VALORIZATION STRATEGIES OF COCONUT FLOUR

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UGent, August 2018

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ABSTRACT

The processing of coconuts into coconut milk and coconut oil has been the major area of focus within the coconut industry. During the production process, a by-product called coconut residue is obtained. In many cases, it is usually thrown away or used as a feed for livestock. However, the processes of drying and grounding of the residue into flour enhance its potential application in food formulation and production. Therefore, this study aimed at investigating how coconut flour (pared and un-pared) compares to commonly used staple flours (wheat, cassava and maize flours) in terms of chemical composition and functional properties. Furthermore, it examined the physical characteristics and sensorial attributes of chapatti (unleavened flat bread) made by incorporating coconut flour (pared and un-pared) into wheat flour at different levels of substitution (10 % and 20 %).

The chemical composition showed that pared coconut flour had a protein content of 6.3 % while un-pared coconut flour contained 8.3 %. The staples flours; wheat, cassava and maize flours, showed protein content of 10.6 %, 1.4 % and 7.8 %, respectively. Similarly, fibre content was recorded to be significantly higher in pared coconut flour (16.7 %) which was followed by un-pared coconut flour (15.6 %), maize flour (7.7 %), cassava flour (4.8 %) and wheat flour (2.8 %). Furthermore, the coconut flours had significantly higher fat content than any of the staple flours.

Generally, the study revealed that coconut flour (pare and un-pared) possessed poor pasting properties. On the other hand, the hydration properties and oil absorption capacity indicated prospect of the possibilities of applying coconut flour in food systems. Sensorial evaluation of chapatti made from composite wheat-coconut flours with level of substitutions (10 % and 20 %) of pared and un-pared coconut flours in the composite mix remarkably revealed that in terms of overall acceptability, there was no significant difference between all the coconut flour incorporated chapatti and the reference chapatti (100 % wheat flour).

Keywords: Coconut flour, functional properties, food application, chapatti.
CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

Coconut (*Cocos nucifera*) belongs to the family of palm *Arecaceae*. It is the most important plant within the family because it has application both as an ornamental crop and as a food crop (Fife *et al.*, 2011). All the plant parts have been found to have useful purposes in human’s life such as in foods, house construction materials and in the making of house hold items such as baskets and hand fans *etc.* (Igbabul *et al.*, 2014). The plant has been estimated to have an economic lifespan of about fifty years. However, some of the varieties can live for over a century (Danyo, 2011).

More than 70% of the world production directly or indirectly contributes to the nutrition of local house-holds, while the other remaining amount is only used in industrial applications (Peiris *et al.*, 2000). Coconut consumption can come in different ways. For instance, in India, coconut is consumed in the form of the raw kernels, tender nuts, coconut oil, copra (the dried flesh of the nut) and desiccated coconuts (Dhankhar, 2013; Hareya *et al.*, 2000), while in Nigeria, coconut milk is an ingredient to make coconut rice. It is important to note that meals which are made from coconut meat or kernel can be high in fat, fibre and other nutrients, therefore it may help in reducing the nutrient deficiencies that are associated with staple foods that contain predominantly starch which are consumed in many developing countries. Asides from being a source of food, it helps create job opportunities for those living along coastal region (Danyo, 2011).

Coconut fruit is an important source of vegetable oil which has application both industrially; in the production of soaps and paints *etc.*, and for edible purposes (Yalegama and Chavan, 2006). The oil has received special attention, particularly among the Asian and Pacific populations compared to other vegetable oils because of the special healing properties that has been attributed to it (Dhankhar, 2013). According to Arora *et al.* (2011), the oil was reported to be effective against a number of viruses which are lipid-coated such as visna virus, influenza virus, leukemia virus, pneumonia virus, and hepatitis C virus. What was identified to be responsible is the medium chain fatty acids such as lauric acid that is found in coconut oil which helps to inactive these organisms. During coconut oil production a by-product called coconut residue is obtained. This residue can be processed into coconut flour (Sujirtha and Mahendran, 2015).
1. 2 PROBLEM STATEMENT

For many decades, the coconut oil industry had been the most vibrant as many processors of the coconut fruit focus on the oil production. In fact, a number of studies that have been done are tailored towards the nutritional, health benefits and the applications of coconut oil (Muller et al., 2003; Agero and Verallo, 2004; Debmandal and Mandal, 2011). However, the leftover residue obtained during the coconut oil production procedure can be used in the making of coconut flour (Yalegama and Chavan, 2006). This gluten-free flour has recently become increasingly important in the bakery industries where it is used in partial substitution to wheat in order to produce baked snacks such as cookies (Dhankhar, 2013). This idea can be extended to other wheat based foods. There is also the possibility of combining coconut flour with other flour types like corn flour and cassava flour which are lacking in some essential nutrients to produce gluten-free products which are important for patients that are gluten intolerant (Gallagher et al., 2004; Daniela, 2016). Furthermore, it has been reported that coconut flour possesses important nutritional constituents such as fiber and proteins which are necessary in the formulation of healthy foods (Gunathilake et al., 2009). Yet, little attention has been given to the incorporation of coconut flour into commonly consumed foods like baked snacks and porridges.

Although, some studies have been done concerning the application of coconut flour as composite flour in baking industries (Sujirtha and Mahendran, 2015; Gunathilake et al., 2009), still there is dearth in knowledge as regards its overall functionality and possible potentials in other food systems.

1.3 JUSTIFICATION:

There is a necessity to continuously find ways of converting industrial by-products into functional ingredients, including coconut flour made from coconut milk residue (Ramaswamy, 2014). This may further contribute to sustainability and improved food security within the households. As mentioned above, coconut residue is a by-product of coconut oil production and it is majorly fed to livestock or used as livestock ingredient. Many of the previous studies being carried out on coconuts had focused primarily on coconut oil. Therefore, it is important to investigate the functional properties of this coconut flour and compare it with already known staple flours which have received greater attention in the food industries. This will enable us to further understand its potential applications in other food systems. Through this, the research will provide additional
information to farmers, researchers, food developers and those involved in the processing of coconuts, helping them to maximize its full potential.

