty acids, cholesterol, protein and amino acids. *Food and Nutrition Board, Institute of Medicine. National Academy Press.* (KH)*Washington, DC* pp 422-541

Frei, M. and Becker, K. (2004). Agro-biodiversity in subsistence-oriented farming systems in a Philippine upland region: nutritional considerations. *Biodiversity and Conservation* 13(8): 1591-1610.

Galvez, F. C. F. and Resurreccion, A. V. A. (1993). The Effects of Decortication and Method of Extraction on the Physical and Chemical Properties of Starch from Mungbean (*Vigna Radiata* (L.) Wilczec). *Journal of Food Processing and Preservation* 17 (2): 93–107.

Gamedoagbao, D. K. and Bennett-Lartey, S.O. (2007). Conservation and use of breadfruit: Ghanaian perspective. *Acta Horiculturae* (ISHS) 757:125-128

Gebrie-Mariam, T, Ababa, A. and Schmidt, P. C. (1998). Some physic-chemical properties of Dioscera Starch from Etiopia. *Starch* 50: 173-182.

Geiser, D. M., Dorner, J.W., Horn, B.W. and Taylor, J. W. (2000). The phylogenetics of mycotoxin and sclerotium production in *Aspergillus flavus* and *Aspergillus oryzae*. *Fungal Genet Biol*. 31(3):169-79.

Ghiasi, K., Varriano-Marston, K. and Hoseney, R.C. (1982). Gelatinization of wheat starch. II. Starch-surfactant interaction. *Cereal Chemistry* 59: 86.

Giami, S. Y., Adindu, M. N., Akusu, M. O. and Emelike, J. N. (2000). Compositional, functional and storage properties of flours from raw and heat processed African breadfruit (*Treculia africana* Decne) seeds. *Plant Foods for Human Nutrition* (Dordrecht, Netherlands) 55(4):357-368.

Giami, S.Y. and T. Amasisi, 2003. Performance ofAfrican breadfruit *(T. africana* Decne) seed flour in breadmaking. *Plant Food for Human Nutrition* 58: 1-8

Giami, S. Y., Okonkwo, V. I. and Akusu, M. O. (1994). Chemical composition and functional properties of raw, heat-treated and partially proteolysed wild mango (*Irvingia gabonensis*) seed flour. *Food Chemistry* 49 (3): 237-243

Gibinski, M., Polasinki, M. and Tomasik, P. (1993). Physicochemical properties of defatted oat starch. *Starch* 45: 354-357

Gomez and Valdivieso (1983). The effect of species and plant age on cyanide content, chemical composition and quality of cassava roots. *Nutrition Research International* 27: 857-865

Grant, R. (1995). Taste of Africa. *70 easy-to-cook recipes from an undiscovered cuisine*. Anness Publishing Limited. London. Pp. 18.

Green, J., Mcintosh, M. and Wilson, A. (1991). Changes in nutrition knowledge scores and calcium intake in female adolescents. *Family and Consumer Sciences Research Journal* 19 (3): 207-214.

Greenberg, M. J. (1995). Chewing gum with dental benefits employing calcium glycerophosphate. United States Patent Number 5,378,131. Date of Patent January 3, 1995

Grosskinsky, B. and Gullick, C. (2000). *Exploring the Potential of Indigenous Wild Food Plants in Southern Sudan*. Proceedings of a Workshop Held in Lokichoggio, Kenya, June 3-5 1999. [http://pdf.usaid.gov/pdf_docs/pnacg706.pdf][Accessed September 4, 2012]

Han, B., Kiers, J. L. and Nout, R. M. J. (1999). Solid-Substrate Fermentation of Soybeans with *Rhizopus spp*.: Comparison of Discontinuous Rotation with Stationary Bed Fermentation. *Journal of Bioscience and Bioengineering* 88 (2):205-209(5)

Harris, D. C. (2003). *Quantitative Chemical Analysis* 6th ed.”; 258-261, 407-422, 453, 461-476, 707-709. [http://www.chem.utk.edu/~chem319/Experiments/exp10.pdf][accessed 4th July 2007]

Harris, R. V. (2006). Effect of *Rhizopus* fermentation on the lipid composition of cassava flour. Journal of the Science of Food and Agriculture 21 (12): 626-627

Harunian-Sowa, M. and White, P. J. (1992). Characterization of starch isolated from oat groats with different amount of lipid. Cereal Chemistry 69: 521-527

Harvey, J. (1999). Laticifers in Olona and Ulu: Biological Comparison and Ethnobotanical Significance. *Journal of Young Investigators* 2 (1) [http://www.jyi.org/volumes/volume2/issue1/articles/harvey.html][Accessed 21st June2009].

Helsper, J.P.F.G., Hoogendijk, J.M. van Norel, A. and Burger-Meyer, K. (1993). Antinutritional factors in faba beans (*Vicia faba* L.) as affected by breeding toward the absence of condensed tannin. *Journal of Agricultural Food Chemistry* 41: 1058-1061.

Hoover, R., Rorke, S. and Martin (1991). Isolation and Characterization of Lima Bean (*Phaseolus lunatus*) starch. *Journal of Food Biochemistry* 15: 1117-1136

Huang, J., Schols, H. A., van Soest, J. J. G., Jin, Z., Sulmann, E. and Voragen, A. G. J. (2007). Physicochemical properties and amylopectin chain profiles of cowpea, chickpea and yellow pea starches. *Food Chemistry* 101 (4): 1338-1345

Huhtanen, P., Nousiainen, J., Rinne, M. (2006): Recent developments in forage evaluation with special reference to practical applications. *Agricultural Food Science* 15: 293-323.

ICC (1992). General Principles of the available ICC Standard Methods. [http://www.icc.or.at/methods3.php] [accessed 16th July, 2008]

ICRAF (2010). AgroForestryTree Database. A tree species reference and selection guide. International Center for Research in Agroforestry[http://www.worldagroforestry.org/sea/Products/AFDbases/af/asp/SpeciesInfo.asp?SpID=1734][Accessed 20th July, 2010]

ICUC (2002). Fruits for the future in Asia. International Centre for Underutilised Crops. (eds. Haq, H. and Hughes, A.). University of Southampton, Southampton, UK. pp.234

Ihekoronye, A. I. and Ngoddy, P. O. (1985). *Integrated Food Science and Technology for the Tropics*. MacMillan Publishers, London pp 306

Ijarotimi, O. S. and Ashipa, F. (2005). Chemical composition, sensory and physical property of home processed weaning food based on low cost locally available food materials (1). *International Journal of Molecular and Advance Sciences* 1 (3): 213-219.

Ikegwu, O. J., Okechikwu, P. E.. and Ekumankana, E. O. (2010). Physico-Chemical and Pasting Characteristics of Flour and Starch from Achi *Brachystegia eurycoma* Seed. *Journal of Food Technology* 8(2): 58-66

Ikegwu, O. J., Okechukwu, P. E., Ekumankama, E. O. and Egbedike, C. N. (2009). Functional properties of chemically modified amylose and amylopectin fractions isolated from 'achi' Starch (*Brachystegia eurycoma). Nigeria Food Journal* 27 (2): 50-54

Indrawati, L., Wang, Z., Narsimhan, G and Gonzalez, J. (2008). Effect of processing parameters on foam formation using a continuous system with a mechanical whipper. *Journal of Food Engineering* 88(1): 65-74

Iwe, M. O. (2003) Science and Technology of Soyabean, Chemisry, Nutrition, processing and Utilization. Rojoint communication Services, Enugu, Nigeria.

Iwuoha, C. I. (2004). Comparative evaluation of physicochemical qualities of flours from steam-processed yam tubers. *Food Chemistry* 85 (4): 541-551

Jacobs, H., Eerlingen, R. C., Clauwaert, W. and Delcour, J. A. (1995). Influence of annealing on the pasting properties of starches from varying botanical sources. *Cereal Chemistry 72: 480-487*

Janic, J. and Paull, R. E. (2008). The Encyclopedia of Fruit and Nuts. CABI International, Oxfordshire, UK. pp. 954

Janick, F., Homolka, P., Cermak, B. and Lad, F. (2008). Determination of indigestible neutral detergent fibber contents of grasses and its prediction from chemical composition. *Czekoslovavia Journal of Animimal Science*. 53 (3): 128-135

Jansman. A. J. M. (1993). Tannins in feedstuffs for simple-stomached Animals. *Nutrition Research Reviews 6,* 20y: 236-209

Jenkins, P. J., and Donald, A. M. (1998). Gelatinisation of starch: A combined SAXS/WAXS/SANS study. *Carbohydrate Research* 308:133.

Jimoh, K. O. and Olatidoye, O. P. (2009). Evaluation of physicochemical and rheological characteristics of soybean fortified yam flour. *Journal of Applied Biosciences* 13: 703 - 706.

Jinshui, W., Cristina, M.R., and Benedeto de Barber, C. (2002). Effect of the addition of different fibres on wheat dough performance and bread quality. *Food Chemistry* 79: 221-226

Johnson, A., Aderele, W. I., Osinusi, K. O., Gbadero, D. A. (2001). Effect of malting and traditional heat processing on paste viscosity. *African Journals Online, Nigerian Journal of Paediatrics.* 28(4): 119-127.

Johnson, E. J. and Marlett, J. A. (1986). A simple method to estimate neutral detergent fiber content of typical daily menus. *The American Journal of Clinical Nutrition* 44: 127-134.

Johnston, D. E. and Oliver, W. T. (1982). The influence of cooking technique on dietary fiber of boiled potato. *Journal of Food Technology 17, 99-107.*

June, E. R., Masako, A. and Blanshard, J. M. (1991). The physio-chemical properties of cassava starch. *Tropical Science, 31: 105-110*

Jung, H. G. and Allen, M. S. (1995). Characteristics of plant cell walls affecting intake and digestibility of forages by ruminants. *Journal of Animal Science* 73 (9): 2774-2790

Kader, A. A. (2012). Breadfruit: Recommendations for Maintaining Postharvest Quality. [http://postharvest.ucdavis.edu/PFfruits/Breadfruit/][Accessed September 3, 2012]

Kaur, M. and Singh, N. (2005). Studies on functional, thermal and pasting properties of flours from different chickpea (*Cicer arietinum* L.) cultivars. *Food Chemistry* 91 (3): 403-411

Kemi, V. E, Karkkainen, M. U., Rita, H. J., Laaksonen., M. M., Outila, T. A. and Lamberg-Allardt C. J. . (2010). Low calcium:phosphorus ratio in habitual diets affects serum parathyroid hormone concentration and calcium metabolism in healthy women with adequate calcium intake. *British Journal of Nutrition* 103(4):561-568.

Kerr, B. (2009). Breadfruit. [http://globalgardensfoundation.org/wordpress/?page_id=127Breadfruit][Accessed 2nd January, 2010]

Kim, Y. S., Wiesenborn, D. P., Orr, P. H., and Grant, L. A. (1995). Screening potato starch for novel properties using differential scanning calorimetry. *Journal of Food Science* 60: 1060–1065.

King, A. J., (2005). High pressure processing of corn and wheat Starch. http://www.kb.osu.edu/dspace/bistream/Alexa

Kirk, S. R. and Sawyer, R. (1991). Pearson's Composition and Analysis of foods, 9th edn., Longman Scientific and Technical, UK. p 641

Lahl, W. J. and Braun, S. D. (1994). Enzymatic production of protein hydrolysates for food use. *Food Technology* 48: 68-71.

Lawal, O.S., Adebowale, K.O. and Oderinde, R.A. (2004). Functional properties of amylopectin and amylose fractions isolated from Bambara groundnut Starch. 3(8), 399- 404.

Lawal, O. S. and Adebowale, K. O. (2004). Effect of acetylation and succinylation on solubility profile, water absorption capacity, oil absorption capacity and emulsifying properties of muncuna bean (*Mucuna pruiens*) protein concentrate. Nahrung/Food, 48(2): 129-136.

Leelavathi, K., Indrani, D. and Sidhu, J. S. (1987). Amylopgraph pasting behavior of cereal and tuber starches. *Starch/Staerke* 39:378

Leipzig (1996) Ghana: Country Report to the FAO International Technical Conference on Plant Genetic Resources. [http://www.pgrfa.org/gpa/gha/docs/ghana.pdf][Accessed 18th July, 2009]

Li, Jeng-Yune and Yeh, An-I. (2000). Relationships between thermal, rheological characteristics and swelling power for various starches. *Journal of Food Engineering* 50 (3): 141-148.

Liener, L. E. (1981). Factors affecting the nutritional qua1ity of soya products. *Journal of the American Oil Chemists' Society* 58: 406-409.

Lin, M. J. Y., Humbert, E. S. and Sosulki, F. W. (1974). Certain functional properties of sunflower meal product. *Journal of Food Science* 39: 368-370.

Lin, C. S and Zayas, J. F. (1987). Functionality of deffated corn germ proteins in a model system fat binding and water retention. *Journal of Food Science* 52: 1308-1311

Logie, P. (2010). Health benefits of arnica. In Helium. [http://www.helium.com/items/1609980-the-health-benefits-of-arnica][Accessed 28 March, 2010]

Loos, P.J., L.F. Hood and H.D. Graham. (1981). Isolation and characterization of starch. *Cereal Chemistry* 58(4): 282-286

Mbata, T. I., Ikenebomeh, M. J. and Ezeibe, S. (2009). Evaluation of mineral content and functional properties of fermented maize (Generic and specific) flour blended with bambara groundnut (*Vigna subterranean* L). *African Journal of Food Science* 3(4): 107-112

McComick, K. M., Panozzo, J. F. and Hong, S. H. (1991). A swelling power test for selecting potential noodle quality wheats. *Australian Journal of Agricultural Research* 42 (3): 317-323.

McDowell, L. R. (2003). *Minerals in animal and human nutrition*. 2nd edn. Elsevier Science B. V. Amsterdam, The Netherland. 644pp.

McPherson, J. (1992). Dieetary fibre – A perpective. In *CRC Handbook of dieatary fiber in Human Nutrition* (Spiller, G. A. ed.). CRC Press, Boca Raton. pp7-14

Melo, E. A., Stamford, T. L. M., Silva., M. P. C., Krieger, N. and Stamford, N. P. (2003). Functional properties of yam bean (*Pachyrhizus erosus*) starch. *Bioresource Technology* 89 (1): 103-106

Mensah, N. G. (2011). Modification of bambara groundnuts starch, composited with defatted bambara groundnut flour for noodle formulation. An MSc.Thesis submitted to the Department of Food Science and Technology Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. pp96.

Mepba, H. D., Achinewhu, S. C and Ademiluyi, T. (2008). Solubility, Emulsion And Foaming Properties Of Coconut (*Cocos Nucifera*) Protein Concentrates. *African Journal of Food Agriculture Nutrition and Development* 8: (2): 170-191

Mira, I., Eliasson, A. C. and Person, K. (2005). Effect of surfactant structure on the pasting properties of wheat flour and starch suspensions. *Cereal Chemistry* 62: 44-52.

Moore, J. E. (2002). Relative Forage Quality (RFQ). Indexing Legumes and Grasses for Forage Quality. [http://www.uwex.edu/ces/forage/pubs/rfq.htm][Accessed 24th August, 2011]

Moorthy, S. N. (1994). Tuber crop starch. *CTCRI Technical Bulletin Series* 18: 5-39

Moorthy, S. N., Rickard, J., Blanshard, J. M. V. (1996). Influence of gelatinization characteristics of cassava starch and flour on the textural properties of some food products. In: Dufour D, O'Brien GM, Best R (eds) Cassava Flour and Starch: Progress in Research and Development, CIAT, Colombia, pp. 150-155.

Moorthy, S. N. (2002). Physicochemical and functional properties of tropical tuber starches: review. *Starch* 54: 559-592

Moorthy, S. N. and Ramanujam, T. (1986). Variation in properties of starch in cassava varieties in relation to age of the crop. *Starch/Staeke, 38*:2.

Morgan, T. O. (1999). Restriction of salt intake is needed to ameliorate the cardiovascular disease epidemic. *The Medical Journal of Australia* 170: 176-178.

Morris, C. F., Shackley, B. J., King, G. E. and Kidwell, K. K. (1997). Genotypic and environmental variation for flour swelling volume in wheat. *Genetics and Physiology* 74 (1): 16-21.

Morton, J. (1987). Breadfruit: Fruits of Warm Climates, Jr .Dowling, CF. (Ed.). Greensborough, US: Media Incorporated. pp: 50-63.

Morton, J. E. N. (2002). Functional properties of raw and processed pigeon pea (*Cajanus cajan*) flour. *International Journal of Food Sciences and Nutrition* 52:343-346.

Morse, D. and Sedivic, K. (1990). Know your forages. North Dakota State University Publication AS-991. [http://www.ag.ndsu.edu/pubs/ansci/dairy/as991w.htm][Accessed 1st October 2011]

Mosha, A. C. and Lorri, W. S. M. (1987). High-nutrient-density weaning foods from germinated cereals. In: Alnwick, D., Moses, S. and Schmidt, O. G. (eds.) Improving young child feeding in Eastern and Southern Africa. Nairobi, New York, Stockholm: IDRC, UNICEF, SIDA. pp. 288-299.

Muralidharan, V. K., Ganapathy, M. M., Velayudhan, K. C. and Amalraj, V. A. (1997). Collecting jackfruit germplasm in Western Ghats. *Indian Journal of Plant Genetic Resources* 10 (2): 227–231.

Nagai, T. (2008). Competitiveness of Cowpea-Based Processed Products: A Case Study in Ghana. A Thesis submitted to Michigan State University in partial fulfillment of the requirements for the Degree of Master of Science Department of Agricultural, Food, and Resource Economics pp337. [http://aec3.aec.msu.edu/theses/fulltext/nagai_ms.pdf][Accessed 26th February 2009]

Narayana, K and Narasimga, R. N. M. S. (1982). Functional properties of raw and heat processed winged bean flour. *Journal of Food Science* 47: 1534-1538.

Naruenartwongsakul, S., Chinnan, M. S., Bhumiratana, S and Yooridhya, T. (2004). Pasting characteristics of wheat flour-based batter containing cellulose esters. *Lebensmitted-Wissenchaft und-Tennologie* 37 (4): 489-495.

Nassar, N. M. A., Alves, J. and de Souza, E. (2003). Nutritive Value and Stature of a Cassava (Mandioca), *Manihot esculenta* Crantz Hybrid. *Gene Conserve* 2 (8): 111-117

Nelson-Quartey, F. C., Amagloh, F. K., Oduro, I. and Ellis, W. O. (2007). Formulation of an infant food based on breadfruit (*Artocarpus altilis*) and breadnut (*Artocarpus camansi*). *Acta Horticulturae*. (ISHS) 757:212-224.

Nochera, C. and Caldwell, M. (1992). Nutritional evaluation of breadfruit-containing composite flour products. Journal of food Science 57 (6): 1420-1422

Nousiainen J., S. Ahvenjärvi, M. Rinne, M. Hellämäki, and P. Huhtanen. 2004. Prediction of indigestible cell wall fraction of grass silage by near infrared reflectance spectroscopy. *Animal Feed Science and Technology* 115, 295–311.

NTBG (2009). Hunger initiative. Breadfruit Institute. National Tropical Botanical Garden. [http://www.ntbg.org/breadfruit/hunger.php]

NTBG (2010). Breadfruit. National Tropical Botanical Garden. [http://www.ntbg.org/breadfruit/breadfruit/][Accessed 26th August, 2010]

Nunoo, P. (2009). Pasting of G-Irradiated Proteins from *Vigna subterranea* in Native Starch Models and the Surface Functional Properties of the Proteins. MSc. Thesis submitted to the Department Of Food Science and Technology Kwame Nkrumah University of science and Technology, Kumasi, Ghana. pp. 72.

Nwabueze, T. U. and Atuonwu, A. C. (2007). Effect of Malting African Breadfruit, (*Treculia africana*) Seeds on Flour Properties and Biscuit Sensory and Quality Characteristics as Composite. *Journal of Food Technology* 5 (1): 42-48

Nwabueze, T. U. and Nwokenna, C. (2006). Inter- relationship of Physical and Physico-chemical Parameters to Cooking Time of African Breadfruit (*Treculia africana*) Seeds. *Journal of Food, Agriculture and Envnronment* 4(3&4): 84-88.

Nwokolo, E. (1985). Nutritional quality of the seeds of the African breadfruit (*Treculia africana* Decne). *Tropical Science* 27:39-47

Oba, M., Allen M. S. (1999): Evaluation of the importance of the digestibility of neutral detergent fiber from forage: effects on dry matter intake and milk yield of dairy cows. *Journal of Dairy Science* 82: 589-596.

Obizoba, I. C. (1998). Fermentation of African locust bean. Text on Nutritional quality of plant fruits. (Edn) Osagie, Eka (2000). Post Harvest Research Unit. Department of. Biochemistry. Uniben. Nigeria, pp: 160- 198.

Odoemelam, S. A. (2000). Chemical composition and functional properties of conophor nut flour (*Tetracarpidium conophorum*) flour. *International Journal of Food Science and Technology* 38: 729-734.

Odoemelam, S. A. (2005). Functional properties of raw and heat processed Jackfruit (*Artocarpus heterophyllus*) flour. *Pakistan Journal of Nutrition* 4 (6): 366-370.

Oduro, I., Ellis, W. O., Aryeetey, S. K., Ahenkora, K. and Otoo, J. A. (2000). Pasting characteristics of starch from new varieties of sweet potato. *Tropical Science* 40: 25–28.

Oduro, I., Ellis, W. O., Sulemana, A. and Oti-Boateng, P. (2007). Breakfast meal from breadfruit and soyabean composite. *Discovery and Innovation* 19: 238-242

Oduro, I., Larbie, C., Amoako, T. N. E. and Antwi-Boasiako, A. F. (2009). Proximate composition and basic phytochemical assessment of two common varieties of *Terminalia catapa* (Indian Almond). *Journal of Science and Technology* 29 (2): 1-6.

Oladele, A. K. and Aina, J. O. (2007). Chemical composition and functional properties of flour produced from two varieties of tigernut (*Cyperus esculentus*) *African Journal of Biotechnology* 6 (21): 2473-2476

Olaofe, O., Adeyemi, F. O. and Adediran, G. O. (1994). Amino acid and mineral and functional properties of some Oilseeds. *Journal of Agricultural and Food Chemistry* 42: 878-881

Olayinka, E. M. and Kehinde, A. (2008). Production of Cassava Bread Using Indigeneous Micro-fl ora and Improved Cultivars. *Gene Conserve* 7 (27): 432 - 437

Oledinma, N. U., Ikegwu, O. T., Nwobasi, V. N. and Odoh, M. O. (2009): Evaluation of the pasting and some functional properties of starch isolated from some improved cassava varieties in Nigeria. *Nigerian Food Journal* 5: 99-100.

Oluwatooyin, F. Osundahunsi and (2002). A preliminary study on the use of tempe-based formula as a weaning diet in Nigeria. *Plant Foods for Human Nutrition* 57 (3-4): 365-376

Omobuwajo, T. O. (2007). Overview of the status of breadfruit in Africa. I International Symposium on Breadfruit Research and Development. ISHS Acta Horticulturae 757: 60-63.

Osungbaro, T. O; Jimoh, D. and Osundeyi, E. (2010). Functional and Pasting Properties of Composite Cassava-Sorgum Flour Meals. Agriculture and Biology Journal of North America 1(4): 715-720

Onweluzo, J. C. and Nnamuch, O. M. (2009). Production and Evaluation of Porridge-Type Breakfast Product from *Treculia africana* and Sorghum Bicolor Flours. *Pakistan Journal of Nutrition* 8 (6): 731-736

Onweluzo, J. C. and Nwabugu, C. C. (2009). Fermentation of Millet (*Pennisetum americanum*) and Pigeon Pea (*Cajanus cajan*) seeds for flour production: Effects on composition and selected functional properties. *Pakistan Journal of Nutrition* 8(6): 737-744

Onweluzo, J. C. and Nwakalor, C. (2009). Development and evaluation of vegetable milk from *Treculia africana* (Decne) seed. *Pakistan Journal of Nutrition* 8: 233-238

Opata, D. D., Asiedu-Larbi, J., Ellis, W. O. and Oduro, I. (2007). Production of Couscous and French Fries from Dioscorea Alata (Water Yam) Securing livelihood through Yams. Proceeding of a Technical Workshop on Progress in Yam Research for Development in West and Central Africa held in Accra, Ghana, 11 – 13 September 2007, edited by B. Nkamleu, D. Annang, and N.M. Bacco. IFAD TAG 704, IITA Nigeria, page 165.

Openwetware (2011). Acid Detergent Fiber (ADL). [http:// Openwetware,org/wiki/Richard_Lab:ADL#Overview][Accessed 1st October 2011]

Ortega, E. I., Villegas, E. and Vassal, S. K. (1986). A comparative study of protein changes in normal and quality protein maize during tortilla making. *Cereal Chemistry* 63: 446-451.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S. (2009). Agroforestree Database: A tree reference and selection guide version 4.0 [http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp][Accessed 10th August, 2010]

Osabor, V. N., Ogar, D. A., Okafor, P. C. and Egbung, G. E. (2009). Profile of the African Bread Fruit (*Treculia africana*). *Pakistan Journal of Nutrition* 8 (7): 1005-1008.

Osuji, J. O. and Owei, S. D. (2010). Mitotic index studies on *Treculia africana* Decne. in Nigeria. *Australian Journal of Agricultural Engineering* 1(1): 25-28

Osundahunsi, O. T. (2009). Scanning electron microscope study and pasting properties of ripe and unripe plantain *Journal of Food, Agriculture & Environment*., 7(3/4): 182-186.

Osuntogun, B. A., Adewusi, S. R. A., Telek, L. and Oke, O. L. (1987). *Human Nutrition. Food Science and Nutrition*. 41F: 41-46

Otegbayo, B., Aina, J., Asiedu, R. and Bokanga, M. (2006). Pasting characteristics of fresh yams (*Dioscerea* spp.) as indicators of textural quality in a major food product – 'pounded yam'. *Food Chemistry* 99: 663-669.

Oti, E. and Akobundu, E. N. T. (2007). Physical, functional and amylograph pasting properties of cocoyam-soybean-crayfish flour blends. *Nigerian Food Journal* 25 (1): 161-170

Otitoju, G. T. O. (2009)). Effect of dry and wet milling processing techniques on the nutrient composition and organoleptic attributes of fermented yellow maize (Zea mays). *African Journal of Food Science* 3(4): 113-116

Patenaude, F. (2007). The Importance of Eating Assimilable Greens. [http://www.fredericpatenaude.com/assimilable_greens.html][Accessed 14th August, 2010]

Perez-Hidalgo, M., Guerra-Hernandez, E. and Garcia-Villanova, B. (1997). Determination of insoluble dietary fiber compounds: Cellulose, hemicelluloses and lignin in legumes. *Ars Pharmaceutica* 38 (4): 357-364.

Peroni, F. H. G., Rocha, T. S. and Franco, C. M. L. (2006). Some structural and physicochemical characteristics of tuber and root starches. *Food Science and Technology International* 12: 505-510

Pomeranz, Y. (1991). Functional properties of food components, 2nd ed. Academic Press, New York. pp.27-28

Price, M. L., Van Socoyoc, S. and Butter, L. G. (1978). A critical evaluation of the vanillin reaction as an assay for tannin in sorghum grain. *Journal of Agricultural Food Chemistry* 26: 1214-1218

Progressive Nutrition (2011). Relative Feed value. [http://www.prognutrition.com/libraryrfv.html][Accessed 24th August 2011].

Quartermain, A. (2006). Underutilised Species - Policies and Strategies. *Information Bulletin No. 15*. National Agricultural Research Institute, Lae, Papua New Guinea.

Ragone, D. (1991). Collection, Establishment, and Evaluation of a Germplasm Collection of Pacific Island Breadfruit. Ph.D. Dissertation. University of Hawaii, Honolulu.

Ragone, D. (1997). Breadfruit. *Artocarpus altilis* (Parkinson) Fosberg. Promoting the conservation and use of underutilized and neglected crops. 10. Institute of Plant Genetics and Crop Plant Research, Gatersleben/International Plant Genetic Resources Institute, Rome, Italy. pp 77

Ragone, D. (2006a). *Artocarpus altilis* (breadnut). Moraceae (mulberry family) Species Profiles for Pacific Island Agroforestry pp 1-17

Ragone, D. (2006b). *Artocarpus camansi* (breadnut). Moraceae (mulberry family) Species Profiles for Pacific Island Agroforestry pp. 1-11 [http://www.agroforestry.net/tti/A. camansi-breadnut.pdf]

Ragone, D. (2007). Breadfruit: Diversity, Conservation and Potential. Proc. 1st International Symposium on Breadfruit Research and Development. *Acta Horticulturae* 757: 19-30

Rahman, M. A., Nahar, N., Jabbar, M. A. and Mosihuzzaman, M. (1999). Variation of carbohydrate composition of two forms of fruit from jack tree (*Arthocarpus heterophyllus* L.) with different maturity and climatic conditions. *Food Chemistry* 65: 91-97

Richards, D. J., Ivanova, L. K., Smallman, D. J. and Zheng, B. (2005). Assessment of waste degradation using acid digestible fibre analysis. International Workshop 'Hydro-Physico-Mechanics of Landfills. LIRIGM, Grenoble 1 University, France, pages 1-5. 21-22 March 2005.

Rincon, A. M. and Padilla, F. C. (2004). Physicochemical properties of Venezuelan breadfruit (*Atocarpus altilis*) starch. Arch. Latinoan Nutr. 54 (4):449-456

Rinne, M., Jaakkola, S., Huhtanen, P. (1997). Grass maturity effects on cattle fed silage-based diets. 1. Organic matter digestion, rumen fermentation and nitrogen utilization. *Animal Feed Science and Technology* 67: 1-17

Roberts, L. B. Barbie, N. and Roberts-Nkrumah, L. (2007). Colour and sensory characteristics of fried chips from three Breadfruit (*Artocarpus altilis*) cultivars. Acta Horticulturae 757: 225-231

Roberts-Nkrumah, L. B. (2005). Fruit and seed yields in chataigne (*Artocarpus camansi* Blanco) in Trinidad and Tabago. *Fruits* 60:397-393.

Rojas-Molina, I., Gutierrez-Cortez, Elsa., Palacios-Fonseca, Alen.,Baños, L., Pons-Hernandez, J. L., Guzmán-Maldonado, S. H., Pineda-Gomez, P. and Rodríguez1, M. E. (2007). Study of Structural and Thermal Changes in Endosperm of Quality Protein Maize During Traditional Nixtamalization Process. *Cereal Chemistry* 84(4):304–312

Rooney, L. W. and Pflugfelder, R. L. (1986). Factors affecting starch digestibility with special emphasis on Sorghum and Corn. *Journal of Animal Science* 63:1607-1623

Rotary International (2007). Environmental challenges and opportunities; using land wisely. [http://www.rli33.org/downloads/2007/2007_Part_III_RLI_CD/internationalservice/materials/SubjectAreaHandbooks/PlanetEarthHnbk.pdf][accessed 16th September, 2008]

Runsewe-Abiodun, I., Olowu,O. A. and Olanrewaju, F. A.A. (2001). Efficacy of the African Breadfruit DM (*Treculia africana*) in the Nutritional Rehabilitation of Children with Protein-energy Malnutrition. *Nigerian Journal of Paediatrics* 28:128-134

Sandhu, K. S, nd Singh, N. (2007). Some properties of corn starches II: Physicochemical, gelatinization, retrogradation, pasting and gel textural properties. Food Chem., 101: 1499–1507.

Samaddar, H. N. (1985). Jackfruit. *Fruits of India: Tropical and Subtropical. Ed.* T. k. Bose, Naya Prokash, Calcutta, pp. 487- 497.

Sanni, L. O, Adebowale, A. A., Filani, T. A., Oyewol, O. B. and Westby, A. (2006). Quality of flash and rotary dried flour. *Journal of Food Agriculture and Environment* 4 (3& 4): 74-78.

Sanni, L.O., Kosoko, S.B., Adebowale, A.A. and Adeoye, R.J. (2004). The influence of palm oil and chemical modification on the pasting and sensory properties of fufu flour. *International Journal of Food Properties* 7(2): 229-237

Sathe, S. K. and Salunkhe, D. K. (1981a). Isolation, partial characterization, and modification of the great Northern bean (*Phaseolus vulgaris* L.) starch. *Journal of Food Science* 46: 617-621

Sathe, S. K. and Salunkhe, D. K. (1981b). Functional properties of the great Northern bean (*Phaseolus vulgaris* L.) proteins: emulsion, foaming, viscosities and gelation properties. *Journal of Food Science* 46: 71-81

Sathe, S. K. , Deshpande, S. S. and Salunkhe, D. K. (1982). Functional properties of winged bean (*Psophocarpus tetragonolobus*, L) proteins. *Journal of Food Sci*ence 47: 503-506.

Schroeder, J. W. (1994). Interpreting forage analysis. North Dakota State University 1080 [http://www.ag.ndsu.edu/pubs/plantsci/hay/r1080w.htm][Accessed 17th August 2011]

SCSG (2007). Calcium to Phosphorus Ratios in Food. GliderVet. Sun Coast Sugar Gliders. [http://www.sugar-gliders.com/glidervet-60.htm][Accessed 14th August, 2010].

Sefah–Dedeh, S., Cornelius, B., Sakyi-Dawson, E. and Ohene Afoakwa, E. (2004). Effect of nixtamalization on the chemical and functional properties of maize. *Food Chemistry* 86: 317-324.

Selvaraj, Y. and Pal, D.K. (1989). Biochemical changes during ripening of jackfruit (*Artocarpus heterophyllus* Lam.). *Journal of Food Science and Technology* 26: 304-307.

Shamekh, S., Forssell, P., and Poutanen, K. (1994). Solubility pattern and recrystallization behavior of oat starch. *Starch* 46:129-133.

Shankar, S. and Lanza, E. (1991): Dietary fiber and cancer prevention. *Hematology/Oncology Clinics of North America* 5(1):25-41.

Shimelis, E. A., Meaza, M. and Rakshit, S. K. (2006). Physico-chemical Properties, Pasting Behavior and Functional Characteristics of Flours and Starches from Improved Bean (*Phaseolus vulgaris* L.) Varieties Grown in East Africa. *Agricultural Engineering International CIGR Ejournal*. 8:1-19.

Shirahata, S., Murakami, H., Nishiyama, K., Yamado, K., Nonaka, G., Nishioka, I. and Omura, H. (1989). DNA breakage by flavan-3-ols and procyanidins in the presence of cupric ion. Journal of Agricultural and Food Chemistry 37: 299-303

Singh, A. V. and Nath, L. K. (2009). Evaluation of Physicochemical Character and Pasting Behaviour of *Phaseolus Acontifolius* Jacq. Starch. *Electronic Journal of Environmental, Agricultural and Food Chemistry* 8 (10): 984-990.

Singh, A., Kumar, S. and Singh, I. S. (1991). Functional properties of Jack fruit seed flour. *Lebensm Wiss u Technol* 24: 373-374

Singh, H. (2009). Tapping into breadfruit's bounty. Available online at: http://www.universityaffairs.ca/tapping-into-breadfruits_bounty.aspx

Singh, S., Singh, N. and MacRitchie, F. (2010). Relationship of polymeric proteins with pasting, gel dynamic and dough empirical-rheology in different Indian Wheat varieities. *Food Hydrocolloids* 25 (1): 19-24

Singh, U. (2001). Functional properties of grain legume flours, *Journal of Food Science and Technology* 38 (3): 191–199.

Slavin, J. L., Brauer, P. M. and Marlett, J. A. (1981) Neutral detergent fiber, hemicelluloses and cellulose digestibility in human subjects. *Journal of Nutrition* 111: 287-297.

Snedecor, G.W. and Cochran, W.G. (1976), *Statistical Methods*, Sixth Edition, Ames, IA: Iowa State University Press.

Sounne, M. W. (1985) Le nenetou: technologie et microbiologie. In:development of indigenous foods and food technology in Africa. Proceeding from the IFS/UNU WORKSHOP, Douala, Cameroon, Oct.1985. International foundation of science, Stochholm, Sweden, pp. 310-330.

Spore (2007). Breadfruits: Ripe for the new markets. Spore, N° 131 - October 2007 CTA.

[http://spore.cta.int/index.php?option=com_home&task=view&lang=en&id_publication=4] [accessed 18th May 2008]

Stanojeska, M. and Sokoloski, B. (2012). Creating the correlation model at flour T-400 among amylograph units and γ slope of mixolab curve. *Journal of Hygienic Engineering and Design* 1: 247-250.

Subramania, S. and Viswanathan, R. (2007). Bulk density and friction coefficients of selected minor millet grains and flours. *Journal of Food Engineering* 81 (1): 118-126

Szentmihalyi, K., Kery, A., Then, M., Lakatos, B., Sandor, Z. and Vinkler, P. (1998). Potassium–sodium ratio for the characterization of medicinal plant extracts with diuretic activity. *Phytotherapy Research* 12(3):163–166.

Taffouo, V. D., Djiotie, N. L., Kenne, M., Din, N., Priso, R. J., Dibong, S. D., and Amougou, A. (2008). Effects of salt stress on physiological and agronomic characteristics of three tropical cucurbit species. *Journal of Applied Biosciences* 10: 434-441.

Tan, S. Y. (2003). Resistant Rice Starch Development. MSc. Thesis. Department of Food Science. Louisian State university, USA. pp130

Tester, R. F. and Morrison, W. R. (1990). Swelling and gelatinization of cereal starches. II. Waxy rice starches. *Cereal Chemistry* 67 (6): 558-563.