1.4 OBJECTIVES

This research is aimed at studying the functional properties of coconut flour and understanding the potential applicability of the flour in food systems.

The first specific task was to compare the nutritional composition and functional properties of coconut flour with commonly used staple flours such as wheat flour, cassava flour and corn flour that have received greater attention in the food industries. In addition, to investigate if there are differences in the nutritional and functional properties of the pared and un-pared coconut flour. Furthermore, to develop a food product and investigate the effects of different levels of coconut flour incorporation in composite ratio with a staple flour.
CHAPTER 2
LITERATURE REVIEW

2.1 COCONUT

The coconut palm which is botanically called *Cocos nucifera* only grow in sandy soil which may not suitable for other cash crops (Danyo, 2011). It is difficult to grow coconut palm in dry climates, except with the use of proper irrigation, else the entire plant including the leaves and the fruit will not grow well (Foale 2003). The coconut plant grows up to about 30 meters tall with pinnate leaves of about 4-6 meters long. The old leaves easily break off leaving the trunk of the plant looking smooth (Fife *et al*., 2001). The coconut palm begins it fruiting about three to five years after planting. This is largely dependent on the variety of coconut palm (NARI, 2003).

Cocos palms are located across the humid intertropical zone (Srivastava, 2011). It is believed to have originated from Southeast Asia (Indonesia, Philippines and Malaysia) and the islands that lie between the Pacific and Indian oceans. It is from these regions that the plant had been introduced to India, East Africa and West Africa. From here, they were dispersed to America and other tropical regions of the world (Lima *et al*., 2015).

According to FAO STATS (2016), coconut is grown in more than 86 countries worldwide, with a total production of about 60 million tonnes yearly. The top three countries in the leading position as regards its production are Indonesia, Philippines, and India (Srivastava, 2011). India occupies the premier position in the world with an annual production of more than 13 billion nuts. In many cases, depending on its variety, 70-150 trees/hectare are planted which can produce about 5 to15 nuts per bunch and 60-100 nuts per tree if planted on a fertile soil (Fife *et al*., 2001). A coconut tree during its entire life span can produce up to 10,000 nuts (NARI, 2003; Debmandal and Mandal, 2011).

A full-sized coconut fruit (*Figure 1a*) weighs about 1.5 kg (Bourke *et al*., 2009). The fruit of the coconut palm is botanically called a drupe and not a nut. It has three main layers (*Figure 1b*): the exocarp which is the woody part that in many cases have been removed before being placed on shelf for sales, the mesocarp which is the shell that protects the inner part of the coconut which surrounds the coconut meat and water, and the endosperm which is the meat of the coconut (Fife
et al., 2001). Coconut meats or kernel and water (Figure 1b) are majorly protected by the coconut husk which helps in its post-harvest processing and stability. Mold growth which arises on the surface of the husk due to condensation of water or storage at relative humidity above 90% does not penetrate into the nut. The coconut water of an intact coconut tastes sweeter and has an increased shelf life compared to those which had been de-husked (NARI, 2003).

Figure 1 (a): Coconut fruits (useofcoconut.com) (b): Structure of coconut fruit (healthtipsinfo.com)

2.1.1 Variety and geography of coconuts

The varieties of coconut palm can be divided into two subgroups which are named “Tall” and the “Dwarf”. The tall cultivar group are called Cocos nucifera var. typical and the dwarf cultivars group: Cocos nucifera var. nana (Fife et al., 2001). The tall cultivars are high yielding and also long-lived compared to the dwarf cultivars. The tall cultivars are mature between 6-10 years after planting and can be productive till they are almost a century old, while the dwarf cultivars which yield coconut fruits with exocarp that come in green and orange colours; are short-lived, less hardy and needing specific climatic conditions for better yields (Debmandal and Mandal, 2011). The dwarf cultivar which has a worldwide cultivation represents only 5% of coconut palms and it is characterized by slow trunk growth and self-pollination (Bourdeix et al., 2001). Therefore, the tall cultivars are mostly used for planting on a commercial scale. It is important to note that the cultivars are specific to each region e.g. “Ceylon tall”, “Jamaican Tall”, “Indian Tall” and “West Africa Tall” (Fife et al., 2001).
2.2 USAGE OF THE MAJOR COMPONENTS OF COCONUT PALM

The coconut plant has valorization potentials in both food and non-food applications contributing to the economy of many communities and nations. Many smallholder farmers regard this plant as the “tree of life” because of its value chain which is an important source of income as well as nutrition (Chan et al., 2006).

2.2.1 Coconut shell

Coconut shell constitutes about 15% of de-husked coconut. The shell is a hard, fine grain substance which can be used for the production of cups and some artworks. In many coconut producing communities, these shells are left unattended to and are usually given to women who use them as a source of energy for home cooking (NARI, 2004). The shell charcoal is obtained by burning the coconut shell obtained from a fully grown coconut in an environment where there is a limited supply of oxygen. The shell is also an important raw material for obtaining active carbon for gas production, deodorization and bleaching (Fife et al., 2011). It is also used to obtain coconut shell powders by pulverizing the mature shells (Muralidharan and Jayashree, 2011). This is used as an Electromagnetic Interference absorbing material (Siti et al., 2016).

2.2.2 Coconut husk

Coconut husks act as an important material to protect the endosperm of the coconut fruit. It is composed of fibers which are tightly packed. The fibers are called coir. The fibers are 15 to 35 cm long (Muralidharan and Jayashree, 2011). When this coir is soaked in salt water, they separate and can be used in the making of different items such as ropes, rugs, mat and chairs. In other applications, the coir can be grounded to be used as soil mixes in greenhouse plants. The coir fiber has some characteristic properties which make it useful for different applications. These properties include elasticity and resistance to mechanical wear (Fife et al., 2011).

2.2.3 Coconut leaves

The leaves of coconut grow up to 6.1 meters in length. They are used for shading seedlings and covering up nursery beds. The leaves are also used in the making of rooftops and fences. The thin leaf strip can be weaved into clothing and furnishing (Fife et al., 2011). They have also been used in the feeding of elephants. Also, the dry leaves are used as a source of fuel (Gunn et al., 2011).
Many rural communities where coconut trees are cultivated utilize the leaves for the production of baskets, brooms and brushes.