The National Academy of Sciences (2004). Dietary Reference Intakes (DRIs): Recommended Intakes for Individuals, Elements. Food and Nutrition Board, Institute of Medicine, National Academies. Available online at: hrrp://www.nap.edu

Tietz, N. W. (1995). Clinical Guide to Laboratory Tests, 3rd ed., W. B. Saunders Co, Philadelphia, PA.

Tonheim, S. K.,Nordgreen, A., Høgøy, I. Hamre, K. and Rønnestad, I. (2007). In vitro digestibility of water-soluble and water-insoluble protein fractions of some common fish larval feeds and feed ingredients. *Acquaculture* 262: 426-435

Traxler, M. J., Fox D. G., Van Soest P. J., Pell A. N., Lascano C. E., Lanna D. P. D., Moore J. E., Lana R. P., Vélez M., Flores A. (1998): Predicting forage indigestible NDF from lignin concentration. *Journal of Animal Science* 76, 1469-1480.

Treche, S. and Agbor-Egbe, T. (1995). Evaluation of the chemical composition Camerronian yam gerplasm. *Journal of Food Composition and Analysis* 8: 274-283.

Tumaalii, F, Wooton, R. (1988). Properties of starch isolated from Western Samoan breadfruit using a traditional method. *Starch/Starke* 40: 7-10

Udensi, E. A. and Okoronkwo, K. A. (2006). Effects of fermentation and germination on the physicochemical properties of *Mucuna cochinchinensis* protein isolate. *African Journal of Biotechnology* 5 (10): 896-900.

Udensi, E. A., Eke, O. and Ukachukwu, S. N. (2001). Effect of traditional processing on the physicochemical properties of *Mucuna* cochinchinensis and *Mucuna Utilis* flours. *Journal of Agriculture, Food Technoogy and Environment* 1: 133-137.

Udensi, E. A., Oselebe, H. O. and Iweala, O.O. (2008). The Investigation of Chemical Composition and Functional Properties of Water Yam (*Dioscorea alata*): Effect of Varietal Differences. *Pakistan Journal of Nutrition* 7 (2): 342-344

Ukpabi, U. J. (2010). Farmstead bread making potential of lesser yam (*Dioscorea esculenta*) flour in Nigeria. *Australian Journal of Crop Science* 4(2):68-73

Vaclavik, V. A. and Christian, E. W. (2003) Essentials of food science, 2nd Ed, Elizabeth Christian publishing, England. Part III, chapter 8.

van Soest, P. J. (1994): Nutritional Ecology of The Ruminant. Cornell University. ISBN 0-8014-2772-X, 476 p.

van Soest, P. J. and R.H. Wine. 1967. Use of detergents in the analysis of fibrous feeds. IV. Determination of plant cell wall constituents. *Journal of the Association of Official. Agricultural. Chemists* 50: 50-55.

van Soest, P. J., Robertson, J. B. and Lewis, B. A. (1991). Methods for dietary fiber, neutral-detergent fiber and non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* 74: 3585-3597

Verheij, E. W. M. (1991). Muntingia calabura L. In. *Plant Resources of South-East Asia 2. Edible Fruits and Nuts*. E.W.M. Verheij and R.E. Coronel (eds.). PROSEA, Pudoc, Wageningen. pp. 223-225.

Virtanen, T., Auti, K., Sourti, K and Poutanen, K. (1993). Heat-induced changes in native and acid-modified oat starch pastes. *Journal of Cereal Science* 17: 137-145

Visser, A. and Thomas, A. (1987) Review; Soya protein production their processing, functionality, an application aspects. *Food Reviews international. 31 (1&1), 1-32.*

Vitabase (2009). Vitamin and health Guide. [http://www.vitamins-supplements.org/dietary-minerals/phosphorus.php]

Wang, L. Z., and White, P. J. (1994). Functional properties of oat starches and relationships among functional and structural characteristics. *Cereal Chemistry* 71: 451-458

Whelton, P. K., Appel, L. J., Espeland, M. A., Applegate, W. B. and Ettinger, W. H. J. (1997).Effects of oral potassium on blood pressure. *Journal of the American medical Association* 277:1624-1632.

Whistler, R. L., and BeMiller, J. N. (1996). Starch/Processing and use of carbohydrate and their derivatives. In Carbohydrate chemistry for food scientists Eagen Press. St. Paul: Minnespta, USA pp. 63–151.

Wilhelmi, F. (2010). Potassium/Sodium Dietaty Ratio and Your Health. [http://www.seniorfitness.com/article/Franks_Column_680404_editorial_article.html] [accessed 6th May 2010]

Willams, K. and Badrie, N. (2005). Nutritional composition and sesnsory acceptance of boiled breadnut (*Artocarpus camansis* Blanco) seeds. Journal of Food Technology 3 (4): 546-551.

Xiong, Y. L. and Brekke, C. J. (1989). Changes in Protein Solubility and Gelation properties of Chicken Myofibrils during storage. *Journal of Food Science* 54 (5): 1141-1146

Zeleznak, K. J. and Hoseney, R.C. (1987). The glass transition in starch. *Cereal Chemistry* 64: 121-124.

Zhao, W., Zhai F., Zhang D., An Y., Liu Y., He Y., Ge K. and Scrimshaw N.S. (2004). Lysine fortified wheat flour improves the nutritional and immunologicalstatus of wheat eating families in Northern China. Food and Nutrition Bulletin, 25: 114-122.

Zhou, M., Glennie-Holmes, M., Robards, K. and Helliwell, S. (1999a). Effects of Processing and Short-term Storage on the Pasting Characteristics of Slurries made from Raw and Rolled Oats. *Food Australia* 51 (6): 251-258

Zhou, M., Robards, K., Glennie-Holmes, M., and Helliwell, S. (1998). Structure and Pasting Properties of Oat Starch. *Cereal Chemistry*. 75(3):273–281

Zobel, H. F. (1984). Gelatinization of Starch and Mechanical Properties of Starch Pastes. In *Starch: Chemistry and Technology*. (Eds.)Whistler, R L, BeMiller J .N. and Paschall E F), Academic Press, New York. pp 300-302.

Zobel, H. F. (1988). Molecules to granules, a comprehensive starch review 40(2): 44-50

Web-Site References

http://www.troikaindia.com/solvent-extraction-plant.html

http://home.earthlink.net/~ggda/flour_summary.htm

http://www.health-science-spirit.com/calcium.html)

www.health-science-spirit.com/calcium.html).

APPENDICES

Appendix A1: Survey Questionnaires

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY (KNUST)
STUDENT PROJECT ON *TRECULIA AFRICANA*
SOCIO-ECONOMIC SURVEY

Introduction

I would be very grateful if you would answer the following questions to enable me generate data on Breadfruits in Ghana. Thank you.

GENERAL INFORMATION

1. Date of interview …………………………………………
2. Name of Town / Village Community ………………………
3. District …………………………………………………
4. Region …………………………………………………

SOCIAL INFORMATION

5. Name / Identity of Respondent ………………………………
6. Sex: a. Female ☐ b. Male ☐
7. Ethnicity …………………………………………………
8. Age (years) ………………………………………………
9. Marital status: a. Single ☐ b. Married Monogamy☐ c. Married Polygamy ☐ d. Divorced ☐
10. How many people are in your household (same pot), as indicated in the following age groups:
11. Below 16 years ☐
12. 16-25 years ☐
13. 26-60 years ☐
14. Above 60 years ☐
15. What is your main occupation? ………………………………

AGRICULTURAL / TRADITIONAL USE

16. Do you know D-Ball/Ototim? a. Female ☐ b. Male ☐
17. Where can they be found in Ghana? ……………………………………………..
18. What are the local names for D-Ball/Ototim? …………………………………………
19. Is it indigenous to your area? a. Yes ☐ b. No ☐
20. How abundant is it in your area? a. very abundant ☐ abundant ☐ neither abundant nor scarce d. scarce ☐ e. very scarce ☐
21. Have you used this fruit? a. Yes ☐ b. No ☐
22. If yes, what for? …………………………………………………………………
23. Which part of the fruit is used eaten? a. seed b. pulp ☐ ☐c. bark d. ☐ latex e. leaf ☐ ☐
24. Do livestock browse on it? a. Yes ☐ b. No ☐

25. Do you know what other people in your community use the fruit for? a. food b. oil c. soap d. cash crop e. I don't know f. others (specify) …………………………………..
26. Does the tree have any religious / traditional significance? a. Yes b. No c. Not sure
27. How many species / kinds do you know? a. 1 b. 2 c. 3 4
28. What are they? ……………………………………………………………………………
29. Who owns the individual breadfruit trees? a. land owners b. farmers c. paramount chief d. local e. others (specify) ………………
30. What is the size of land on which you have the breadfruit tree? a. <1 acre b. 1-5 acres c. >5 acres
31. How many trees do you have on your land? a. 1-10 b. 11-20 c. >20
32. Were they deliberately planted? a. Yes b. No
33. If no, how many did they appear on your land? a. planted by someone b. grew wild
34. What are the various ways by which it is propagated? a. root cuttings b. stem cutting c. seeds d. others (specify) ………………………………
35. Which method is best? a. root cuttings b. stem cutting c. seed d. others (specify) ………………………………
36. How are the trees spaced? ……………………………………………
37. Where are they found? a. food crop lands b. forests c. cocoa fields d. others (specify) ……………………………
38. Did you plant them yourself? a. Yes b. No
39. How long does it take to fruit after planting? a. <3 years b. 4-5 years c. >5 years
40. How many times can you harvest the fruit in a year? a. Once b. twice c. thrice d. others
41. How long does the cropping season last? a. 2 months 3 months c. 4 months d. >4 months
42. How many fruits are borne on a tree in a season? a. 0-100 b. 100-200 c. >200
43. Who has access to collecting the fruit from a particular area? a. land owner b. farmer c. indigenous d. community members e. everybody, including outsiders f. others (specify) ………………………………….
44. Is maintenance carried on the breadfruit? a. Yes b. No
45. If yes, what kind of maintenance is carried out? a. weeding b. watering c. pruning d. any other ……………………………………
46. Who does the maintenance? a. self b. hired labour
47. When is the harvest time for the fruits (season / month)? a. Jan-Mar b. Apr-Jun c. Jun-Sep d. Oct-Dec e. any other ……………………
48. How many D-Ball fruits can you gather at one time? a. <50 b. 50-100 c. >100
49. How many times do you pick D-Ball when in season? a. 1-3 times / week b. 4-5 times / week c. < once a week
50. Does it have any known pest or disease? a. Yes b. No

51. If yes, what are they? ……………………………………………………………
52. What other activities do you perform during the harvesting period of breadfruit? a. weeding ☐ b. cocoa harvesting / drying ☐ c. land preparation (new farm) ☐ others (specify) ……………………………………
53. How do you bring breadfruit fruits from source to house? a. by cart ☐
54. b. carrying (head) ☐ c. transport ☐ d. hired labour ☐

MARKETING INFORMATION

55. Do you know anyone who has ever purchase D-Ball? a. Yes ☐ b. No ☐
56. If yes, do you know what it was used for? State ………………………………….
57. Are you interested in collecting the fruit? a. Yes ☐ b. No ☐
58. If yes, explain ……………………………………………………

STORAGE AND SHELF LIFE

59. How is it stored / preserved? a. drying ☐ b. cooking ☐ c. frying ☐ d. roasting ☐ others (specify) ……………………………………
60. How long does it store fresh? a. <1 week ☐ b. 1-2 weeks ☐ c. 2-4 weeks ☐ d. >4 weeks ☐
61. Does taste change with storage? a. Yes ☐ b. No ☐
62. If yes, how? a. taste better ☐ b. more aromatic ☐ c. taste bitter ☐ d. others (specify) ……………………………………
63. Does it have any known side effects if eaten in excess? a. constipation ☐ b. flatulence ☐ c. bloating ☐ d. thirst ☐ e. others ☐ (specify) ……………

PROCESSING

64. Which part of the fruit is processed? a. seed ☐ b. pulp ☐ c. testa / coat ☐
65. How is it processed? Described
66. ………………………………………………………………………………………

OPTIONAL COMMENTS ……………………………………………………………

Thank you.

Appendix A2: Some Communities Where Breadfruit Species Are Found In Ghana

Region	Communities
Western	*Ahanta East District:* Wasa Simpa/Pepesa Simpa, Dompem, Nsuaem, Kyekyewere, Bameanko, Tarkwa-Ayitease, Anyinasee, Kwakukrom, Duma, Akokyikrom, Sukusuku, Dominase, Asungwa, Ebokrom, Adalazo, Ntama, Nkwatana, Dwira Banso, Kolabla, Adiesre, and Kyekyewere. *Sefwi Wiawso District:* Amafie, Larwehkrom, Buako, Bopa, Asantekrom, Wruwru, Abrabra, Chorichori, Kramokrom, Betenase, Kwaadapaa.
Volta	Alavanyo -Abehenease, Kpeme, Lolobi-Kumase, Lolobi Huyeasem, Golokwati, Hohoe, Juapong, Wudidi, Kpando, Agbosome, Avetime, Avidome, Jasikan, and Nkonya
Eastern	Tafo, Jejeti, Bunso
Central	Bremang Asikuma, Assin Brofoyedur, Odoben, Kuntu Twifo Praso, Assin Fosu, Endoe, Enunua, Nyamebekyere, Betwease. Nuamahkrom, and Bimponso
Ashanti	New Edubiase-Kwame Agyeikrom, Fumso, Juaso, Bobri, Nobewam, Abofour, Tepa, Tepa-Karimkrom, Nkawie-(Akonkye, Apatreto), Agona (Afomaso, Mooso), Jamase, Mampong, Asante Akyem (Juaso, Agogo, Brentuo), Offinso, Efiduase-Asokore (Ahwirewa, Ntumkumso, Banko), Kunsu-Mankraso-Besease, Mamponteng-Ankaase, Atwima Brofoyedur, Abore.
Brong Ahafo	Buokrom, Bechem, Duayaw Nkwanta (Awurupi), Techeri, Yamfo, Adroben, Subriso, and Nkwaatoo, Bomaa, Yaw Doohenekrom, Camp, Akwadaa Yemobo, Wenchi, Seikwa, Bechem (Kwaso, Koso Bredi, Nyinasua, Kwabenatenten, Biokrom., Sankore (Dodowa), Aboum, Akomadan (Nyinatase), Nkoranza, Goaso-Hwediem(Asubra), Techiman.

Appendix A3: Sensory Evaluation Form

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY, FACULTY OF BIOSCIENCES, COLLEGE OF SCIENCE, KNUST, KUMASI

SENSORY EVALUATION FORM

Name:…………………………………………………………………………….…………..

Sex: ☐ Male ☐ Female

Age: ……………………………………………………………………………………….

INSTRUCTION

Please kindly evaluate each coded product for the quality factors listed below using appropriate scale. Rinse mouth with water between samples.

Scale

1 – Like very much
2 – Like slightly
3 – Neither like nor dislike
4 – Dislike slightly
5– Dislike very much

Product Code	Colour	Mouthfeel	Aroma	Taste	Overall Acceptability
T301					
T133					
T834					
T592					
T677					
T218					

Remarks
(Optional)……………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………Thank you.

Appendix B: Analysis of Variance Tables

Appendix B1: Analysis of Variance Tables for Artocarpus heterophyllus, Artocarpus camansi and Treculia africana

Proximate Composition

Completely Randomized AOV for Moisture

Source	DF	SS	MS	F	P
treatment	2	22.9411	11.4705	73.2	0.0001
Error	6	0.9404	0.1567		
Total	8	23.8815			

Grand Mean 8.5662 CV 4.62
Alpha 0.01 Standard Error for Comparison 0.3233
Critical T Value 3.707 Critical Value for Comparison

Completely Randomized AOV for Crude Protein

Source	DF	SS	MS	F	P
treatment	2	58.5339	29.2669	146	0.0000
Error	6	1.2050	0.2008		
Total	8	59.7389			

Grand Mean 15.839 CV 2.83
Alpha 0.01 Standard Error for Comparison 0.3659
Critical T Value 3.707 Critical Value for Comparison 1.3566

Completely Randomized AOV for Crude Fat

Source	DF	SS	MS	F	P
treatment	2	20.3768	10.1884	218	0.0000
Error	6	0.2810	0.0468		
Total	8	20.6578			

Grand Mean 6.9944 CV 3.09
Alpha 0.01 Standard Error for Comparison 0.1767
Critical T Value 3.707 Critical Value for Comparison 0.6551

Completely Randomized AOV for Crude Fiber

Source	DF	SS	MS	F	P
treatment	2	2.30040	1.15020	147	0.0000
Error	6	0.04691	0.00782		
Total	8	2.34731			

Grand Mean 2.2658   CV 3.90
Alpha   0.01   Standard Error for Comparison 0.0722
Critical T Value 3.707   Critical Value for Comparison 0.2677

Completely Randomized AOV for ASH

Source	DF	SS	MS	F	P
treatment	2	0.92993	0.46497	290	0.0000
Error	6	0.00963	0.00161		
Total	8	0.93956			

Grand Mean 2.5553   CV 1.57
Alpha   0.01   Standard Error for Comparison 0.0327
Critical T Value 3.707   Critical Value for Comparison 0.1213

Completely Randomized AOV for Carbohydrate

Source	DF	SS	MS	F	P
treatment	2	260.037	130.018	324	0.0000
Error	6	2.410	0.402		
Total	8	262.447			

Grand Mean 63.779   CV 0.99
Alpha   0.01   Standard Error for Comparison 0.5175
Critical T Value 3.707   Critical Value for Comparison 1.9186

Mineral Content

Completely Randomized AOV for Calcium (Ca)

Source	DF	SS	MS	F	P
treatment	2	5880.50	2940.25	28.1	0.0009
Error	6	627.00	104.50		
Total	8	6507.50			

Grand Mean 95.167   CV 10.74
Alpha   0.01   Standard Error for Comparison 8.3467
Critical T Value 3.707   Critical Value for Comparison 30.945

Completely Randomized AOV for Iron (Fe)

Source	DF	SS	MS	F	P
treatment	2	85.5237	42.7619	205	0.0000
Error	6	1.2529	0.2088		
Total	8	86.7767			

Grand Mean 5.1083 CV 8.95
Alpha 0.01 Standard Error for Comparison 0.3731
Critical T Value 3.707 Critical Value for Comparison 1.3833

Completely Randomized AOV for Mg

Source	DF	SS	MS	F	P
treatment	2	37257.5	18628.8	2139	0.0000
Error	6	52.2	8.7		
Total	8	37309.8			

Grand Mean 90.194 CV 3.27
Alpha 0.01 Standard Error for Comparison 2.4095
Critical T Value 3.707 Critical Value for Comparison 8.9329

Completely Randomized AOV for Potassium (K)

Source	DF	SS	MS	F	P
treatment	2	1135445	567722	11384	0.0000
Error	6	299	50		
Total	8	1135744			

Grand Mean 812.02 CV 0.87
Alpha 0.01 Standard Error for Comparison 5.7660
Critical T Value 3.707 Critical Value for Comparison 21.377

Completely Randomized AOV for Sodium(Na)

Source	DF	SS	MS	F	P
treatment	2	513.500	256.750	3081	0.0000
Error	6	0.500	0.083		
Total	8	514.000			

Grand Mean 48.167 CV 0.60
Alpha 0.01 Standard Error for Comparison 0.2357
Critical T Value 3.707 Critical Value for Comparison 0.8738

Completely Randomized AOV for Phosphorus (P)

Source	DF	SS	MS	F	P
treatment	2	103226	51613.0	154839	0.0000
Error	6	2	0.3		
Total	8	103228			

Grand Mean 289.20 CV 0.20
Alpha 0.01 Standard Error for Comparison 0.4714
Critical T Value 3.707 Critical Value for Comparison 1.7477

Completely Randomized AOV for Ca:P

Source	DF	SS	MS	F	P
treatment	2	0.05959	0.02980	23.1	0.0015
Error	6	0.00775	0.00129		
Total	8	0.06734			

Grand Mean 0.3462 CV 10.38
Alpha 0.01 Standard Error for Comparison 0.0293
Critical T Value 3.707 Critical Value for Comparison 0.1088

Completely Randomized AOV for K:Na

Source	DF	SS	MS	F	P
treatment	2	1205.25	602.625	26382	0.0000
Error	6	0.14	0.023		
Total	8	1205.39			

Grand Mean 18.674 CV 0.81
Alpha 0.01 Standard Error for Comparison 0.1234
Critical T Value 3.707 Critical Value for Comparison 0.4575

PHYSICAL PROPERTY

Completely Randomized AOV for Bulk density

Source	DF	SS	MS	F	P
treatment	2	0.08100	0.04050	230	0.0000
Error	6	0.00105	0.00018		
Total	8	0.08205			

Grand Mean 0.6532 CV 2.03
Alpha 0.01 Standard Error for Comparison 0.0108
Critical T Value 3.707 Critical Value for Comparison 0.0401

Functional Properties

Completely Randomized AOV for Water Absorption Capacity

Source	DF	SS	MS	F	P
treatment	2	1.26389	0.63194	18.2	0.0028
Error	6	0.20833	0.03472		
Total	8	1.47222			

Grand Mean 2.3056 CV 8.08
Alpha 0.01 Standard Error for Comparison 0.1521
Critical T Value 3.707 Critical Value for Comparison 0.5641

Completely Randomized AOV for Oil Absorption Capacity

Source	DF	SS	MS	F	P
treatment	2	1.12500	0.56250	15.0	0.0046
Error	6	0.22500	0.03750		
Total	8	1.35000			

Grand Mean 0.7500   CV 25.82
Alpha   0.01   Standard Error for Comparison 0.1581
Critical T Value 3.707   Critical Value for Comparison 0.5862

Completely Randomized AOV for Solubility

Source	DF	SS	MS	F	P
treatment	2	17.9426	8.97130	6.61	0.0304
Error	6	8.1422	1.35703		
Total	8	26.0848			

Grand Mean 9.9667   CV 11.69
Alpha   0.01   Standard Error for Comparison 0.9512
Critical T Value 3.707   Critical Value for Comparison 3.5263

Completely Randomized AOV for Swelling Power

Source	DF	SS	MS	F	P
treatment	2	3.40878	1.70439	55.1	0.0001
Error	6	0.18547	0.03091		
Total	8	3.59425			

Grand Mean 5.4962   CV 3.20
Alpha   0.01   Standard Error for Comparison 0.1436
Critical T Value 3.707   Critical Value for Comparison 0.5322

Completely Randomized AOV for Foam Capacity

Source	DF	SS	MS	F	P
treatment	2	5.79167	2.89583	83.4	0.0000
Error	6	0.20833	0.03472		
Total	8	6.00000			

Grand Mean 1.6667   CV 11.18
Alpha   0.01   Standard Error for Comparison 0.1521
Critical T Value 3.707   Critical Value for Comparison 0.5641

Completely Randomized AOV for Foam Stability after 30 minutes

Source	DF	SS	MS	F	P
treatment	2	1.62500	0.81250	39.0	0.0004

Error	6	0.12500	0.02083		
Total	8	1.75000			

Grand Mean 0.4167 CV 34.64
Alpha 0.01 Standard Error for Comparison 0.1179
Critical T Value 3.707 Critical Value for Comparison 0.4369

Completely Randomized AOV for Foam Stability after 60 minutes

Source	DF	SS	MS	F	P
treatment	2	0.18056	0.09028	1.86	0.2356
Error	6	0.29167	0.04861		
Total	8	0.47222			

Grand Mean 0.1944 CV 113.39
Alpha 0.01 Standard Error for Comparison 0.1800
Critical T Value 3.707 Critical Value for Comparison 0.6674

Completely Randomized AOV for Foam Stability after 90 minutes

Source	DF	SS	MS	F	P
treatment	2	0.93056	0.46528	1.16	0.3764
Error	6	2.41667	0.40278		
Total	8	3.34722			

Grand Mean 0.3056 CV 207.70
Alpha 0.01 Standard Error for Comparison 0.5182
Critical T Value 3.707 Critical Value for Comparison 1.9211

Completely Randomized AOV for Least Gelation Concentration

Source	DF	SS	MS	F	P
treatment	2	8.0000	4.00000	1.00	0.4219
Error	6	24.0000	4.00000		
Total	8	32.0000			

Grand Mean 6.6667 CV 30.00
Alpha 0.01 Standard Error for Comparison 1.6330
Critical T Value 3.707 Critical Value for Comparison 6.0542

Pasting Properties

Completely Randomized AOV for Pasting Temperature

Source	DF	SS	MS	F	P
treatment	2	952.596	476.298	479	0.0000
Error	6	5.967	0.994		
Total	8	958.562			

Grand Mean 81.956 CV 1.22

Alpha 0.01 Standard Error for Comparison 0.8142
Critical T Value 3.707 Critical Value for Comparison 3.0187

Completely Randomized AOV for Peak viscosity

Source	DF	SS	MS	F	P
treatment	2	18402.0	9201.00	1624	0.0000
Error	6	34.0	5.67		
Total	8	18436.0			

Grand Mean 62.000 CV 3.84
Alpha 0.01 Standard Error for Comparison 1.9437
Critical T Value 3.707 Critical Value for Comparison 7.2059

Completely Randomized AOV for End of Final Holding

Source	DF	SS	MS	F	P
treatment	2	20024.0	10012.0	1767	0.0000
Error	6	34.0	5.7		
Total	8	20058.0			

Grand Mean 71.333 CV 3.34
Alpha 0.01 Standard Error for Comparison 1.9437
Critical T Value 3.707 Critical Value for Comparison 7.2059

Completely Randomized AOV for Breakdown

Source	DF	SS	MS	F	P
treatment	2	470.889	235.444	2119	0.0000
Error	6	0.667	0.111		
Total	8	471.556			

Grand Mean 6.7778 CV 4.92
Alpha 0.01 Standard Error for Comparison 0.2722
Critical T Value 3.707 Critical Value for Comparison 1.0090

Completely Randomized AOV for Setback

Source	DF	SS	MS	F	P
treatment	2	1448.22	724.111	6517	0.0000
Error	6	0.67	0.111		
Total	8	1448.89			

Grand Mean 20.889   CV 1.60
Alpha   0.01   Standard Error for Comparison 0.2722
Critical T Value 3.707   Critical Value for Comparison 1.0090

Completely Randomized AOV for Time Taken to reach Peak Viscosity

Source	DF	SS	MS	F	P
treatment	2	694106	347053	21.0	0.0020
Error	6	99267	16544		
Total	8	793372			

Grand Mean 2239.4   CV 5.74
Alpha   0.01   Standard Error for Comparison 105.02
Critical T Value 3.707   Critical Value for Comparison 389.36

DIGESTIBILITY COEFFICIENTS AND ANTINUTRIENTS

Completely Randomized AOV for TANIN

Source	DF	SS	MS	F	P
treatment	2	0.03582	0.01791	5.66	0.0416
Error	6	0.01900	0.00317		
Total	8	0.05482			

Grand Mean 3.5144   CV 1.60
Alpha   0.01   Standard Error for Comparison 0.0459
Critical T Value 3.707   Critical Value for Comparison 0.1703

Completely Randomized AOV for Neutral Detergent Fibre (NDF)

Source	DF	SS	MS	F	P
treatment	2	729.556	364.778	182	0.0000
Error	6	12.000	2.000		
Total	8	741.556			

Grand Mean 58.222   CV 2.43
Alpha   0.01   Standard Error for Comparison 1.1547
Critical T Value 3.707   Critical Value for Comparison 4.2810

Completely Randomized AOV for Acid Detergent Fiber (ADF)

Source	DF	SS	MS	F	P
treatment	2	208.222	104.111	117	0.0000
Error	6	5.333	0.889		
Total	8	213.556			

Grand Mean 17.222 CV 5.47
Alpha 0.01 Standard Error for Comparison 0.7698
Critical T Value 3.707 Critical Value for Comparison 2.8540

Completely Randomized AOV for Acid Detergent Lignin (ADL)

Source	DF	SS	MS	F	P
treatment	2	148.667	74.3333	134	0.0000
Error	6	3.333	0.5556		
Total	8	152.000			

Grand Mean 9.3333 CV 7.99
Alpha 0.01 Standard Error for Comparison 13.675
Critical T Value 3.707 Critical Value for Comparison 50.699

Completely Randomized AOV for LIGNIN

Source	DF	SS	MS	F	P
treatment	2	129.451	64.7256	111	0.0000
Error	6	3.510	0.5850		
Total	8	132.961			

Grand Mean 6.7780 CV 11.28
Alpha 0.01 Standard Error for Comparison 0.6667
Critical T Value 3.707 Critical Value for Comparison 2.4716

Completely Randomized AOV for HEMICELLULOSE

Source	DF	SS	MS	F	P
treatment	2	1618.67	809.333	1457	0.0000
Error	6	3.33	0.556		
Total	8	1622.00			

Grand Mean 41.000 CV 1.82

Alpha 0.01 Standard Error for Comparison 0.6667
Critical T Value 3.707 Critical Value for Comparison 2.4716

Completely Randomized AOV for CELLULOSE

Source	DF	SS	MS	F	P
treatment	2	4.2222	2.11111	0.70	0.5314

Error	6	18.0000	3.00000
Total	8	22.2222	

Grand Mean 5.5556   CV 31.18
Alpha   0.01   Standard Error for Comparison 0.4714
Critical T Value 3.707   Critical Value for Comparison 1.7477

Completely Randomized AOV for Cell solubles

Source	DF	SS	MS	F	P
treatment	2	729.556	364.778	182	0.0000
Error	6	12.000	2.000		
Total	8	741.556			

Grand Mean 41.778   CV 3.39
Alpha   0.01   Standard Error for Comparison 1.1547
Critical T Value 3.707   Critical Value for Comparison 4.2810

Completely Randomized AOV for Digestible Dry Matter (DDM)

Source	DF	SS	MS	F	P
treatment	2	126.358	63.1789	117	0.0000
Error	6	3.236	0.5394		
Total	8	129.594			

Grand Mean 75.484   CV 0.97
Alpha   0.01   Standard Error for Comparison 0.5997
Critical T Value 3.707   Critical Value for Comparison 2.2232

Completely Randomized AOV for DMI

Source	DF	SS	MS	F	P
treatment	2	0.95237	0.47619	144	0.0000
Error	6	0.01984	0.00331		
Total	8	0.97222			

Grand Mean 2.1120   CV 2.72

Alpha   0.01   Standard Error for Comparison 0.0470
Critical T Value 3.707   Critical Value for Comparison 0.1741

Completely Randomized AOV for Net Energy (NE)

Source	DF	SS	MS	F	P
treatment	2	0.03150	0.01575	117	0.0000
Error	6	0.00081	0.00013		
Total	8	0.03231			

Grand Mean 0.8322   CV 1.39

Alpha   0.01   Standard Error for Comparison 9.469E-03
Critical T Value 3.707   Critical Value for Comparison 0.0351

Completely Randomized AOV for RFV

Source	DF	SS	MS	F	P
treatment	2	1614.24	807.120	40.7	0.0003
Error	6	119.09	19.849		
Total	8	1733.33			

Completely Randomized AOV for RFV

Source	DF	SS	MS	F	P
treatment	2	1614.24	807.120	40.7	0.0003
Error	6	119.09	19.849		
Total	8	1733.33			

Grand Mean 122.73   CV 3.63

Alpha   0.01   Standard Error for Comparison 3.6376
Critical T Value 3.707   Critical Value for Comparison 13.486

Appendix B2: *Artocarpus Altilis* T-Test Tables

Proximate Composition

Two-Sample T Tests for MOISTURE by treatment

treatment	Mean	N	SD	SE
NUTS	8.5662	3	1.9554	1.1289
PULP	9.1080	3	0.1901	0.1098
Difference	-0.5418			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	-0.48	4	0.6578	-3.6910	2.6074
Unequal Variances	-0.48	2.0	0.6792	-5.3364	4.2528

Test for Equality	F	DF	P
of Variances	105.77	2,2	0.0094

Two-Sample T Tests for PROTEIN by treatment

treatment	Mean	N	SD	SE
NUTS	15.703	3	3.0059	1.7355
PULP	3.8000	3	0.6083	0.3512
Difference	11.903			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	6.72	4	0.0026	6.9867	16.819
Unequal Variances	6.72	2.2	0.0174	4.8104	18.995

Test for Equality	F	DF	P
of Variances	24.42	2,2	0.0393

Two-Sample T Tests for FAT by treatment

treatment	Mean	N	SD	SE
NUTS	6.9333	3	1.8784	1.0845
PULP	2.2600	3	0.1000	0.0577
Difference	4.6733			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

Assumption	T	DF	P	95% CI for Difference Lower	Upper
Equal Variances	4.30	4	0.0126	1.6580	7.6887
Unequal Variances	4.30	2.0	0.0495	0.0256	9.3211

Test for Equality	F	DF	P
of Variances	352.85	2,2	0.0028

Two-Sample T Tests for FIBRE by treatment

treatment	Mean	N	SD	SE
NUTS	2.2658	3	0.6192	0.3575
PULP	3.1228	3	0.0823	0.0475
Difference	-0.8570			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

Assumption	T	DF	P	95% CI for Difference Lower	Upper
Equal Variances	-2.38	4	0.0763	-1.8583	0.1443
Unequal Variances	-2.38	2.1	0.1364	-2.3590	0.6450

Test for Equality	F	DF	P
of Variances	56.59	2,2	0.0174

Two-Sample T Tests for ASH by treatment

treatment	Mean	N	SD	SE
NUTS	2.5603	3	0.3954	0.2283
PULP	2.3647	3	0.0446	0.0258
Difference	0.1955			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

Assumption	T	DF	P	95% CI for Difference Lower	Upper
Equal Variances	0.85	4	0.4426	-0.4423	0.8333
Unequal Variances	0.85	2.1	0.4824	-0.7697	1.1607

Test for Equality	F	DF	P
of Variances	78.49	2,2	0.0126

Two-Sample T Tests for Carbohydr by treatment

treatment	Mean	N	SD	SE
NUTS	63.972	3	6.4929	3.7487
PULP	79.344	3	0.7956	0.4594
Difference	-15.373			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	-4.07	4	0.0152	-25.859	-4.8870
Unequal Variances	-4.07	2.1	0.0527	-31.177	0.4314

Test for Equality	F	DF	P
of Variances	66.60	2,2	0.0148

MINERALS

Two-Sample T Tests for K by treatment

treatment	Mean	N	SD	SE
NUTS	812.02	3	435.02	251.16
PULP	673.50	3	2.5890	1.4948
Difference	138.51			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	0.55	4	0.6107	-558.83	835.85
Unequal Variances	0.55	2.0	0.6367	-942.08	1219.1

Test for Equality	F	DF	P
of Variances	28231.99	2,2	0.0000

Two-Sample T Tests for Na by treatment

treatment	Mean	N	SD	SE
NUTS	48.167	3	9.2511	5.3411
PULP	69.000	3	2.0000	1.1547
Difference	-20.833			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper

Equal Variances	-3.81	4	0.0189	-36.005	-5.6614
Unequal Variances	-3.81	2.2	0.0541	-42.524	0.8572

Test for Equality	F	DF	P
of Variances	21.40	2,2	0.0447

Two-Sample T Tests for Fe by treatment

treatment	Mean	N	SD	SE
NUTS	5.1083	3	3.7754	2.1798
PULP	3.9063	3	0.7813	0.4511
Difference	1.2021			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	0.54	4	0.6178	-4.9781	7.3823
Unequal Variances	0.54	2.2	0.6395	-7.6877	10.092

Test for Equality	F	DF	P
of Variances	23.35	2,2	0.0411

Two-Sample T Tests for Mg by treatment

treatment	Mean	N	SD	SE
NUTS	90.194	3	78.801	45.496
PULP	90.625	3	6.2500	3.6084
Difference	-0.4306			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	-0.01	4	0.9929	-127.14	126.28
Unequal Variances	-0.01	2.0	0.9933	-194.48	193.62

Test for Equality	F	DF	P
of Variances	158.97	2,2	0.0063

Two-Sample T Tests for P by treatment

treatment	Mean	N	SD	SE
NUTS	289.20	3	131.17	75.728
PULP	140.00	3	5.0000	2.8868
Difference	149.20			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

Assumption	T	DF	P	95% CI for Difference Lower	Upper
Equal Variances	1.97	4	0.1203	-61.208	359.61
Unequal Variances	1.97	2.0	0.1875	-175.97	474.37

Test for Equality	F	DF	P
of Variances	688.17	2,2	0.0015

Two-Sample T Tests for Ca by treatment

treatment	Mean	N	SD	SE
NUTS	95.167	3	31.306	18.075
PULP	60.833	3	0.434	8.3333
Difference	34.333			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

Assumption	T	DF	P	95% CI for Difference Lower	Upper
Equal Variances	1.73	4	0.1596	-20.927	89.594
Unequal Variances	1.73	2.8	0.1890	-31.450	100.12

Test for Equality	F	DF	P
of Variances	4.70	2,2	0.1753

Two-Sample T Tests for K~01 by treatment

treatment	Mean	N	SD	SE
NUTS	18.674	3	14.173	8.1828
PULP	9.7609	3	0.0375	0.0217
Difference	8.9126			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

Assumption	T	DF	P	95% CI for Difference Lower	Upper
Equal Variances	1.09	4	0.3373	-13.807	31.632
Unequal Variances	1.09	2.0	0.3898	-26.295	44.120