2.2.4 Coconut water

Coconut water volume is dependent on the maturity of the coconut fruit (Figure 1a). It is higher in immature fruit but as the fruit matures, the coconut water is gradually absorbed into the meat and the meat solidifies more (NARI, 2003). Coconut water is found to contain numerous amounts of both macro- and micronutrients. The main macronutrients are the soluble sugars such as sucrose, glucose and fructose, proteins, water (95.5 %) and little amount of oil which makes the coconut water to have low energy value of 44 kcal/l (Thampan and Rethinam 2004).

According to Loki and Rajamohan (2003), the micro-components are majorly inorganic ions such as K (290 mg %), Na (42 mg %), Ca (44 mg %), Mg (10 mg %), P (9.2 mg %). Fife et al. (2011) reported that coconut water contains vitamin C which could vary from 20-40 mg/l which helps in reducing the rate of oxidation but at a limited rate due to the small quantity. Coconut water also contains vitamins from group B, including nicotinic acids, pantothenic acids, biotin, riboflavin, folic acid, trace amount of thiamine and pyridoxine. Furthermore, the water is said to have some amino acids such as alanine, cysteine and serine (Fife et al., 2011).

Coconut water might be applicable for rehydration due to its electrolytes content such as potassium and sodium. It also has application as a growth medium for certain microorganisms such as Acetobacter xylinum, as medicine in the management of certain diseases such as high blood pressure, and as a biocatalyst which helps in the synthesis of proteins (Prades et al. (2012); NARI, 2003).

2.2.5 Coconut kernel or meat

The coconut kernel is often the most commercially processed component of the coconut plant. The whitish, firm substance found inside the coconut fruit is highly nutritious containing a substantial amount of fats and proteins (Fife et al., 2011).

Through different processing methods, various kinds of products can be obtained from the kernel. They include desiccated coconuts which are obtained through the removal of the brownish coat of the kernel. The whitish substance obtained is disintegrated and dried to a moisture content of less than 3 %. Its commercial usage in food industries has gained popularity all over the world
(Muralidharan and Jayashree, 2011). Also, a whitish liquid (coconut milk) can be obtained from the coconut kernel that has been subjected to milling followed by squeezing with or without the inclusion of water. The milk has application in the production of coconut cream and sauces (Fife et al., 2011). Furthermore, virgin coconut oil (VCO), which is a highly sought-after product in the international market can be made from the coconut kernel. It is obtained from the fresh, hard and mature coconut with or without the application of heat. The different processes used in its production must exclude the application of techniques such as bleaching, deodorizing and other forms of chemical treatments so as to keep its natural properties (Divina et al., 2016).

VCO is currently used as food supplement and has application as cosmetics. A number of physiotherapists also use it for massage. The increase in its demand may have been linked with the report of the health benefits of the medium chain triglycerides (MCT) present in the oil (Muralidharan and Jayashree, 2011). However, there are also contrary reports on the possible negative health implication of the coconut oil MCT on Total Cholesterol Levels (Laurence et al., 2013).

2.3 COCONUT FLOUR

Coconut flour is obtained by drying, expelling and/or removing the oil or milk from the mature coconut kernel or meat. The kernel can be pared (removal of the external brown coat) or unpared. The flour is usually bland in taste but is a good source dietary fibre (Hossain et al., 2016). According to Trinidad et al. (2006), coconut flour contains about 60 g dietary fiber/100 g, of which 56 percent is insoluble dietary fiber while 4 percent is soluble dietary fiber. This was found to be almost double that of wheat bran and 4 times that of oat bran (Ramaswamy, 2014). Coconut flour is different from other types of flours particularly because it does not contain phytic acid, a well-known plant anti-nutrient commonly found in grain flours that inhibit the absorption of some micronutrients such as iron (Ramaswamy, 2014).

2.3.1 Processing of coconut flour

Coconuts which are to be used for coconut flour production should be harvested when they are completely matured. This can be observed when the skin has turned mostly brown. At this state, it will also enhance maximum oil and coconut residue recovery (NARI, 2003). The production of coconut flour (Figure 2) according to Igbadul et al. (2011) showed that the coconut fruits are de-
shelled to have access to the coconut meat or kernels. The brown coat surrounding the kernel is then carefully removed using a knife. This is called paring (PCA, 2006). The pared nuts are then sliced into about 10 mm sizes and washed in water. This is followed by drying and cooling. They will further be subjected to grinding using a powerful electric grinder after which the oil extraction process is carried out using the screw press method. The residue obtained after the completion of this procedure is re-dried in oven at 60 °C for 30 min. This is then followed by milling and packaging of the flour. This produces coconut flour that is high in protein and can be used as a partial substitute for wheat in the making of baked food products (Ramaswamy, 2014).
Figure 2. Flow chart of coconut flour production (Igbadul et al., 2011)
2.3.2 Macro composition of coconut flour

Coconut flour composition varies based on the extraction methods that are applied. This can significantly affect the retention of components such as the amount of fats that will remain in the final product (Gunathilake et al., 2009). According to Philippine Coconut Authority (2006), coconut flour contains per 100 g: 12.6 % proteins, 13.0 % fibers, 9.2 % fat, 13.7 % sugars, 8.2 % ash and 4.2 % moisture. In another study, Lai Quoc and Vo Thi (2017) reported that coconut flour contains 6.1 % moisture, 1.15 % ash, 5.8 % protein, 29.8 % fat, 37.3 % carbohydrate and 19.8 % crude fiber. The macronutrient composition of coconut and other commonly used staple flours (Table 2.1) shows that coconut flour provides higher energy (429 kcal/100g) in comparison to wheat, cassava and maize flours which supplies 364 kcal/100g, 380 kcal/100g and 364 kcal/100g, respectively. This is strongly related to the high fat content of coconut flour (14.2 g/100g) as compared to low fat content of the staple flours (< 6 g/100g) (USDA, 2017). This clearly differs from 21 % fat content of coconut flour that was reported by Gunathilake et al. (2009). Furthermore, fibre content is higher in coconut flour (35.7 g/100g) compared to 2.7 g/100g, 7.5 g/100g and 8.8 g/100g in wheat, cassava and maize flours, respectively (USDA, 2017).