Test for Equality	F	DF	P
of Variances	142676.35	2,2	0.0000

Two-Sample T Tests for Ca~01 by treatment

treatment	Mean	N	SD	SE
NUTS	0.3462	3	0.0997	0.0575
PULP	0.4345	3	0.1031	0.0595
Difference	-0.0883			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	-1.07	4	0.3463	-0.3182	0.1416
Unequal Variances	-1.07	4.0	0.3463	-0.3183	0.1417

Test for Equality	F	DF	P
of Variances	1.07	2,2	0.4831

PHYSICAL PROPERTY

Two-Sample T Tests for BULK by treatment

treatment	Mean	N	SD	SE
NUTS	0.6532	3	0.1162	0.0671
PULP	0.5717	3	0.0163	9.44E-03
Difference	0.0814			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	1.20	4	0.2956	-0.1066	0.2695
Unequal Variances	1.20	2.1	0.3483	-0.1997	0.3625

Test for Equality	F	DF	P
of Variances	50.55	2,2	0.0194

FUNCTIONAL PROPERTIES

Two-Sample T Tests for WAC by treatment

treatment	Mean	N	SD	SE
NUTS	2.3056	3	0.4590	0.2650
PULP	3.6667	3	0.5774	0.3333
Difference	-1.3611			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	-3.20	4	0.0330	-2.5434	-0.1788
Unequal Variances	-3.20	3.8	0.0354	-2.5675	-0.1547

Test for Equality	F	DF	P
of Variances	1.58	2,2	0.3872

Two-Sample T Tests for OAC by treatment

treatment	Mean	N	SD	SE
NUTS	0.7500	3	0.4330	0.2500
PULP	1.5000	3	0.2000	0.1155
Difference	-0.7500			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	-2.72	4	0.0528	-1.5146	0.0146
Unequal Variances	-2.72	2.8	0.0775	-1.6596	0.1596

Test for Equality	F	DF	P
of Variances	4.69	2,2	0.1758

Two-Sample T Tests for SOLUBILIT by treatment

treatment	Mean	N	SD	SE
NUTS	9.9667	3	1.7293	0.9984
PULP	11.550	3	2.2461	1.2968
Difference	-1.5833			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	-0.97	4	0.3881	-6.1273	2.9606
Unequal Variances	-0.97	3.8	0.3914	-6.2468	3.0802

Test for Equality	F	DF	P
of Variances	1.69	2,2	0.3722

Two-Sample T Tests for SWELLING by treatment

treatment	Mean	N	SD	SE
NUTS	5.4962	3	0.7537	0.4352
PULP	7.0179	3	0.0831	0.0480
Difference	-1.5217			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	-3.48	4	0.0255	-2.7373	-0.3061
Unequal Variances	-3.48	2.0	0.0712	-3.3632	0.3198

Test for Equality	F	DF	P
of Variances	82.20	2,2	0.0120

Two-Sample T Tests for FOAM by treatment

treatment	Mean	N	SD	SE
NUTS	1.6667	3	0.9825	0.5672
PULP	0.9167	3	0.2887	0.1667
Difference	0.7500			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	1.27	4	0.2734	-0.8915	2.3915
Unequal Variances	1.27	2.3	0.3160	-1.4684	2.9684

Test for Equality	F	DF	P
of Variances	11.58	2,2	0.0795

Two-Sample T Tests for FS30 by treatment

treatment	Mean	N	SD	SE
NUTS	0.4167	3	0.5204	0.3005
PULP	0.0200	3	0.0100	5.77E-03
Difference	0.3967			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

Assumption	T	DF	P	95% CI for Difference Lower	Upper
Equal Variances	1.32	4	0.2573	-0.4377	1.2310
Unequal Variances	1.32	2.0	0.3176	-0.8954	1.6888

Test for Equality	F	DF	P
of Variances	2708.33	2,2	0.0004

Two-Sample T Tests for FS60 by treatment

treatment	Mean	N	SD	SE
NUTS	0.1944	3	0.1735	0.1002
PULP	6.67E-03	3	5.77E-03	3.33E-03
Difference	0.1878			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

Assumption	T	DF	P	95% CI for Difference Lower	Upper
Equal Variances	1.87	4	0.1342	-0.0904	0.4660
Unequal Variances	1.87	2.0	0.2015	-0.2425	0.6180

Test for Equality	F	DF	P
of Variances	902.78	2,2	0.0011

Two-Sample T Tests for FS90 by treatment

treatment	Mean	N	SD	SE
NUTS	0.3056	3	0.3938	0.2274
PULP	0.0300	3	0.0100	5.77E-03
Difference	0.2756			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

Assumption	T	DF	P	95% CI for Difference Lower	Upper
Equal Variances	1.21	4	0.2924	-0.3559	0.9070
Unequal Variances	1.21	2.0	0.3493	-0.7019	1.2530

Test for Equality	F	DF	P
of Variances	1550.93	2,2	0.0006

Two-Sample T Tests for LGC by treatment

treatment	Mean	N	SD	SE
NUTS	6.6667	3	1.1547	0.6667

PULP	9.3333	3	1.1547	0.6667
Difference	-2.6667			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	-2.83	4	0.0474	-5.2843	-0.0490
Unequal Variances	-2.83	4.0	0.0474	-5.2843	-0.0490

Test for Equality	F	DF	P
of Variances	1.00	2,2	0.5000

PASTING PROPERTIES

Two-Sample T Tests for Pasting by treatment

treatment	Mean	N	SD	SE
NUTS	81.956	3	12.600	7.2747
PULP	73.200	3	0.2000	0.1155
Difference	8.7556			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	1.20	4	0.2952	-11.445	28.956
Unequal Variances	1.20	2.0	0.3519	-22.534	40.045

Test for Equality	F	DF	P
of Variances	3969.15	2,2	0.0003

Two-Sample T Tests for PV by treatment

treatment	Mean	N	SD	SE
NUTS	62.000	3	55.381	31.974
PULP	354.33	3	9.8658	5.6960
Difference	-292.33			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	-9.00	4	0.0008	-382.50	-202.16
Unequal Variances	-9.00	2.1	0.0100	-424.38	-160.28

Test for Equality	F	DF	P
of Variances	31.51	2,2	0.0308

Two-Sample T Tests for End of Final Holding /Final Viscosity by treatment

treatment	Mean	N	SD	SE
NUTS	76.667	3	60.178	34.744
PULP	395.33	3	8.3865	4.8419
Difference	-318.67			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	-9.08	4	0.0008	-416.06	-221.27
Unequal Variances	-9.08	2.1	0.0105	-464.32	-173.01

Test for Equality	F	DF	P
of Variances	51.49	2,2	0.0191

Two-Sample T Tests for Setback by treatment

treatment	Mean	N	SD	SE
NUTS	20.889	3	15.536	8.9698
PULP	84.000	3	6.9282	4.0000
Difference	-63.111			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	-6.43	4	0.0030	-90.379	-35.843
Unequal Variances	-6.43	2.8	0.0097	-95.923	-30.299

Test for Equality	F	DF	P
of Variances	5.03	2,2	0.1659

Two-Sample T Tests for Breakdown by treatment

treatment	Mean	N	SD	SE
NUTS	6.3333	3	9.2916	5.3645
PULP	43.667	3	3.2146	1.8559
Difference	-37.333			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

95% CI for Difference					
Assumption	T	DF	P	Lower	Upper
Equal Variances	-6.58	4	0.0028	-53.094	-21.573
Unequal Variances	-6.58	2.5	0.0127	-57.790	-16.877

Test for Equality	F	DF	P
of Variances	8.35	2,2	0.1069

Two-Sample T Tests for TTPV by treatment

treatment	Mean	N	SD	SE
NUTS	2239.4	3	340.12	196.37
PULP	1798.3	3	14.572	8.4130
Difference	441.11			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

95% CI for Difference					
Assumption	T	DF	P	Lower	Upper
Equal Variances	2.24	4	0.0882	-104.60	986.82
Unequal Variances	2.24	2.0	0.1535	-401.62	1283.8

Test for Equality	F	DF	P
of Variances	544.82	2,2	0.0018

DIGESTIBILITY AND ENERGY COEFFIENTS

Two-Sample T Tests for TANIN by treatment

treatment	Mean	N	SD	SE
NUTS	3.5144	3	0.0773	0.0446
PULP	4.3019	3	1.1982	0.6918
Difference	-0.7875			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

95% CI for Difference					
Assumption	T	DF	P	Lower	Upper
Equal Variances	-1.14	4	0.3194	-2.7122	1.1373
Unequal Variances	-1.14	2.0	0.3729	-3.7468	2.1718

Test for Equality	F	DF	P
of Variances	240.49	2,2	0.0041

Two-Sample T Tests for NDF by treatment

treatment	Mean	N	SD	SE
NUTS	58.222	3	11.027	6.3664
PULP	45.333	3	1.5275	0.8819
Difference	12.889			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	2.01	4	0.1154	-4.9558	30.734
Unequal Variances	2.01	2.1	0.1780	-13.809	39.586

Test for Equality	F	DF	P
of Variances	52.11	2,2	0.0188

Two-Sample T Tests for ADF by treatment

treatment	Mean	N	SD	SE
NUTS	17.222	3	5.8910	3.4012
PULP	16.333	3	1.5275	0.8819
Difference	0.8889			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	0.25	4	0.8128	-8.8665	10.644
Unequal Variances	0.25	2.3	0.8214	-12.641	14.419

Test for Equality	F	DF	P
of Variances	14.87	2,2	0.0630

Two-Sample T Tests for ADL by treatment

treatment	Mean	N	SD	SE
NUTS	9.3333	3	4.9777	2.8739
PULP	6.6667	3	1.1547	0.6667
Difference	2.6667			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	0.90	4	0.4172	-5.5244	10.858

Unequal Variances	0.90	2.2	0.4534	-8.9181	14.251

Test for Equality	F	DF	P
of Variances	18.58	2,2	0.0511

Two-Sample T Tests for LIGNIN by treatment

treatment	Mean	N	SD	SE
NUTS	6.7780	3	4.6449	2.6817
PULP	4.3019	3	1.1982	0.6918
Difference	2.4761			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	0.89	4	0.4218	-5.2134	10.166
Unequal Variances	0.89	2.3	0.4560	-8.1990	13.151

Test for Equality	F	DF	P
of Variances	15.03	2,2	0.0624

Two-Sample T Tests for HEMICELLU by treatment

treatment	Mean	N	SD	SE
NUTS	41.000	3	16.425	9.4829
PULP	29.000	3	1.0000	0.5774
Difference	12.000			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	1.26	4	0.2752	-14.378	38.378
Unequal Variances	1.26	2.0	0.3331	-28.590	52.590

Test for Equality	F	DF	P
of Variances	269.78	2,2	0.0037

Two-Sample T Tests for CELLULOSE by treatment

treatment	Mean	N	SD	SE
NUTS	7.8889	3	1.6443	0.9493
PULP	9.6667	3	2.0817	1.2019
Difference	-1.7778			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	-1.16	4	0.3103	-6.0301	2.4745
Unequal Variances	-1.16	3.8	0.3135	-6.1215	2.5660

Test for Equality	F	DF	P
of Variances	1.60	2,2	0.3842

Two-Sample T Tests for Cell Solubles by treatment

treatment	Mean	N	SD	SE
NUTS	41.778	3	11.027	6.3664
PULP	54.667	3	1.5275	0.8819
Difference	-12.889			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	-2.01	4	0.1154	-30.734	4.9558
Unequal Variances	-2.01	2.1	0.1780	-39.586	13.809

Test for Equality	F	DF	P
of Variances	52.11	2,2	0.0188

Two-Sample T Tests for DDM by treatment

treatment	Mean	N	SD	SE
NUTS	75.484	3	4.5891	2.6495
PULP	76.176	3	1.1899	0.6870
Difference	-0.6924			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper

Equal Variances	-0.25	4	0.8128	-8.2919	6.9070
Unequal Variances	-0.25	2.3	0.8214	-11.232	9.8474

Test for Equality	F	DF	P
of Variances	14.87	2,2	0.0630

Two-Sample T Tests for DMI by treatment

treatment	Mean	N	SD	SE
NUTS	2.1120	3	0.3984	0.2300
PULP	2.6490	3	0.0884	0.0510
Difference	-0.5371			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	-2.28	4	0.0848	-1.1912	0.1171
Unequal Variances	-2.28	2.2	0.1389	-1.4688	0.3946

Test for Equality	F	DF	P
of Variances	20.33	2,2	0.0469

Two-Sample T Tests for NE by treatment

treatment	Mean	N	SD	SE
NUTS	0.8322	3	0.0725	0.0418
PULP	0.8431	3	0.0188	0.0108
Difference	-0.0109			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	-0.25	4	0.8128	-0.1309	0.1091
Unequal Variances	-0.25	2.3	0.8214	-0.1774	0.1555

Test for Equality	F	DF	P
of Variances	14.87	2,2	0.0630

Two-Sample T Tests for RFV by treatment

treatment	Mean	N	SD	SE

NUTS	122.73	3	16.402	9.4700
PULP	156.48	3	7.6374	4.4095
Difference	-33.755			

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

				95% CI for Difference	
Assumption	T	DF	P	Lower	Upper
Equal Variances	-3.23	4	0.0319	-62.758	-4.7517
Unequal Variances	-3.23	2.8	0.0523	-68.171	0.6609

Test for Equality	F	DF	P
of Variances	4.61	2,2	0.1782

Appendix B3: Anova Tables For Sensory Evaluation

Breakfast meal

Completely Randomized AOV for colour

Source	DF	SS	MS	F	P
trt	5	78.500	15.7000	16.3	0.0000
Error	354	341.400	0.9644		
Total	359	419.900			

Grand Mean 2.6833 CV 36.60
Alpha 0.01 Standard Error for Comparison 0.1793
Critical T Value 2.590 Critical Value for Comparison 0.4643

Completely Randomized AOV for mouthfeel

Source	DF	SS	MS	F	P
trt	5	155.700	31.1400	68.8	0.0000
Error	354	160.200	0.4525		
Total	359	315.900			

Grand Mean 3.1500 CV 21.36
Alpha 0.01 Standard Error for Comparison 0.1228
Critical T Value 2.590 Critical Value for Comparison 0.3181

Completely Randomized AOV for aroma

Source	DF	SS	MS	F	P
trt	5	73.200	14.6400	48.5	0.0000
Error	354	106.800	0.3017		
Total	359	180.000			

Grand Mean 1.5000 CV 36.62
Alpha 0.01 Standard Error for Comparison 0.1003
Critical T Value 2.590 Critical Value for Comparison 0.2597

Completely Randomized AOV for taste

Source	DF	SS	MS	F	P
trt	5	157.700	31.5400	65.8	0.0000
Error	354	169.800	0.4797		
Total	359	327.500			

Grand Mean 2.5833 CV 26.81
Alpha 0.01 Standard Error for Comparison 0.1264
Critical T Value 2.590 Critical Value for Comparison 0.3275

Completely Randomized AOV for overall

Source	DF	SS	MS	F	P
trt	5	39.4063	7.88125	47.5	0.0000
Error	354	58.6875	0.16578		
Total	359	98.0937			

Grand Mean 2.4792 CV 16.42
Alpha 0.01 Standard Error for Comparison 0.0743
Critical T Value 2.590 Critical Value for Comparison 0.1925
Shortcake
Completely Randomized AOV for colour

Source	DF	SS	MS	F	P
trt	5	562.400	112.480	246	0.0000
Error	354	162.000	0.458		
Total	359	724.400			

Grand Mean 2.5667 CV 26.36
Alpha 0.01 Standard Error for Comparison 0.1235
Critical T Value 2.590 Critical Value for Comparison 0.3199

Completely Randomized AOV for mouthfeel

Source	DF	SS	MS	F	P
trt	5	410.400	82.0800	161	0.0000
Error	354	180.000	0.5085		
Total	359	590.400			

Grand Mean 2.9000 CV 24.59
Alpha 0.01 Standard Error for Comparison 0.1302
Critical T Value 2.590 Critical Value for Comparison 0.3372

Completely Randomized AOV for aroma

Source	DF	SS	MS	F	P
trt	5	378.500	75.7000	122	0.0000
Error	354	219.000	0.6186		
Total	359	597.500			

Grand Mean 2.5833 CV 30.45
Alpha 0.01 Standard Error for Comparison 0.1436
Critical T Value 2.590 Critical Value for Comparison 0.3719

Completely Randomized AOV for taste

Source DF SS MS F P

trt	5	280.100	56.0200	102	0.0000
Error	354	193.800	0.5475		
Total	359	473.900			

Grand Mean 2.3167 CV 31.94
Alpha 0.01 Standard Error for Comparison 0.1351
Critical T Value 2.590 Critical Value for Comparison 0.3498

Completely Randomized AOV for overall

Source	DF	SS	MS	F	P
trt	5	390.650	78.1300	526	0.0000
Error	354	52.575	0.1485		
Total	359	443.225			

Grand Mean 2.5917 CV 14.87
Alpha 0.01 Standard Error for Comparison 0.0704
Critical T Value 2.590 Critical Value for Comparison 0.1822

TATALE

Completely Randomized AOV for colour

Source	DF	SS	MS	F	P
trt	5	274.100	54.8200	203	0.0000
Error	354	95.400	0.2695		
Total	359	369.500			

Grand Mean 2.0833 CV 24.92
Alpha 0.01 Standard Error for Comparison 0.0948
Critical T Value 2.590 Critical Value for Comparison 0.2455

Completely Randomized AOV for mouthfeel

Source	DF	SS	MS	F	P
trt	5	33.200	6.64000	18.0	0.0000
Error	354	130.800	0.36949		
Total	359	164.000			

Grand Mean 2.3333 CV 26.05
Alpha 0.01 Standard Error for Comparison 0.1110
Critical T Value 2.590 Critical Value for Comparison 0.2874

Completely Randomized AOV for aroma

Source	DF	SS	MS	F	P
trt	5	266.000	53.2000	154	0.0000
Error	354	122.400	0.3458		

Total 359 388.400
Grand Mean 2.2667 CV 25.94
Alpha 0.01 Standard Error for Comparison 0.1074
Critical T Value 2.590 Critical Value for Comparison 0.2780

Completely Randomized AOV for taste

Source	DF	SS	MS	F	P
trt	5	32.100	6.42000	16.1	0.0000
Error	354	141.000	0.39831		
Total	359	173.100			

Grand Mean 2.0500 CV 30.79
Alpha 0.01 Standard Error for Comparison 0.1152
Critical T Value 2.590 Critical Value for Comparison 0.2984

Completely Randomized AOV for overall

Source	DF	SS	MS	F	P
trt	5	113.975	22.7950	237	0.0000
Error	354	34.050	0.0962		
Total	359	148.025			

Grand Mean 2.1833 CV 14.20
Alpha 0.01 Standard Error for Comparison 0.0566
Critical T Value 2.590 Critical Value for Comparison 0.1466

KOOSE

Completely Randomized AOV for colour

Source	DF	SS	MS	F	P
trt	5	488.400	97.6800	260	0.0000
Error	354	133.200	0.3763		
Total	359	621.600			

Grand Mean 3.3000 CV 18.59
Alpha 0.01 Standard Error for Comparison 0.1120
Critical T Value 2.590 Critical Value for Comparison 0.2900

Completely Randomized AOV for mouthfeel

Source	DF	SS	MS	F	P
trt	5	226.500	45.3000	133	0.0000
Error	354	120.600	0.3407		
Total	359	347.100			

Grand Mean 2.0500 CV 28.47

Alpha 0.01 Standard Error for Comparison 0.1066
Critical T Value 2.590 Critical Value for Comparison 0.2760

Completely Randomized AOV for aroma

Source	DF	SS	MS	F	P
trt	5	420.500	84.1000	160	0.0000
Error	354	186.600	0.5271		
Total	359	607.100			

Grand Mean 2.7833 CV 26.08
Alpha 0.01 Standard Error for Comparison 0.1326
Critical T Value 2.590 Critical Value for Comparison 0.3433

Completely Randomized AOV for taste

Source	DF	SS	MS	F	P
trt	5	279.600	55.9200	122	0.0000
Error	354	162.000	0.4576		
Total	359	441.600			

Grand Mean 2.2000 CV 30.75
Alpha 0.01 Standard Error for Comparison 0.1235
Critical T Value 2.590 Critical Value for Comparison 0.3199

Completely Randomized AOV for overall

Source	DF	SS	MS	F	P
trt	5	330.500	66.1000	594	0.0000
Error	354	39.375	0.1112		
Total	359	369.875			

Grand Mean 2.5833 CV 12.91
Alpha 0.01 Standard Error for Comparison 0.0609
Critical T Value 2.590 Critical Value for Comparison 0.1577

Condiment

Completely Randomized AOV for aroma

Source	DF	SS	MS	F	P
trt	2	39.900	19.9500	41.9	0.0000
Error	177	84.300	0.4763		
Total	179	124.200			

Grand Mean 1.9000 CV 36.32
Alpha 0.05 Standard Error for Comparison 0.1260
Critical T Value 1.973 Critical Value for Comparison 0.2487

Completely Randomized AOV for overall

Source	DF	SS	MS	F	P
trt	2	22.8000	11.4000	30.3	0.0000
Error	177	66.6375	0.3765		
Total	179	89.4375			

Grand Mean 1.8750 CV 32.72
Alpha 0.05 Standard Error for Comparison 0.1120
Critical T Value 1.973 Critical Value for Comparison 0.2211

Completely Randomized AOV for colour

Source	DF	SS	MS	F	P
trt	2	17.1000	8.55000	19.4	0.0000
Error	177	77.8500	0.43983		
Total	179	94.9500			

Grand Mean 1.8500 CV 35.85
Alpha 0.05 Standard Error for Comparison 0.1211
Critical T Value 1.973 Critical Value for Comparison 0.2390

Stew Produced Using Condiment
Completely Randomized AOV for aroma

Source	DF	SS	MS	F	P
trt	3	53.400	17.8000	26.3	0.0000
Error	236	159.600	0.6763		
Total	239	213.000			

Grand Mean 2.2500 CV 36.55
Alpha 0.05 Standard Error for Comparison 0.1501
Critical T Value 1.970 Critical Value for Comparison 0.2958

Completely Randomized AOV for overall

Source	DF	SS	MS	F	P
trt	3	56.503	18.8344	46.2	0.0000
Error	236	96.262	0.4079		
Total	239	152.766			

Grand Mean 2.2813 CV 28.00
Alpha 0.05 Standard Error for Comparison 0.1166
Critical T Value 1.970 Critical Value for Comparison 0.2297

Completely Randomized AOV for taste

Source	DF	SS	MS	F	P
trt	3	61.313	20.4375	25.6	0.0000
Error	236	188.250	0.7977		
Total	239	249.563			

Grand Mean 2.3125 CV 38.62
Alpha 0.05 Standard Error for Comparison 0.1631
Critical T Value 1.970 Critical Value for Comparison 0.3212

APPENDIX B4 Predicting the digestibility of nutrients and energy values of 4 breadfruit species based on chemical analysis

APPENDIX B 4.1 CHEMICAL COMPOSITION

Completely Randomized AOV for Protein

Source	DF	SS	MS	F	P
treatment	3	384.637	128.212	527	0.0000
Error	8	1.945	0.243		
Total	11	386.582			

Grand Mean 12.829 CV 3.84
Alpha 0.01 Standard Error for Comparison 0.4026
Critical T Value 3.355 Critical Value for Comparison 1.3509

Completely Randomized AOV for Fat

Source	DF	SS	MS	F	P
treatment	3	21.3602	7.12008	118	0.0000
Error	8	0.4827	0.06033		
Total	11	21.8429			

Grand Mean 6.8292 CV 3.60
Alpha 0.01 Standard Error for Comparison 0.2006
Critical T Value 3.355 Critical Value for Comparison 0.6729

Completely Randomized AOV for Fiber

Source	DF	SS	MS	F	P
treatment	3	3.95286	1.31762	174	0.0000
Error	8	0.06046	0.00756		
Total	11	4.01332			

Grand Mean 2.4800 CV 3.51
Alpha 0.01 Standard Error for Comparison 0.0710
Critical T Value 3.355 Critical Value for Comparison 0.2382

Completely Randomized AOV for ASH

Source	DF	SS	MS	F	P
treatment	3	1.01166	0.33722	198	0.0000
Error	8	0.01361	0.00170		
Total	11	1.02527			

Grand Mean 2.5077 CV 1.65
Alpha 0.01 Standard Error for Comparison 0.0337

Critical T Value 3.355 Critical Value for Comparison 0.1130

Completely Randomized AOV for Carbohydrate

Source	DF	SS	MS	F	P
treatment	3	557.176	185.725	480	0.0000
Error	8	3.093	0.387		
Total	11	560.269			

Alpha 0.01 Standard Error for Comparison 0.5077
Critical T Value 3.355 Critical Value for Comparison 1.7035

APPENDIX B 4.2 ANTINUTRIENT (TANNIN)

Completely Randomized AOV for TANIN

Source	DF	SS	MS	F	P
treatment	3	1.43113	0.47704	1.32	0.3337
Error	8	2.89058	0.36132		
Total	11	4.32172			

Grand Mean 3.7113 CV 16.20
Alpha 0.01 Standard Error for Comparison 0.4908
Critical T Value 3.355 Critical Value for Comparison 1.6468

APPENDIX B 4.3 DIGESTIBILITY COEFFICIENTS

Completely Randomized AOV for NDF

Source	DF	SS	MS	F	P
treatment	3	1103.33	367.778	177	0.0000
Error	8	16.67	2.083		
Total	11	1120.00			

Grand Mean 55.000 CV 2.62
Alpha 0.01 Standard Error for Comparison 1.1785
Critical T Value 3.355 Critical Value for Comparison 3.9544

Completely Randomized AOV for ADF

Source	DF	SS	MS	F	P
treatment	3	210.000	70.0000	56.0	0.0000
Error	8	10.000	1.2500		
Total	11	220.000			

Grand Mean 17.000 CV 6.58
Alpha 0.01 Standard Error for Comparison 0.9129
Critical T Value 3.355 Critical Value for Comparison 3.0630

Completely Randomized AOV for ADL

Source	DF	SS	MS	F	P
treatment	3	164.667	54.8889	73.2	0.0000
Error	8	6.000	0.7500		
Total	11	170.667			

Grand Mean 8.6667   CV 9.99
Chi-Sq   DF   P
Alpha   0.01   Standard Error for Comparison 0.7071
Critical T Value 3.355   Critical Value for Comparison 2.3726

Completely Randomized AOV for LIGNIN

Source	DF	SS	MS	F	P
treatment	3	143.246	47.7486	59.9	0.0000
Error	8	6.381	0.7977		
Total	11	149.627			

Grand Mean 6.1590   CV 14.50
Alpha   0.01   Standard Error for Comparison 0.7292
Critical T Value 3.355   Critical Value for Comparison 2.4469

Completely Randomized AOV for HEMICELLU

Source	DF	SS	MS	F	P
treatment	3	1942.67	647.556	1554	0.0000
Error	8	3.33	0.417		
Total	11	1946.00			

Grand Mean 38.000   CV 1.70
Alpha   0.01   Standard Error for Comparison 0.5270
Critical T Value 3.355   Critical Value for Comparison 1.7684

Completely Randomized AOV for CELLULOSE

Source	DF	SS	MS	F	P
treatment	3	42.2500	14.0833	4.22	0.0458
Error	8	26.6667	3.3333		
Total	11	68.9167			

Grand Mean 6.5833   CV 27.73
Alpha   0.01   Standard Error for Comparison 1.4907
Critical T Value 3.355   Critical Value for Comparison 5.0019

Completely Randomized AOV for Cell

Source	DF	SS	MS	F	P
treatment	3	1103.33	367.778	177	0.0000

Error	8	16.67	2.083
Total	11	1120.00	

Grand Mean 45.000 CV 3.21
Alpha 0.01 Standard Error for Comparison 1.1785
Critical T Value 3.355 Critical Value for Comparison 3.9544

Completely Randomized AOV for DDM

Source	DF	SS	MS	F	P
treatment	3	127.437	42.4789	56.0	0.0000
Error	8	6.068	0.7586		
Total	11	133.505			

Grand Mean 75.657 CV 1.15
Alpha 0.01 Standard Error for Comparison 0.7111
Critical T Value 3.355 Critical Value for Comparison 2.3861

APPENDIX C: TABLES OF ASSOCIATION

Appendix C1: Correlation Coefficientsc for *A. heterophyllus, A. camansi* and *T. africana*

	Ash	Bulk density	Break down	Ca	Ca ratio	Carbohydrate	End of cooling
Ash	1.00						
Bulk density	-0.78	1.00					
Breakdown	-0.31	0.40	1.00				
Ca	0.30	-0.36	0.06	1.00			
Ca ratio	0.33	-0.33	0.08	1.00	1.00		
Carbohydrate	-0.64	0.82	0.27	-0.65	-0.61	1.00	
End of cooling	0.60	-0.20	0.31	0.65	0.71	-0.35	1.00
End of final holding	0.66	-0.28	0.20	0.67	0.73	-0.41	0.99
Fat	0.39	-0.65	-0.21	0.79	0.74	-0.93	0.31
Fibre	-0.05	-0.26	-0.61	0.33	0.26	-0.54	-0.30
Foam capacity	-0.08	0.28	0.20	-0.44	-0.37	0.70	-0.01
Fs30	-0.06	0.03	0.18	-0.47	-0.43	0.53	-0.20
Fs60	0.41	-0.37	-0.10	-0.29	-0.25	0.13	0.03
Fs90	0.52	-0.36	-0.12	-0.26	-0.22	0.07	0.19
Fe	-0.24	0.09	-0.04	0.77	0.76	-0.17	0.23
K	0.78	-0.27	0.02	0.10	0.17	-0.12	0.76
K ratio	0.74	-0.25	-0.09	-0.19	-0.12	0.01	0.52
LGC	0.06	0.02	0.31	0.79	0.79	-0.40	0.60
Moisture	-0.19	-0.30	0.22	0.39	0.31	-0.56	-0.18
Mg	-0.25	-0.20	-0.18	0.56	0.49	-0.55	-0.20
Na	-0.56	0.22	0.38	0.54	0.50	-0.16	-0.05
OAC	0.56	-0.94	-0.49	0.33	0.28	-0.80	-0.03
P	0.07	-0.52	-0.35	0.32	0.23	-0.74	-0.30
Protein	0.94	-0.84	-0.33	0.43	0.43	-0.82	0.55
PV	0.41	-0.05	0.55	0.62	0.68	-0.21	0.96
Pasting temp	0.25	0.36	0.33	0.15	0.24	0.27	0.76

Appendix C1: Correlation Coefficientsc for *A. heterophyllus, A. camansi* and *T. africana contd.*

	Ash	Bulk density	Break down	Ca	Ca ratio	Carbohydrate	End of cooling
Solubility	-0.40	0.57	0.51	0.43	0.44	0.13	0.36
Swelling power	0.52	-0.15	-0.28	-0.50	-0.44	0.24	0.13
Setback	0.55	-0.15	0.52	0.35	0.40	-0.32	0.86
Start of cooling	0.61	-0.24	0.27	0.69	0.75	-0.37	1.00
Start of holding	0.41	-0.03	0.51	0.62	0.68	-0.19	0.97
TTPV	0.28	0.19	-0.13	-0.25	-0.22	0.08	0.23
Time onset gelatinization	0.45	0.01	-0.14	-0.12	-0.09	-0.18	0.37
WAC	0.52	-0.18	-0.48	-0.51	-0.47	0.14	0.02
Cold paste	-0.35	0.56	0.94	0.11	0.16	0.42	0.41
Gelatinisation onset BU	0.46	-0.67	-0.09	0.25	0.20	-0.76	0.10
Hot paste	-0.55	0.61	0.93	-0.24	-0.22	0.54	0.00

Appendix C1: Correlation Coefficientsc for *A. heterophyllus, A. camansi* and *T. africana contd.*

	End of final holding	Fat	Fibre	Foam capacity	FS 30	FS 60	FS 90	Fe
End of final holding	1.00							
Fat	0.36	1.00						
Fibre	-0.23	0.66	1.00					
Foam capacity	-0.05	-0.80	-0.80	1.00				
Fs30	-0.23	-0.66	-0.70	0.90	1.00			
Fs60	0.05	-0.37	-0.57	0.72	0.83	1.00		
Fs90	0.21	-0.34	-0.55	0.60	0.63	0.82	1.00	
Fe	0.25	0.46	0.40	-0.25	-0.33	-0.39	-0.45	1.00
K	0.78	-0.10	-0.49	0.32	0.14	0.44	0.62	-0.31
K ratio	0.54	-0.29	-0.54	0.44	0.30	0.58	0.73	-0.54
LGC	0.58	0.55	0.22	-0.44	-0.57	-0.46	-0.50	0.61
Moisture	-0.20	0.67	0.48	-0.67	-0.39	-0.41	-0.51	0.26
Mg	-0.18	0.76	0.82	-0.78	-0.63	-0.63	-0.68	0.62
Na	-0.09	0.45	0.38	-0.48	-0.42	-0.65	-0.74	0.70
OAC	0.05	0.70	0.47	-0.41	-0.11	0.22	0.19	0.01
P	-0.24	0.79	0.83	-0.85	-0.59	-0.44	-0.44	0.17
Protein	0.62	0.61	0.17	-0.31	-0.24	0.26	0.39	-0.15

Appendix C1: Correlation Coefficientsc for *A. heterophyllus, A. camansi* and *T. africana contd.*

	End of final holding	Fat	Fibre	Foam capacity	FS 30	FS 60	FS 90	Fe
PV	0.92	0.21	-0.43	0.08	-0.10	0.01	0.12	0.26
Pasting temp	0.73	-0.30	-0.54	0.35	0.00	0.05	0.21	0.03
Solubility	0.31	0.11	0.05	-0.30	-0.52	-0.72	-0.56	0.54
Swelling power	0.16	-0.53	-0.51	0.62	0.53	0.73	0.82	-0.63
Setback	0.82	0.20	-0.40	-0.10	-0.22	-0.04	0.16	-0.18
Start of cooling	0.99	0.34	-0.27	0.00	-0.19	0.05	0.19	0.29
Start of holding	0.94	0.19	-0.42	0.09	-0.11	0.01	0.13	0.28
TTPV	0.24	-0.19	-0.07	-0.14	-0.39	-0.18	0.05	-0.41
Time onset gelatinization	0.39	0.04	0.07	-0.32	-0.52	-0.26	0.04	-0.43
WAC	0.07	-0.40	-0.23	0.36	0.27	0.53	0.66	-0.63
Cold paste	0.30	-0.31	-0.65	0.32	0.18	-0.13	-0.12	0.12
Gelatinisation onset BU	0.13	0.65	0.38	-0.65	-0.42	-0.14	-0.06	-0.22
Hot paste	-0.13	-0.46	-0.61	0.30	0.28	-0.12	-0.17	-0.15

Appendix C1: Correlation Coefficientsc for *A. heterophyllus, A. camansi* and *T. africana contd.*

	K	K:Na	LGC	Moisture	Mg	Na	OAC	P	Protein	PV
K	1.00									
K ratio	0.95	1.00								
LGC	0.05	-0.23	1.00							
Moisture	-0.62	-0.71	0.36	1.00						
Mg	-0.69	-0.82	0.46	0.81	1.00					
Na	-0.69	-0.87	0.59	0.74	0.80	1.00				
OAC	-0.02	-0.01	-0.08	0.44	0.42	-0.05	1.00			
P	-0.52	-0.55	0.17	0.80	0.85	0.44	0.70	1.00		
Protein	0.62	0.54	0.16	0.05	0.00	-0.37	0.69	0.31	1.00	
PV	0.64	0.40	0.63	-0.10	-0.21	0.10	-0.17	-0.38	0.36	1.00
Pasting temp	0.76	0.63	0.32	-0.64	-0.60	-0.29	-0.58	-0.75	0.09	0.76
Solubility	-0.14	-0.36	0.71	0.17	0.29	0.65	-0.58	-0.09	-0.36	0.48
Swelling power	0.73	0.89	-0.56	-0.79	-0.86	-0.97	-0.05	-0.58	0.32	0.01
Setback	0.72	0.55	0.45	-0.05	-0.30	-0.12	-0.09	-0.22	0.51	0.86
Start of cooling	0.74	0.50	0.61	-0.18	-0.17	-0.04	0.01	-0.28	0.56	0.95
Start of holding	0.66	0.42	0.63	-0.15	-0.22	0.07	-0.19	-0.40	0.35	1.00

Appendix C1: Correlation Coefficientsc for *A. heterophyllus, A. camansi* and *T. africana contd.*

	K	K:Na	LGC	Moisture	Mg	Na	OAC	P	Protein	PV
TTPV	0.47	0.50	0.01	-0.42	-0.37	-0.46	-0.30	-0.20	0.17	0.11
Time onset gelatinization	0.57	0.56	0.08	-0.32	-0.29	-0.46	-0.14	-0.04	0.42	0.22
WAC	0.63	0.81	-0.51	-0.73	-0.70	-0.95	0.03	-0.36	0.35	-0.15
Cold paste	0.10	-0.03	0.36	0.00	-0.25	0.36	-0.66	-0.55	-0.41	0.63
Gelatinisation onset BU	0.02	-0.02	0.11	0.59	0.38	0.08	0.68	0.69	0.60	0.02
Hot paste	-0.18	-0.20	0.09	0.14	-0.23	0.34	-0.65	-0.40	-0.60	0.25

Appendix C1: Correlation Coefficientsc for *A. heterophyllus, A. camansi* and *T. africana contd.*