Table 2.1 Macro nutrients of coconut flours, wheat flour, cassava flour and maize flour (USDA, 2017)

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Coconut flour</th>
<th>Wheat flour</th>
<th>Cassava flour</th>
<th>Maize flour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kcal)</td>
<td>429</td>
<td>364</td>
<td>380</td>
<td>364</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>14.3</td>
<td>10.3</td>
<td>0</td>
<td>8.8</td>
</tr>
<tr>
<td>Total fat (g)</td>
<td>14.2</td>
<td>0.9</td>
<td>0</td>
<td>5.1</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>57.1</td>
<td>76.3</td>
<td>92.5</td>
<td>73.4</td>
</tr>
<tr>
<td>Total Dietary fibre (g)</td>
<td>35.7</td>
<td>2.7</td>
<td>7.5</td>
<td>8.4</td>
</tr>
<tr>
<td>Total sugars (g)</td>
<td>14.3</td>
<td>0.3</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>


2.3.3 Nutrient composition of coconut flour

Coconut protein component is majorly categorized into three fractions namely albumins, globulins and glutelins. It is important to know that the amino acid composition in each of these fractions differs. The amino acids composition of glutelins and globulins are quite similar but the amino acids absolute value is higher in globulins than in glutelins. Therefore, the globulin is the major fraction of coconut flour protein (Kwon, 1996). **Table 2.2** revealed the amino acid composition of coconut flour from two different studies; Kwon (1996) and Rasyid *et al.* (1992). It indicated similarities in some amino acids such as valine, seline and glutamic acid while marked differences existed in their glycine and alanine content. Rasyid *et al.* (1992) reported that coconut flour protein is comparable with that of soy flour and could play a role in food systems where the beany flavor of soy flour is unacceptable. The amino acid profile further provided an information that coconut flour has a balance in its amino acid profile and that it may be used to enrich certain flours that are limiting in their amino acid composition. For instance Shoup *et al.* (1966) provided information about of wheat flour obtained from several wheat varieties. Lysine, the limiting amino acid in wheat flour were found to be in the range of 1.7-1.9 g/100g of protein which is lower than the range of 3.1-4.7 g/100g of protein reported by the two authors in **Table 2.2**.

Interestingly, in the production of coconut flour, a substantial amount of the fat component had been removed and used in the production of oil but the flour still contains some fats which is majorly saturated fats (14.3 g/100g) but free from *trans* fats (USDA, 2017). These saturated fatty acids are mainly medium chain fatty acids such as lauric and myristic acids (Arora *et al.*, 2011). It is important to note that there are traces of unsaturated fatty acids such as oleic acid, linoleic acid and linolenic acids (Shamina, 2007).

Compared to cereals crops which can be grown on less mineralized soils, coconuts plants are commonly grown in highly rich mineralized soil which contributes to the presence of trace minerals such as iron (18 mg/100g), calcium (57 mg/100g) and sodium (200 mg/100g) (USDA, 2017). These minerals may be easily absorbable due to the absence of phytic acid which inhibits bioavailability of trace element in many kinds of cereal product (Ramaswamy, 2014).
Table 2. Amino acid composition of coconut flour (gram/100gram of protein) (Kwon, 1996; Rasyid et al., 1992)

<table>
<thead>
<tr>
<th>Amino Acids</th>
<th>Coconut flour (Kisung, 1996)</th>
<th>Coconut flour (Rasyid et al., 1992)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isoleucine</td>
<td>4.2</td>
<td>3.6</td>
</tr>
<tr>
<td>Leucine</td>
<td>7.4</td>
<td>8.1</td>
</tr>
<tr>
<td>Lysine</td>
<td>4.7</td>
<td>3.1</td>
</tr>
<tr>
<td>Methionine</td>
<td>1.8</td>
<td>1.4</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>5.1</td>
<td>3.9</td>
</tr>
<tr>
<td>Threonine</td>
<td>2.5</td>
<td>3.9</td>
</tr>
<tr>
<td>Valine</td>
<td>5.4</td>
<td>5.9</td>
</tr>
<tr>
<td>Histidine</td>
<td>1.8</td>
<td>2.6</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>1.8</td>
<td>2.2</td>
</tr>
<tr>
<td>Aspartic acid</td>
<td>9.3</td>
<td>8.5</td>
</tr>
<tr>
<td>Proline</td>
<td>3.6</td>
<td>4.5</td>
</tr>
<tr>
<td>Serine</td>
<td>5.3</td>
<td>5.9</td>
</tr>
<tr>
<td>Glutamic acid</td>
<td>22.4</td>
<td>18.2</td>
</tr>
<tr>
<td>Glycine</td>
<td>5.1</td>
<td>9.4</td>
</tr>
<tr>
<td>Alanine</td>
<td>4.8</td>
<td>6.5</td>
</tr>
<tr>
<td>Arginine</td>
<td>12.3</td>
<td>11.2</td>
</tr>
</tbody>
</table>
2.3.4 The Nutritional benefits of coconut flour

Trinidad et al. (2004) and Daniela (2016) both reported that coconut flour is gluten-free. Therefore, it may be suitable for individuals who develop allergic reaction upon the consumption of gluten-rich foods (Ramaswamy, 2014).

Coconut flour contains medium chain fatty acids which are mostly saturated but has no trans fats and cholesterol (USDA, 2017). The Fatty acid composition of the coconut oil shows that it contains 92.7 % saturated fats of which 59.7 % is MCFA while mono unsaturated fatty acids and poly unsaturated fatty acids constitutes 6.1 % and 1.2 %, respectively (Bhatnagar et al., 2009). Although, there is conflicting evidence about the nutritional relevance of these acids particularly the principal lauric acid which constitute about 50 % of the total fatty acids (Nevin and Rajamohan, 2006). However, Awasthi (2016) describes these medium chain fatty acids to be easily digestible and absorbed within the level of the small intestine. This ensures that the MCFA which are supplied, do not interfere or participate in the transportation and biosynthesis of cholesterol in the body (Debmandal and Mandal, 2011). Bhatnagar et al. (2009) further revealed that coconut oil was deficient in total tocopherols when compared with other vegetable oils such as soybean, sunflower oil etc.

Coconut flour is a low carbohydrate supplier that contains a high amount of dietary fibre compared to flours like wheat and maize flour. Dietary fibre can be described as plant materials such as cellulose, pectin, hemicellulose and polysaccharides such as gums that cannot be digested by the digestive enzymes in the human body. Based on the study of Raghavarao et al. (2008), coconut dietary fibre contained 58.7 % insoluble dietary fibre and 4.5 % soluble dietary fibre. The fibre fractions are neutral detergent fibre (81.4 %) which comprises of 44.5 % acid detergent fibre and 36.9 % hemicellulose; cellulose (16.1 %) and lignin (1.3 %) (Yalegama and Chavan, 2004). The World Health Organization recommends at least 25 g daily consumption of dietary fibre (Fuller et al., 2016). According to USDA (2017) in Table 2.1, 100 g of coconut flour supplies more than this minimum daily intake level of dietary fibre. However, Philippine Coconut Authority (2006) reported a coconut flour with dietary fibre of 13 g/100g which implies that it will require about 200 g of this flour to meet the minimum requirement. It is important to note that dietary fibre can help in regulating bodyweight (Galisteo et al., 2008). It is associated with increasing faecal bulk and decreasing the transit time of food within the intestine (Heredia et al., 2002). It can be metabolized
in the colon to produce butyrate which is an important substrate for the maintenance of colonic health (Ramaswamy, 2014). These butyrates help to enhance cell differentiation and prevent tumor formation at the level of the colon (Trinidad et al., 2006). In another study, Trinidad et al. (2004) reported that the fibrous nature of coconut flour may have been important in binding the bile acids which prevents their reabsorption at the level of the liver which eventually leads to their excretion. Furthermore, high amount of dietary fibre from coconut flour contributes to delaying the glycemic responses of the coconut flour supplemented food. This may be of particular benefit to people of high blood glucose (Ramaswamy, 2014).

2.3.5 Possible applications of coconut flour

The development and application of different flours such as wheat flour, cassava flour and coconut flour in different food applications have been well documented (Olaoye et al., 2006; Shittu et al., 2008; Chavan et al., 2009). These flours constitute a substantial amount in the diet of many around the world. The summary of some of the studies which was conducted that entail the incorporation of coconut flour in composite ratio with other commonly used flours in the food industry is presented in Table 2.3. The data shows the type of food products that coconut flour have been incorporated into and the optimum level of incorporation.

Conventionally, wheat flour has been the major ingredient used in the production of breads, cakes and cookies because of the functionality of wheat flour (Tharise et al., 2014). What makes wheat flour unique for the baking industry is its ability to retain gas during baking, which aids in the formation of an aerated foam structure. This is attributed to the gluten protein which is not present in other flours (Lazaridou et al., 2007). However, many countries have decided to shift the attention away from wheat flour in order to give value addition to other staple flour types which can be sourced locally. A typical example is cassava flour which has received attention in bread making (Shittu et al., 2007). In Nigeria, it has been mandated at National level to include at least 10 % cassava flour in bread production while tax have been imposed on the importation of wheat and wheat flour (Aristizábal et al., 2017). One major constraint is the unusual taste that may be observed in cassava incorporated breads (Alvarenga et al., 2011). Sujirtha and Mahendran (2015) also reported that application of coconut flour in baking industries helps in improving the amino acid content of wheat flour, especially lysine. Hossain et al. (2016) showed that incorporation of coconut
flour at different proportions in cake formulation improved the cake quality attributes particularly in the area of its nutrient and sensory attributes such as taste, aroma and texture.

**Table 2.3** Overview of some studies conducted on the incorporation of coconut flour in composite mix

<table>
<thead>
<tr>
<th>Authors</th>
<th>Products</th>
<th>Type of coconut flour</th>
<th>Percentage of incorporation</th>
<th>Optimal percentage of inclusion</th>
<th>Result summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hosain (2016)</td>
<td>Cake (wheat flour and coconut flour)</td>
<td>Coconut Flour (from coconut milk residue)</td>
<td>10 %, 20 % and 30 %</td>
<td>20 %</td>
<td>Improvement in nutritional value and physical attributes. However at 30% addition, lower sensory score was allotted.</td>
</tr>
<tr>
<td>Gunathilake and Abeyrathne (2009)</td>
<td>Noodles (Wheat and coconut flour)</td>
<td>Coconut flour (cold press method)</td>
<td>10 %, 20 % and 30 %</td>
<td>20 %</td>
<td>Increase in protein and fibre content with increase in coconut flour inclusion but also led to easier breakage.</td>
</tr>
<tr>
<td>Obaroakpo <em>et al.</em> (2017)</td>
<td>Biscuit (Wheat, soybean and coconut flours)</td>
<td>Defatted coconut flour</td>
<td>10 % and 20 %</td>
<td>20 %</td>
<td>Improvement in functional and organoleptic properties.</td>
</tr>
<tr>
<td>Yalegama and Chavan (2014)</td>
<td>Cookies (Wheat flour and coconut fibre)</td>
<td>Coconut flour fibre</td>
<td>10 % and 20 %</td>
<td>10 %</td>
<td>At 20 %, decrease in organoleptic attributes. Increase in nutritional composition especially fibre content.</td>
</tr>
</tbody>
</table>
However, according to Sujirtha and Mahendran (2015), upon substitution of wheat flour with coconut flour at high amount (50%) in the production of biscuits, there was decrease in the score for taste. This was attributed to the strong taste of coconut which dominated the product. Furthermore, depending on consumer’s preference, the texture of biscuit received a decreased score compared to biscuits without or lower amount of coconut flour. Also, baked products supplemented with coconut flour became darker in colour due to the amino acids (lysine) and sugar (fructose) present in the flour contributing to Maillard reaction during baking. However, 20% for supplementation with coconut flour was found acceptable (Gunathilake and Yalegama, 2009).