	Pasting temp.	Solubility	Swelling power	Setback	Start of cooling	Start of holding
Pasting temp	1.00					
Solubility	0.43	1.00				
Swelling power	0.39	-0.59	1.00			
Setback	0.67	0.32	0.15	1.00		
Start of cooling	0.73	0.34	0.12	0.82	1.00	
Start of holding	0.79	0.48	0.04	0.84	0.96	1.00
TTPV	0.51	0.14	0.38	0.39	0.18	0.13
Time onset gelatinization	0.49	0.12	0.36	0.56	0.31	0.23
WAC	0.28	0.52	0.90	0.07	0.01	-0.13
Cold paste	0.54	0.62	-0.22	0.50	0.37	0.62
Gelatinisation onset BU	-0.37	-0.18	-0.20	0.30	0.09	-0.01
Hot paste	0.20	0.45	-0.25	0.25	-0.06	0.21

Appendix C1: Correlation Coefficientsc for *A. heterophyllus, A. camansi* and *T. africana contd.*

	TTPV	Time onset gelatinization	WAC	Cold paste	Gelatinization onset BU	Hot paste
TTPV	1.00					
Time onset gelatinization	0.86	1.00				
WAC	0.55	0.53	1.00			
Cold paste	-0.06	-0.12	-0.45	1.00		
Gelatinisation onset BU	0.04	0.26	-0.11	-0.28	1.00	
Hot paste	-0.12	-0.21	-0.43	0.88	-0.24	1.00

Appendix C2: Correlation Coefficients for *Artocarpus altilis*

	% Ash	% Carbo Hydrate	% Fat	% Fibre	% Moisture	% Protein	Bulk Density	Beginning of gelatinisation
% Ash	1.00							
% Carbohydrate	-0.21	1.00						
% Fat	0.30	0.06	1.00					
% Fibre	-0.28	0.85	0.31	1.00				
% Moisture	0.00	-0.96	-0.13	-0.73	1.00			
% Protein	0.29	-0.84	-0.38	-0.97	0.70	1.00		
Bulk density	-0.18	0.88	-0.10	0.58	-0.93	-0.51	1.00	
Beginning of gelatinisation	0.72	-0.68	0.16	-0.46	0.58	0.52	-0.68	1.00
Breakdown	-0.03	-0.94	0.05	-0.69	0.98	0.65	-0.92	0.52
Ca	0.24	0.28	-0.42	0.16	-0.37	0.06	0.48	0.18
Ca ratio	0.26	0.20	-0.44	0.11	-0.28	0.11	0.39	0.26
End of cooling	0.34	-0.81	-0.07	-0.55	0.86	0.53	-0.94	0.80
End of final holding	0.33	-0.83	-0.07	-0.57	0.87	0.55	-0.95	0.80
Foam capacity	-0.03	0.53	-0.27	0.19	-0.67	-0.05	0.86	-0.38
Fe	0.15	0.91	0.28	0.70	-0.97	-0.72	0.82	-0.50
K	-0.18	0.91	0.06	0.64	-0.96	-0.61	0.98	-0.71
K ratio	-0.19	0.91	0.06	0.64	-0.96	-0.61	0.98	-0.72
LGC	-0.77	-0.30	-0.15	-0.03	0.45	0.10	-0.23	-0.16
	% Ash	% Carbo Hydrate	% Fat	% Fibre	% Moisture	% Protein	Bulk Density	Beginning of gelatinisation
Mg	-0.13	-0.27	-0.77	-0.28	0.30	0.46	-0.08	0.27
Na	-0.18	0.91	0.05	0.64	-0.96	-0.61	0.98	-0.71
OAC	-0.11	-0.92	0.03	-0.67	0.97	0.62	-0.90	0.44
P	-0.18	0.91	0.05	0.64	-0.96	-0.61	0.98	-0.71
Pasting temp.	-0.05	0.92	0.03	0.62	-0.98	-0.59	0.98	-0.64
Solubility	-0.16	0.67	0.17	0.34	-0.70	-0.48	0.63	-0.77
Swelling power	0.43	-0.78	-0.07	-0.58	0.81	0.54	-0.92	0.79
Setback	0.16	-0.88	-0.02	-0.60	0.95	0.56	-0.99	0.68
Stability of cold paste	0.44	-0.64	-0.03	-0.39	0.70	0.36	-0.86	0.80
Stability of hot paste	0.57	-0.57	-0.15	-0.38	0.58	0.41	-0.71	0.86
Start of cooling	0.27	-0.88	-0.05	-0.62	0.92	0.59	-0.97	0.77
Start of holding	0.31	-0.86	-0.06	-0.60	0.90	0.58	-0.96	0.80
TTPV	0.65	0.30	-0.01	0.31	-0.32	-0.26	0.09	0.42
WAC	-0.51	0.61	0.46	0.81	-0.44	-0.90	0.28	-0.61
Gelatinisation onset temp.	-0.10	0.93	0.03	0.67	-0.98	-0.62	0.98	-0.65
Maximum viscosity	0.21	-0.91	-0.03	-0.64	0.95	0.61	-0.98	0.74

Appendix C2: Correlation Coefficients for *Artocarpus altilis* contd.

	Break-down	Ca	Ca ratio	End of cooling	End of final holding	Foam capacity	Fe	K
Breakdown	1.00							
Ca	-0.50	1.00						
Ca ratio	-0.42	0.99	1.00					
End of cooling	0.78	-0.21	-0.11	1.00				
End of final holding	0.80	-0.22	-0.12	1.00	1.00			
Foam capacity	-0.69	0.72	0.65	-0.76	-0.76	1.00		
Fe	-0.92	0.21	0.13	-0.76	-0.78	0.50	1.00	
K	-0.91	0.34	0.25	-0.96	-0.97	0.78	0.88	1.00
K ratio	-0.91	0.34	0.24	-0.97	-0.97	0.77	0.88	1.00
LGC	0.48	-0.14	-0.12	0.07	0.09	-0.12	-0.60	-0.26
Mg	0.14	0.69	0.73	0.27	0.28	0.27	-0.50	-0.25
Na	-0.92	0.35	0.26	-0.96	-0.97	0.78	0.88	1.00
OAC	1.00	-0.55	-0.48	0.74	0.76	-0.70	-0.92	-0.89
P	-0.92	0.35	0.26	-0.96	-0.97	0.78	0.88	1.00
Pasting temp.	-0.96	0.40	0.31	-0.91	-0.93	0.77	0.92	0.99
Solubility	-0.61	-0.30	-0.39	-0.74	-0.74	0.30	0.76	0.72
Swelling power	0.73	-0.24	-0.14	0.99	0.98	-0.76	-0.68	-0.93
Setback	0.91	-0.41	-0.31	0.96	0.97	-0.83	-0.85	-1.00
Stability of cold paste	0.61	-0.15	-0.05	0.97	0.96	-0.76	-0.58	-0.87
Stability of hot paste	0.44	0.13	0.22	0.90	0.89	-0.54	-0.49	-0.76
Start of cooling	0.87	-0.28	-0.18	0.99	0.99	-0.77	-0.84	-0.99
Start of holding	0.83	-0.24	-0.14	1.00	1.00	-0.75	-0.81	-0.98
TTPV	-0.45	0.49	0.51	0.20	0.17	0.00	0.40	0.06
WAC	-0.33	-0.43	-0.48	-0.43	-0.44	-0.19	0.48	0.42
Gelatinisation onset temp.	-0.96	0.42	0.32	-0.92	-0.94	0.77	0.91	0.99
Maximum viscosity	0.91	-0.33	-0.23	0.97	0.98	-0.77	-0.87	-1.00

Appendix C2: Correlation Coefficients for *Artocarpus altilis* contd.

	K ratio	LGC	Mg	Na	OAC	P	Pasting temp.	Solubility	Swelling power
K ratio	1.00								
LGC	-0.26	1.00							
Mg	-0.26	0.38	1.00						
Na	1.00	-0.26	-0.24	1.00					
OAC	-0.89	0.52	0.11	-0.89	1.00				
P	1.00	-0.26	-0.24	1.00	-0.89	1.00			
Pasting temp.	0.99	-0.40	-0.24	0.99	-0.95	0.99	1.00		
Solubility	0.73	-0.42	-0.68	0.72	-0.55	0.72	0.72	1.00	
Swelling power	-0.93	-0.08	0.20	-0.93	0.69	-0.93	-0.86	-0.64	1.00
Setback	-1.00	0.25	0.19	-1.00	0.89	-1.00	-0.98	-0.68	0.93
Stability of cold paste	-0.87	-0.11	0.21	-0.87	0.57	-0.87	-0.79	-0.66	0.97
Stability of hot paste	-0.77	-0.22	0.37	-0.76	0.39	-0.76	-0.66	-0.71	0.91
Start of cooling	-0.99	0.17	0.26	-0.99	0.84	-0.99	-0.96	-0.74	0.96
Start of holding	-0.98	0.13	0.28	-0.98	0.80	-0.98	-0.94	-0.75	0.98
TTPV	0.06	-0.70	0.10	0.07	-0.50	0.07	0.21	-0.13	0.26
WAC	0.42	0.16	-0.59	0.41	-0.27	0.41	0.35	0.50	-0.46
Gelatinisation onset temp.	0.99	-0.34	-0.21	0.99	-0.94	0.99	1.00	0.69	-0.89
Maximum viscosity	-1.00	0.24	0.24	-1.00	0.89	-1.00	-0.98	-0.73	0.94

Appendix C2: Correlation Coefficients for *Artocarpus altilis* contd.

	Setback	Stability of cold paste	Stability of hot paste	Start of cooling	Start of holding	TTPV	WAC	Gelatinisation onset temp	Peak viscosity
Setback	1.00								
Stability of cold paste	0.88	1.00							
Stability of hot paste	0.75	0.96	1.00						
Start of cooling	0.99	0.92	0.83	1.00					
Start of holding	0.98	0.94	0.87	1.00	1.00				
TTPV	-0.06	0.43	0.59	0.05	0.12	1.00			
WAC	-0.35	-0.34	-0.50	-0.44	-0.46	-0.10	1.00		
Gelatinisation onset temp.	-0.99	-0.80	-0.67	-0.97	-0.95	0.19	0.38	1.00	
Peakviscosity	-0.99	-0.80	-0.67	-0.97	-0.95	0.19	0.38	1.00	1.00

Appendix C3 CorrelationCoefficient between aroma and colour of condiment

Correlations (Pearson)

	Aroma
Colour	0.6382
P-VALUE	0.0000

APPENDIX D REGRESSION TABLES OF PREDICTIVE MODELS FOR DIGESTIBILITY COEFFICIENTS

APPENDIX D 1 Effect of chemical constituents on Digestible Dry Matter (DDM) for breadfruit flours

DDM

D 1.1 Artocarpus camansi

D 1.1.1 Lignin

Unweighted Least Squares Linear Regression of DDM

Predictor Variables	Coefficient	Std Error	T	P
Constant	82.0000	0.22582	363.45	0.0018
LIGNIN	-0.75865	0.04786	-15.85	0.0401

R-Squared	0.9960	Resid. Mean Square (MSE)	0.00160
Adjusted R-Squared	0.9921	Standard Deviation	0.04004

Source	DF	SS	MS	F	P
Regression	1	0.40296	0.40296	251.28	0.0401
Residual	1	0.00160	0.00160		
Total	2	0.40456			

D 1.2 Treculia Africana

D 1.2.1 Lignin

Unweighted Least Squares Linear Regression of DDM

Predictor Variables	Coefficient	Std Error	T	P
Constant	82.0742	0.22582	363.45	0.0018
LIGNIN	-0.75865	0.04786	-15.85	0.0401

R-Squared	0.9960	Resid. Mean Square (MSE)	0.00160
Adjusted R-Squared	0.9921	Standard Deviation	0.04004

Source	DF	SS	MS	F	P
Regression	1	0.40296	0.40296	251.28	0.0401
Residual	1	0.00160	0.00160		
Total	2	0.40456			

APPENDIX D 2 Effect of chemical constituents on Dry Matter Intake (DMI) for breadfruit flours

D 2.1 Artocarpus altilis

D 2.1.1 Acid detergent fiber

Unweighted Least Squares Linear Regression of DMI

Predictor Variables	Coefficient	Std Error	T	P
Constant	3.59381	0.01568	229.20	0.0028
ADF	-0.05784	9.572E-04	-60.43	0.0105

R-Squared	0.9997	Resid. Mean Square (MSE)	4.276E-06
Adjusted R-Squared	0.9995	Standard Deviation	0.00207

Source	DF	SS	MS	F	P
Regression	1	0.01561	0.01561	3651.70	0.0105
Residual	1	4.276E-06	4.276E-06		
Total	2	0.01562			

D 2.1.2 Cel solubles

Unweighted Least Squares Linear Regression of DMI

Predictor Variables	Coefficient	Std Error	T	P
Constant	-0.51303	0.05234	-9.80	0.0647
Cell solubles	0.05784	9.572E-04	60.43	0.0105

R-Squared	0.9997	Resid. Mean Square (MSE)	4.276E-06
Adjusted R-Squared	0.9995	Standard Deviation	0.00207

Source	DF	SS	MS	F	P
Regression	1	0.01561	0.01561	3651.70	0.0105
Residual	1	4.276E-06	4.276E-06		
Total	2	0.01562			

D 2.2. Artocarpus camansi

D 2.2.1 Cel solubles

Unweighted Least Squares Linear Regression of DMI

Predictor Variables	Coefficient	Std Error	T	P
Constant	-0.27522	0.04310	-6.39	0.0989
Cellsolubles	0.05340	8.233E-04	64.86	0.0098

R-Squared	0.9998	Resid. Mean Square (MSE)	3.163E-06
Adjusted R-Squared	0.9995	Standard Deviation	0.00178

Source	DF	SS	MS	F	P
Regression	1	0.01331	0.01331	4206.26	0.0098
Residual	1	3.163E-06	3.163E-06		
Total	2	0.01331			

D 2.2.2 Neutral detergent fiber

Unweighted Least Squares Linear Regression of DMI

Predictor Variables	Coefficient	Std Error	T	P
Constant	5.06449	0.03926	129.00	0.0049
NDF	-0.05340	8.233E-04	-64.86	0.0098

R-Squared	0.9998	Resid. Mean Square (MSE)	3.163E-06
Adjusted R-Squared	0.9995	Standard Deviation	0.00178

Source	DF	SS	MS	F	P
Regression	1	0.01331	0.01331	4206.26	0.0098
Residual	1	3.163E-06	3.163E-06		
Total	2	0.01331			

D 2.3 Artocarpus heterophyllus

D 2.3.1 Lignin

Unweighted Least Squares Linear Regression of DDM

Predictor Variables	Coefficient	Std Error	T	P
Constant	83.0952	0.20478	405.78	0.0016
LIGNIN	-1.51421	0.05731	-26.42	0.0241

R-Squared	0.9986	Resid. Mean Square (MSE)	0.00231
Adjusted R-Squared	0.9971	Standard Deviation	0.04811

Source	DF	SS	MS	F	P
Regression	1	1.61593	1.61593	698.18	0.0241
Residual	1	0.00231	0.00231		
Total	2	1.61824			

D 2.3.2 Carbohydrate

Unweighted Least Squares Linear Regression of DMI

Predictor Variables	Coefficient	Std Error	T	P
Constant	-1.74009	0.20839	-8.35	0.0759
Carbohydr	0.05465	0.00297	18.40	0.0346

R-Squared	0.9971	Resid. Mean Square (MSE)	1.072E-05
Adjusted R-Squared	0.9941	Standard Deviation	0.00327

Source	DF	SS	MS	F	P
Regression	1	0.00363	0.00363	338.46	0.0346
Residual	1	0.00001	0.00001		
Total	2	0.00364			

APPENDIX D 3 Effect of chemical constituents on Net Energy of Lactation for breadfruit flours

D 3.1 *Artocarpus heterophyllus*

D 3.1.1 Carbohydrate

Unweighted Least Squares Linear Regression of NE

Predictor Variables	Coefficient	Std Error	T	P
Constant	-0.40861	0.06938	-5.89	0.1071
Carbohydr	0.01819	9.889E-04	18.40	0.0346

R-Squared	0.9971	Resid. Mean Square (MSE)	1.188E-06
Adjusted R-Squared	0.9941	Standard Deviation	0.00109

Source	DF	SS	MS	F	P
Regression	1	4.023E-04	4.023E-04	338.46	0.0346
Residual	1	1.188E-06	1.188E-06		
Total	2	4.034E-04			

D 3.1.2 Lignin

Unweighted Least Squares Linear Regression of NE

Predictor Variables	Coefficient	Std Error	T	P
Constant	0.95234	0.00323	294.54	0.0022
LIGNIN	-0.02391	9.048E-04	-26.42	0.0241

R-Squared	0.9986	Resid. Mean Square (MSE)	5.770E-07
Adjusted R-Squared	0.9971	Standard Deviation	7.596E-04

Source	DF	SS	MS	F	P
Regression	1	4.029E-04	4.029E-04	698.18	0.0241
Residual	1	5.770E-07	5.770E-07		
Total	2	4.034E-04			

D 3.2 Treculia africana

D 3.2.1 Lignin

Unweighted Least Squares Linear Regression of NE

Predictor Variables	**Coefficient**	**Std Error**	**T**	**P**
Constant	0.93622	0.00357	262.57	0.0024
LIGNIN	-0.01198	7.557E-04	-15.85	0.0401

R-Squared	0.9960	Resid. Mean Square (MSE)	3.998E-07
Adjusted R-Squared	0.9921	Standard Deviation	6.323E-04

Source	**DF**	**SS**	**MS**	**F**	**P**
Regression	1	1.004E-04	1.004E-04	251.28	0.0401
Residual	1	3.998E-07	3.998E-07		
Total	2	1.008E-04			

APPENDIX D 4 Effect of chemical constituents on Relative Feed Value (RFV) for breadfruit flours

D 4.1 Artocarpus heterophyllus

D 4.1.1 Carbohydrate

Unweighted Least Squares Linear Regression of RFV

Predictor Variables	Coefficient	Std Error	T	P
Constant	-237.567	19.7726	-12.01	0.0529
Carbohydr	5.18502	0.28184	18.40	0.0346

R-Squared	0.9971	Resid. Mean Square (MSE)	0.09653
Adjusted R-Squared	0.9941	Standard Deviation	0.31070

Source	DF	SS	MS	F	P
Regression	1	32.6723	32.6723	338.46	0.0346
Residual	1	0.0965	0.0965		
Total	2	32.7689			

Appendix D5: Regression Analysis for Sensory Evaluation

Breakfast Meal

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P
Constant	2.29792	0.06383	36.00	0.0000
aroma	0.12083	0.03849	3.14	0.0018

R-Squared	0.0268	Resid. Mean Square (MSE)	0.26666
Adjusted R-Squared	0.0241	Standard Deviation	0.51639