Porridges are also an important part of the diet of many people in developing country. Porridges should be seen as a liquid viscous or thickened food that can be made mostly from cereal flours such as corn, millet, and sorghum (FAO, 2001). The porridges are used in the feeding of young children. During cooking, these flours absorb water and there will be an increase in viscosity due to the starch pasting profile of the cereal flours. The extent of thickness is directly correlated to the quantity of flour added to the boiling water (FAO, 2001). According to Igbabul et al. (2014), fermented defatted coconut flour shows potential to be applied as a porridge. The fermentation process after 72 hr made the defatted coconut flour to increase in water adsorption capacity and viscosity. Furthermore, according to Usman and Okafor (2015), nutritious breakfast can be made from blends of locally available products such as rice, soya beans and coconut flour. Through this, the low nutritional quality of some cereals can be improved through supplementation with blends of coconut flour.

Noodles and pasta products are majorly made from wheat flour (Nagao, 1996). However, many studies have also reported the use of other flours in proportions to wheat flour (Devaraju et al., 2006; Ayo and Nkama, 2003). According to Gunathilake and Abeyrathne (2009), the study concluded that coconut flour added up to 20% was not significantly different from noodles made from 100% wheat flour. However, following the partial substitution of wheat flour with coconut flour in the production of noodles, the absence of gluten protein in coconut flour led to the ease breakage of the noodles as compared to noodles produced from 100% wheat flour. This is due to the reduction of the viscoelastic ability of the wheat protein because of the higher inclusion of
coconut flour. Refined wheat is not an excellent source of dietary fiber. Therefore coconut flour can be incorporated into wheat flour during noodles production in order to improve its fiber content and confer important health benefits (Gunathilake and Yalegama, 2009).
CHAPTER 3
MATERIALS AND METHODS

3.1 MATERIALS

3.1.1 Raw material sources

Fresh and mature coconuts fruit (Figure 1a) were purchased at the Badagry coconut market in Lagos, Nigeria. The coconuts were transported in sacks and stored at room temperature until further use. Cassava flour and corn flour were purchased in a local store in Ghent, Belgium. Wheat flour as well as other ingredients for chapatti production which comprise sugar, salt and vegetable oil were all made available in the laboratory at the Ghent University.

3.1.2 Raw material preparation

3.1.2.1 Experimental site

The preliminary raw material preparatory procedure for the coconuts flour production was carried out at Delay Farms and foods company, Ogun State, Nigeria. All other experimental procedures were carried out at the laboratory of Food Technology and Engineering (FTE), the laboratory of Food Chemistry and Human Nutrition and the Laboratory of Cereals Technology at the Ghent University, Belgium, using analytical grade reagents.

3.1.2.2 Production of coconut flour

Coconut flour was produced according to the method described by Osman et al. (2016) with slight modifications for the production of the un-pared flour sample. Mature coconuts (Figure 3a) were deshelled and the obtained coconut kernels were divided into two portions. One portion of the kernel was carefully pared (Figure 3b) using a knife (removal of the external brown coats), while the other portion was left un-pared (Figure 3c). The two portions were sliced into small sizes of 5 mm - 10 mm using a kitchen knife and washed thoroughly in potable water to remove foreign and unwanted materials. The sliced pared and un-pared coconuts kernels were subjected to size reduction using a locally fabricated wet hammer mill at Ogun, Nigeria. The resultant meals were subjected to manual squeezing in a muslin cloth alongside addition of warm water to remove the coconut milk. The residue (Figure 3d) obtained was dried using a heat pump dryer (10 % RH, 55°C). The dried residue was then ground into flour. The flour obtained according to the process
described in Figure 4, was then packaged using transparent polyethylene film and properly stored in a dark cupboard at ambient temperature.

Figure 3: Images showing some of the stages in the production of coconut flour. De-husked mature coconut (a), pared (removal of external brown coat) coconut kernel (b), sliced un-pared coconut kernels (c), pared and un-pared coconut residue on a drying shelves (d).

3.2 METHODS

3.2.1 Chemical composition of the flours

3.2.1.1 Moisture content

Moisture content was estimated by the oven method described by AOAC (1999) with method number 934.01. A dish containing sea sand and glass stick was heated in the oven for 2 hr at 105 °C. It was allowed to cool in a desiccator and the weight was recorded. About 5 g of each sample was weighed into the dishes and mixed well with the sand and kept in the oven at 105 °C for two hours. Repetition of drying was carried out for one additional hour as long as there is reduction in weight. The % loss of weight from the sample was determined and reported as % moisture content.
3.2.1.2 Ash content

The ash content was determined according to the method described by AOAC (1999) with method number 942.05. Approximately 5 g of sample was weighed into a pre-heated and weighed porcelain crucible. This was then heated up on a hot plate until smoke ceases to appear. The crucible was then transferred into a muffle furnace at 550 °C for three hours. It was allowed to cool in a desiccator and weighed again. The percentage loss in weight after “ashing” is reported as percentage ash content.

3.2.1.3 Protein content

The protein content was determined by Kjedahl method according to the steps described in AOAC (1999) with method number 920.87. Sample weight of 0.3 - 0.5 g was carefully measured into a Kjeldahl tube. One catalyst tablet was added into the tube alongside the addition of 10 ml of concentrated H₂SO₄. The digestion of the sample was done until a bright green colour was obtained. The digested materials was allowed to cool at room temperature. Distillation was then carried out followed by titration with 0.05N HCL to obtain a purple colour. Conversion factors of 6.25 was used for wheat flour while 5.70 was used for the rest of the flour samples to convert nitrogen values into protein content of the flour samples.