Source	DF	SS	MS	F	P
Regression	1	2.6281	2.62812	9.86	0.0018
Residual	358	95.4656	0.26666		
Total	359	98.0938			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P
Constant	1.74187	0.06079	28.65	0.0000
colour	0.27477	0.02102	13.07	0.0000

R-Squared	0.3232	Resid. Mean Square (MSE)	0.18545
Adjusted R-Squared	0.3213	Standard Deviation	0.43064

Source	DF	SS	MS	F	P
Regression	1	31.7013	31.7013	170.94	0.0000
Residual	358	66.3924	0.1855		
Total	359	98.0938			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P
Constant	1.24145	0.06863	18.09	0.0000
mouthfeel	0.39292	0.02088	18.82	0.0000

R-Squared	0.4972	Resid. Mean Square (MSE)	0.13777
Adjusted R-Squared	0.4958	Standard Deviation	0.37117

Source	DF	SS	MS	F	P
Regression	1	48.7718	48.7718	354.01	0.0000
Residual	358	49.3219	0.1378		
Total	359	98.0938			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P
Constant	1.44485	0.05430	26.61	0.0000
taste	0.40038	0.01972	20.30	0.0000

R-Squared	0.5352	Resid. Mean Square (MSE)	0.12736
Adjusted R-Squared	0.5339	Standard Deviation	0.35687

Source	DF	SS	MS	F	P
Regression	1	52.5000	52.5000	412.23	0.0000
Residual	358	45.5937	0.1274		
Total	359	98.0938			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P	VIF
Constant	0.91993	0.05571	16.51	0.0000	
taste	0.28391	0.01745	16.27	0.0000	1.3
mouthfeel	0.26216	0.01777	14.75	0.0000	1.3

R-Squared	0.7112	Resid. Mean Square (MSE)	0.07934
Adjusted R-Squared	0.7096	Standard Deviation	0.28168

Source	DF	SS	MS	F	P
Regression	2	69.7683	34.8841	439.66	0.0000
Residual	357	28.3255	0.0793		
Total	359	98.0938			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P	VIF
Constant	0.76468	0.04257	17.96	0.0000	
taste	0.39034	0.01190	32.79	0.0000	1.0
colour	0.26315	0.01051	25.03	0.0000	1.0

R-Squared	0.8313	Resid. Mean Square (MSE)	0.04636
Adjusted R-Squared	0.8303	Standard Deviation	0.21531

Source	DF	SS	MS	F	P
Regression	2	81.5437	40.7719	879.49	0.0000
Residual	357	16.5500	0.0464		
Total	359	98.0938			

Stepwise Linear Regression of overall
Resulting Stepwise Model

Variable	Coefficient	Std Error	T	P	VIF
Constant	0.50714	0.03498	14.50	0.0000	
colour	0.22346	0.00814	27.46	0.0000	1.1
mouthfeel	0.17985	0.01051	17.11	0.0000	1.4
taste	0.31195	0.00995	31.35	0.0000	1.3

Cases Included	360	R Squared	0.9074	MSE	0.02552
Missing Cases	0	Adjusted R Sq	0.9066	SD	0.15973

Stepwise Linear Regression of overall
Resulting Stepwise Model

Variable	Coefficient	Std Error	T	P	VIF
Constant	4.441E-16	1.860E-09	0.00	1.0000	
colour	0.25000	3.482E-107	18000828.30	0.0000	1.1
mouthfeel	0.25000	4.702E-105	31695240.85	0.0000	1.5
taste	0.25000	4.418E-105	65905415.41	0.0000	1.4
aroma	0.25000	5.587E-104	47487577.37	0.0000	1.2

Cases Included	360	R Squared	1.0000	MSE	4.536E-17
Missing Cases	0	Adjusted R Sq	1.0000	SD	6.735E-09

SHORT CAKE

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P
Constant	0.77916	0.05214	14.94	0.0000
colour	0.70617	0.01778	39.72	0.0000

R-Squared	0.8150	Resid. Mean Square (MSE)	0.22900
Adjusted R-Squared	0.8145	Standard Deviation	0.47854

Source	DF	SS	MS	F	P
Regression	1	361.242	361.242	1577.45	0.0000
Residual	358	81.983	0.229		
Total	359	443.225			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P
Constant	0.39456	0.07044	5.60	0.0000
mouthfeel	0.75762	0.02222	34.10	0.0000

R-Squared	0.7646	Resid. Mean Square (MSE)	0.29145
Adjusted R-Squared	0.7639	Standard Deviation	0.53987

Source	DF	SS	MS	F	P
Regression	1	338.884	338.884	1162.73	0.0000
Residual	358	104.341	0.291		
Total	359	443.225			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P
Constant	0.70335	0.06950	10.12	0.0000
aroma	0.73096	0.02407	30.36	0.0000

R-Squared	0.7203	Resid. Mean Square (MSE)	0.34631
Adjusted R-Squared	0.7195	Standard Deviation	0.58848

Source	DF	SS	MS	F	P
Regression	1	319.248	319.248	921.87	0.0000
Residual	358	123.977	0.346		
Total	359	443.225			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P
Constant	0.74723	0.07501	9.96	0.0000
taste	0.79616	0.02902	27.44	0.0000

R-Squared	0.6777	Resid. Mean Square (MSE)	0.39898
Adjusted R-Squared	0.6768	Standard Deviation	0.63165

Source	DF	SS	MS	F	P
Regression	1	300.391	300.391	752.90	0.0000
Residual	358	142.834	0.399		
Total	359	443.225			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P	VIF
Constant	0.40720	0.04176	9.75	0.0000	
colour	0.49811	0.01669	29.85	0.0000	1.8
taste	0.39107	0.02063	18.95	0.0000	1.8

R-Squared	0.9078	Resid. Mean Square (MSE)	0.11447
Adjusted R-Squared	0.9073	Standard Deviation	0.33833

Source	DF	SS	MS	F	P
Regression	2	402.359	201.180	1757.50	0.0000
Residual	357	40.866	0.114		
Total	359	443.225			

Unweighted Least Squares Linear Regression of overall
Predictor

Variables	Coefficient	Std Error	T	P	VIF
Constant	0.09474	0.04659	2.03	0.0427	
aroma	0.42117	0.01828	23.03	0.0000	1.7
mouthfeel	0.48583	0.01839	26.41	0.0000	1.7

R-Squared	0.9053	Resid. Mean Square (MSE)	0.11756
Adjusted R-Squared	0.9048	Standard Deviation	0.34286

Source	DF	SS	MS	F	P
Regression	2	401.258	200.629	1706.68	0.0000
Residual	357	41.967	0.118		
Total	359	443.225			

Unweighted Least Squares Linear Regression of overall

Variables	Coefficient	Std Error	T	P	VIF
Constant	0.29416	0.04254	6.92	0.0000	
colour	0.44301	0.01760	25.17	0.0000	2.1
mouthfeel	0.40015	0.01950	20.52	0.0000	2.1

R-Squared	0.9151	Resid. Mean Square (MSE)	0.10536
Adjusted R-Squared	0.9147	Standard Deviation	0.32460

Source	DF	SS	MS	F	P
Regression	2	405.610	202.805	1924.82	0.0000
Residual	357	37.615	0.105		
Total	359	443.225			

Unweighted Least Squares Linear Regression of overall
Predictor

Variables	Coefficient	Std Error	T	P	VIF
Constant	0.42976	0.04128	10.41	0.0000	
colour	0.47347	0.01761	26.89	0.0000	2.0
aroma	0.36645	0.01939	18.90	0.0000	2.0

R-Squared	0.9076	Resid. Mean Square (MSE)	0.11477
Adjusted R-Squared	0.9070	Standard Deviation	0.33878

Source	DF	SS	MS	F	P
Regression	2	402.251	201.126	1752.39	0.0000
Residual	357	40.974	0.115		
Total	359	443.225			

Stepwise Linear Regression of overall
Resulting Stepwise Model

Variable	Coefficient	Std Error	T	P	VIF

Constant	-1.651E-15	2.487E-09	-0.00	1.0000	
colour	0.25000	1.119E-09	223412366.38	0.0000	2.9
mouthfeel	0.25000	1.157E-09	215925269.97	0.0000	2.5
taste	0.25000	1.160E-09	215342107.36	0.0000	2.0
aroma	0.25000	1.070E-09	233448187.50	0.0000	2.2

Cases Included	360	R Squared	1.0000	MSE	3.176E-16
Missing Cases	0	Adjusted R Sq	1.0000	SD	1.782E-08

TATALE

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P
Constant	1.07260	0.04176	25.68	0.0000
colour	0.53315	0.01803	29.57	0.0000

R-Squared	0.7095	Resid. Mean Square (MSE)	0.12009
Adjusted R-Squared	0.7087	Standard Deviation	0.34655

Source	DF	SS	MS	F	P
Regression	1	105.031	105.031	874.57	0.0000
Residual	358	42.994	0.120		
Total	359	148.025			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P
Constant	0.89573	0.09928	9.02	0.0000
mouthfeel	0.55183	0.04087	13.50	0.0000

R-Squared	0.3374	Resid. Mean Square (MSE)	0.27398
Adjusted R-Squared	0.3355	Standard Deviation	0.52343

Source	DF	SS	MS	F	P
Regression	1	49.941	49.9405	182.28	0.0000
Residual	358	98.084	0.2740		
Total	359	148.025			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P
Constant	1.00798	0.04415	22.83	0.0000
aroma	0.51854	0.01771	29.29	0.0000

R-Squared	0.7055	Resid. Mean Square (MSE)	0.12176
Adjusted R-Squared	0.7047	Standard Deviation	0.34895

Source	DF	SS	MS	F	P
Regression	1	104.433	104.433	857.67	0.0000
Residual	358	43.592	0.122		
Total	359	148.025			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P
Constant	0.96115	0.08085	11.89	0.0000
taste	0.59619	0.03736	15.96	0.0000

R-Squared	0.4156	Resid. Mean Square (MSE)	0.24162
Adjusted R-Squared	0.4140	Standard Deviation	0.49154

Source	DF	SS	MS	F	P
Regression	1	61.527	61.5265	254.65	0.0000
Residual	358	86.498	0.2416		
Total	359	148.025			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P	VIF
Constant	0.81288	0.03345	24.30	0.0000	
aroma	0.30912	0.01709	18.09	0.0000	1.8
colour	0.32150	0.01752	18.35	0.0000	1.8

R-Squared	0.8484	Resid. Mean Square (MSE)	0.06284
Adjusted R-Squared	0.8476	Standard Deviation	0.25068

Source	DF	SS	MS	F	P
Regression	2	125.591	62.7956	999.30	0.0000
Residual	357	22.434	0.0628		
Total	359	148.025			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P	VIF
Constant	0.48338	0.04274	11.31	0.0000	
taste	0.37580	0.01975	19.03	0.0000	1.1
colour	0.44620	0.01352	33.01	0.0000	1.1

R-Squared	0.8558	Resid. Mean Square (MSE)	0.05978
Adjusted R-Squared	0.8550	Standard Deviation	0.24450

Source	DF	SS	MS	F	P
Regression	2	126.683	63.3414	1059.54	0.0000
Residual	357	21.342	0.0598		

Total	359	148.025

Stepwise Linear Regression of overall
Resulting Stepwise Model

Variable	Coefficient	Std Error	T	P	VIF
Constant	-1.176E-15	2.088E-09	-0.00	1.0000	
colour	0.25000	6.831E-10365986930.82		0.0000	1.9
mouthfeel	0.25000	8.091E-10308974147.06		0.0000	1.2
taste	0.25000	8.120E-10307881165.10		0.0000	1.3
aroma	0.25000	6.669E-10374893506.59		0.0000	1.9

Cases Included	360	R Squared	1.0000	MSE	9.065E-17
Missing Cases	0	Adjusted R Sq	1.0000	SD	9.521E-09

KOOSE

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P
Constant	0.37351	0.07188	5.20	0.0000
colour	0.66964	0.02024	33.09	0.0000

R-Squared	0.7536	Resid. Mean Square (MSE)	0.25457
Adjusted R-Squared	0.7529	Standard Deviation	0.50455

Source	DF	SS	MS	F	P
Regression	1	278.739	278.739	1094.94	0.0000
Residual	358	91.136	0.255		
Total	359	369.875			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P
Constant	0.39456	0.07044	5.60	0.0000
mouthfeel	0.75762	0.02222	34.10	0.0000

R-Squared	0.7646	Resid. Mean Square (MSE)	0.29145
Adjusted R-Squared	0.7639	Standard Deviation	0.53987

Source	DF	SS	MS	F	P
Regression	1	338.884	338.884	1162.73	0.0000
Residual	358	104.341	0.291		
Total	359	443.225			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P

Constant	0.65205	0.05803	11.24	0.0000
aroma	0.69387	0.01889	36.73	0.0000

R-Squared	0.7903	Resid. Mean Square (MSE)	0.21671
Adjusted R-Squared	0.7897	Standard Deviation	0.46552

Source	DF	SS	MS	F	P
Regression	1	292.294	292.294	1348.80	0.0000
Residual	358	77.581	0.217		
Total	359	369.875			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P
Constant	0.89447	0.06486	13.79	0.0000
taste	0.76766	0.02633	29.15	0.0000

R-Squared	0.7036	Resid. Mean Square (MSE)	0.30625
Adjusted R-Squared	0.7028	Standard Deviation	0.55340

Source	DF	SS	MS	F	P
Regression	1	260.238	260.238	849.76	0.0000
Residual	358	109.637	0.306		
Total	359	369.875			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P	VIF
Constant	0.19700	0.04772	4.13	0.0000	
aroma	0.42692	0.01950	21.89	0.0000	2.1
colour	0.36305	0.01928	18.83	0.0000	2.1

R-Squared	0.8948	Resid. Mean Square (MSE)	0.10900
Adjusted R-Squared	0.8942	Standard Deviation	0.33016

Source	DF	SS	MS	F	P
Regression	2	330.961	165.480	1518.11	0.0000
Residual	357	38.914	0.109		
Total	359	369.875			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P	VIF
Constant	0.34173	0.04114	8.31	0.0000	
aroma	0.45733	0.01672	27.35	0.0000	1.8
mouthfeel	0.47253	0.02212	21.37	0.0000	1.8

R-Squared	0.9080	Resid. Mean Square (MSE)	0.09537
Adjusted R-Squared	0.9074	Standard Deviation	0.30881

Source	DF	SS	MS	F	P
Regression	2	335.829	167.915	1760.74	0.0000
Residual	357	34.046	0.095		
Total	359	369.875			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P	VIF
Constant	0.09720	0.04490	2.16	0.0311	
mouthfeel	0.51765	0.02078	24.91	0.0000	1.6
colour	0.43180	0.01553	27.80	0.0000	1.6

R-Squared	0.9100	Resid. Mean Square (MSE)	0.09325
Adjusted R-Squared	0.9095	Standard Deviation	0.30536

Source	DF	SS	MS	F	P
Regression	2	336.587	168.293	1804.85	0.0000
Residual	357	33.288	0.093		
Total	359	369.875			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P	VIF
Constant	0.12371	0.04342	2.85	0.0046	
colour	0.44078	0.01482	29.74	0.0000	1.5
taste	0.45684	0.01759	25.98	0.0000	1.5

R-Squared	0.9148	Resid. Mean Square (MSE)	0.08832
Adjusted R-Squared	0.9143	Standard Deviation	0.29719

Source	DF	SS	MS	F	P
Regression	2	338.344	169.172	1915.41	0.0000
Residual	357	31.531	0.088		
Total	359	369.875			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P	VIF
Constant	0.54036	0.05322	10.15	0.0000	
taste	0.44193	0.02786	15.86	0.0000	2.0

mouthfeel	0.52230	0.03142	16.62	0.0000	2.0

R-Squared	0.8329	Resid. Mean Square (MSE)	0.17311
Adjusted R-Squared	0.8320	Standard Deviation	0.41607

Source	DF	SS	MS	F	P
Regression	2	308.073	154.037	889.80	0.0000
Residual	357	61.802	0.173		
Total	359	369.875			

Stepwise Linear Regression of overall
Resulting Stepwise Model

Variable	Coefficient	Std Error	T	P	VIF
Constant	-1.414E-15	2.372E-09	-0.00	1.0000	
colour	0.25000	9.798E-10	255146609.37	0.0000	2.3
mouthfeel	0.25000	1.334E-09	187384709.02	0.0000	2.4
taste	0.25000	1.142E-09	218795180.99	0.0000	2.2
aroma	0.25000	1.051E-09	237675371.73	0.0000	2.6

Cases Included	360	R Squared	1.0000	MSE	2.568E-16
Missing Cases	0	Adjusted R Sq	1.0000	SD	1.602E-08

CONDIMENT

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P
Constant	0.39493	0.05231	7.55	0.0000
aroma	0.77899	0.02523	30.88	0.0000

R-Squared 0.8427 Resid. Mean Square (MSE) 0.07905
Adjusted R-Squared 0.8418 Standard Deviation 0.28116

Source	DF	SS	MS	F	P
Regression	1	75.3668	75.3668	953.42	0.0000
Residual	178	14.0707	0.0790		
Total	179	89.4375			

Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P
Constant	0.27488	0.06559	4.19	0.0000
colour	0.86493	0.03300	26.21	0.0000

R-Squared 0.7942 Resid. Mean Square (MSE) 0.10340
Adjusted R-Squared 0.7931 Standard Deviation 0.32156

Source	DF	SS	MS	F	P
Regression	1	71.0323	71.0323	686.97	0.0000
Residual	178	18.4052	0.1034		
Total	179	89.4375			

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Unweighted Least Squares Linear Regression of overall

Predictor Variables	Coefficient	Std Error	T	P
Constant	0.76408	0.08101	9.43	0.0000
aroma	0.67430	0.03321	20.30	0.0000

R-Squared 0.6339 Resid. Mean Square (MSE) 0.23496
Adjusted R-Squared 0.6324 Standard Deviation 0.48472

Source	DF	SS	MS	F	P
Regression	1	96.846	96.8457	412.18	0.0000
Residual	238	55.920	0.2350		
Total	239	152.766			

APPENDIX E: PAPERS PUBLISHED IN REFEREED JOURNALS FROM THE STUDY

APPENDIX E1

Appiah, F., Oduro, I. and Ellis, W. O. (2011). Pasting properties of *Treculia africana* seed flour in Ghana and the production of a breakfast meal. *Agriculture and Biology Journal of North America* 2 (2): 325-329

APPENDIX E2

Appiah, F., Oduro, I., and Ellis, W. O. (2011). Proximate and Mineral composition of *Artocarpus altilis* pulp flour as affected by fermentation. *Pakistan Journal of Nutrition* 10 (7): 653-657

APPENDIX E3

Appiah, F., Oduro, I., and Ellis, W. O. (2011). Functional properties of *Artocarpus altilis* pulp flour as affected by fermentation. *Agriculture and Biology Journal of North America.* 2(5): 773-779