3.2.1.4 Fat content

The fat content was estimated by Soxhlet extraction method according to the standard method described in AOAC (1990) with method number 7.057. Approximately 4 - 5 g of samples was weighed into a 250ml beaker containing boiling stones. About 45 ml of boiling water and 55 ml of 25 % HCl was added. The mixture was brought to boil until it turned completely black. The content was filtered and fat was extracted with petroleum ether in the Soxhlet apparatus for 4 hr. The petroleum ether was evaporated using a rotary evaporator and the sample was then subjected to repetitive drying to remove residual petroleum ether. The loss in weight after drying was used to estimate the percentage fat content.
Figure 4. Flow chart for the production of pared and un-pared coconut flour.
3.2.1.5 Crude fibre content

Crude fiber was estimated using the enzymatic-gravimetric method based on the procedure that was described by Johansson et al. (1983) and AOAC (1984) with method number 47.021. Defatting was first performed for samples containing more than 5% fat content by treating with petroleum benzene (3 times) followed by drying. A measurement of 1 g of the dried samples was prepared and 40 ml MES/TRIS buffer solution was added. The solution was digested using alpha amylase, protease and amyllo-glucosidase solution. Following the enzymatic breakdown, 220 ml of heated (60°C) 95% ethanol was added, the precipitates were allowed to settle at room temperature for at least 1 hr. The solution was filtered and the residue was washed with 78% ethanol, 95% ethanol and acetone solutions. The residue was allowed to dry overnight in an oven at 105°C. Protein and ash content of the residues were determined. The fibre content was converted from fat-free basis to product basis.

3.2.1.6 Carbohydrate content

Carbohydrate content was estimated by difference method according to the method described by Ohizua et al. (2016). The carbohydrate content determined according to the equation below;

\[
\% \text{ Carbohydrate Content} = 100 \% - (\text{fat} + \text{fibre} + \text{ash} + \text{protein}) \%.
\]

(Equation 1)

3.2.2 Functional properties

3.2.2.1 Pasting properties of flour samples

The pasting profile of the samples were evaluated using the AR 2000 rheometer according to the method described by AACC (2000). About 3.5 g of samples was suspended in a 25 g of distilled water inside the rheometer canister. The canister was immediately placed firmly into the paddle coupling and the motor tower of the instrument where the stirrer was attached was immediately depressed. The suspension was subjected to controlled heating and cooling cycles from 50°C to 95°C and then to 50°C for a period of 56 min. The suspension was conditioned at 50°C for 11 min, heated to 95°C at 2.8°C/min, held at 95°C for 10 min and cooled to 50°C at the rate of 2.8°C/min. The data obtained was in expressed in pa.s and converted to mPa.s except for pasting temperature that the data was obtained and reported in °C. The following pasting parameters were obtained; pasting temperature (°C), peak viscosity (mPa.s), breakdown viscosity (mPa.s), final viscosity (mPa.s) and set back viscosity (mPa.s) (Olugbenga, 2016).
3.2.2.2 Water absorption capacity

The water absorption capacity was determined based on the method described by Adeleke and Odedeji (2010) with slight modification. 10 ml of distilled water was added into a pre-weighed centrifuge tube. The centrifuge tube was then agitated using a vortex mixer at a speed 2,200/min for 2 min. It was then centrifuged at 8,000 g for 25 min at 25°C. The clear supernatant was decanted and discarded. The excess moisture in the mixture was removed by draining for 10 min at room temperature. The water absorption capacity was expressed as weight of water bound by 100 g of flour according to equation 2 below;

Water absorption capacity (%) = \( \frac{\text{Weight of water bound (g)}}{\text{Weight of sample (g)}} \times 100 \)  
(Equation 2)

3.2.2.3 Oil absorption capacity

The oil absorption capacity was obtained according to the method described by Kaur and Singh (2005). One gram of sample was carefully added into a pre-weighed centrifuge tube and 10 ml of maize oil was added. The dispersion was stirred every five minutes using a vortex at speed 2,500/min for a duration of 30 min. This was followed by centrifugation for 25 min at 8,000 g. The fat absorption is expressed as weight of oil bound by 100gof flour according to the equation 3.

Oil absorption capacity (%) = \( \frac{\text{Weight of oil bound (g)}}{\text{Weight of sample (g)}} \times 100 \)  
(Equation 3)

3.2.2.4 Swelling power

The swelling power was evaluated according to the method described Leach et al. (1959) with modifications. 0.075 g of sample was added into a pre weighted Eppendorf. 1.5 ml of distilled water was added. The Eppendorf was closed and manually shaken. The Eppendorf was heated for 30 min at 65°C using a thermo-shaker at 1,000 rpm. The samples were then centrifuged for 20 min at 25°C with a RCF of 8000. Upon completion of centrifugation, the supernatant was decanted and the weight of the Eppendorf and pellet was determined. The swelling power was determined by dividing the weight of pellet formed (residue) by the weight of sample and multiplying by 100.

Swelling Power (%) = \( \frac{\text{Weight of pellet formed (g)}}{\text{Weight of Sample (g)}} \times 100 \)  
(Equation 4)
3.2.2.5 Foaming capacity and foaming stability

Foaming capacity and foaming stability were obtained according to the method described by Kaur and Singh (2005). 3 g/100 ml of distilled water of flour samples were prepared in a beaker and homogenized at 13,500 rpm for 2 min. The blend was immediately transferred into a 200 ml graduated cylinder and the content of the beaker was immediately and carefully scrapped using a spatula. The foam volume was recorded, and the foam capacity was calculated as the percentage of volume increase due to whipping according to equation 4.

\[
\text{Foaming Capacity} \left(\%\right) = \frac{\text{Foam volume (ml)}}{\text{Initial Volume (ml)}} \times 100 \quad \text{(Equation 5)}
\]

For the foaming capacity, changes in the foam volume were recorded at 60 min. Foaming stability was expressed as the decrease in the foam volume after 60 min in relation to the initial foam volume according to equation 5.

\[
\text{Foaming Stability} = \frac{\text{Foam volume (ml) after 60 min}}{\text{Initial foam volume (ml)}} \times 100 \quad \text{(Equation 6)}
\]

3.2.3 Chapatti

3.2.3.1 Formulation and production

The preparation of the chapatti which was carried out according to the method described by Cheng and Bhat (2015) with slight modifications. Table 3.1 shows that the reference chapatti was made using 100 % wheat flour, while the composite chapatti were prepared from mixing wheat flour and coconut flours at 10 % and 20 % level of substitution for both pared coconut flour and un-pared coconut flour. Water, salt, sugar and corn oil (Figure 5) were added based on predetermined optimum amounts of an experimental trial. These ingredients were carefully and manually mixed into a dough until a smooth consistency was achieved. The dough was set aside for 30 min at room temperature. The dough was portioned into smaller sizes of 84 g each and rolled into a flat round sheet a hand roller (dough rolled for average of 9 to 12 times). The sheets were carefully placed on a preheated pan at 230 - 250°C and baked for 60 - 85 sec on each side. The period of baking was also pre-determined based on the trial. During baking, about 3 g of vegetable oil was applied on the surface of each side of the chapatti. Shortly after baking, the chapatti were wrapped in a foil paper, cooled on a rack and properly stored for further use.
Table 3.1  Chapatti formulation

<table>
<thead>
<tr>
<th>Samples</th>
<th>Control (100:0)</th>
<th>(90:10P)</th>
<th>(80:20P)</th>
<th>(90:10UP)</th>
<th>(80:20UP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat flour</td>
<td>500</td>
<td>450</td>
<td>400</td>
<td>450</td>
<td>400</td>
</tr>
<tr>
<td>Coconut flour</td>
<td>0</td>
<td>50</td>
<td>100</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Water (ml)</td>
<td>100</td>
<td>125</td>
<td>150</td>
<td>125</td>
<td>150</td>
</tr>
<tr>
<td>Vegetable oil (g)</td>
<td>38</td>
<td>38</td>
<td>38</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Salt (g)</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Figure 5. Flow chart for chapatti production (Cheng and Bhat, 2005)
3.2.3.2. Physical properties

3.2.3.2.1 Spread ratio of chapatti

Spread ratio was determined by slightly modifying the methods described by Afroza et al. (2014). Three different chapatti was used and for each of the chapatti sample, three width measurements were taken and the average was recorded. The thickness of the chapatti was measured by placing three chapatti on each other and using a vernier caliper to determine the height in mm from three different positions and the average was recorded. The spread ratio was determined by the formula (W/T) where W represents the average width (mm) and T (mm) corresponds to the average thickness of the chapatti.

3.2.3.2.2 Texture analysis of chapatti

The textural properties of the chapatti samples were determined by using a texture analyzer (TA. XT Plus, Stable Micro System, UK). The analysis was carried out based on the method described by Cheng and Bhat (2015) with slight modifications. The conditions applied were; pretest speed = 5 mm/s, distance = 60 mm and trigger type = auto. Two chapatti strips (10 by 2.5 cm) from each chapatti were cut at the center. One chapatti strip was held at the centre of the two clamps of the texture analyzer. The clamps was made to move in opposite direction in order to pull the chapatti strips apart until it breaks. The peak force (N) and extensibility (mm) were recorded. The experiment was performed in six replications (Yadav et al., 2012).

3.2.3.3 Sensory evaluation of chapatti

The sensory evaluation of the chapatti samples was carried out to determine the taste, texture, colour, smell and overall acceptability. This was performed by inviting students who are familiar with the food at the Faculty of Bioscience Engineering, Ghent University. In total 22 panelists was recruited. The panelists were properly briefed and instructed individually on the procedure with emphasis on rinsing their mouths with water in between sample tasting. A nine point hedonic scale was used, with 1 being the lowest score representing “extremely dislike” and 9 being the highest score representing “extremely like”. The samples were coded in 3 digits, heated for 15 sec in a microwave oven at 500 W power prior to serving the panelists. (Mehfooz et al., 2018)
3.2.3.4 Chemical composition of chapatti

The chapatti samples were all subjected to size reduction using a kitchen knife prior to subjecting them to analysis. The moisture, ash, protein, fat, carbohydrate and fibre contents were determined according to the methods described in section 3.2.1.

In addition, the energy values (kcal/100 g) of chapatti samples were calculated by adding the multiplication values of the protein (g), fat (g) and carbohydrate (g) contents with their respective Atwater factors of 4, 9 and 4.

3.3 Statistical analysis

The results obtained in this study are presented as mean ± standard deviation of three independent replications. The statistical significance was generated by subjecting the results of the analysis to one-way analysis of variance (ANOVA) to compare the means using SPSS version 16. A post doc analysis using Duncan multiple range test was used to separate the means and homogeneity of variance was also carried out. The test was accepted at 5 % significant level (Chinma et al., 2012). The data obtained from the sensory evaluation was subjected to similar statistical test with N=22.
CHAPTER 4
RESULTS AND DISCUSSION

4.1 CHEMICAL COMPOSITION OF FLOURS

The chemical composition of wheat flour, cassava flour, wheat flour, pared and unpared coconut flours are presented in Table 4.1. The data provided in the table shows the moisture, ash, protein, fat, fibre and carbohydrate content for each flour sample.

Table 4.1 Chemical composition of the different flour samples

<table>
<thead>
<tr>
<th></th>
<th>% Moisture</th>
<th>% Ash</th>
<th>% Protein</th>
<th>% Fat</th>
<th>% Fibre</th>
<th>% Carbohydrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat flour</td>
<td>12.7±0.2^a</td>
<td>0.6±0.1^c</td>
<td>10.6±0.1^a</td>
<td>0.8±0.1^d</td>
<td>2.8±0.1^c</td>
<td>72.5±0.8^b</td>
</tr>
<tr>
<td>Cassava flour</td>
<td>10.6±0.1^c</td>
<td>0.9±0.0^ab</td>
<td>1.4±0.0^c</td>
<td>0.5±0.2^e</td>
<td>4.8±0.1^d</td>
<td>81.8±0.1^a</td>
</tr>
<tr>
<td>Maize Flour</td>
<td>11.1±0.1^b</td>
<td>0.8±0.0^bc</td>
<td>7.8±0.2^c</td>
<td>2.1±0.0^e</td>
<td>7.7±0.7^c</td>
<td>70.1±0.6^b</td>
</tr>
<tr>
<td>Coconut flour (P)</td>
<td>4.6±0.3^d</td>
<td>1.0±0.1^a</td>
<td>6.3±0.1^d</td>
<td>52.6±0.3^b</td>
<td>16.7±0.2^a</td>
<td>18.8±0.2^c</td>
</tr>
<tr>
<td>Coconut flour (UP)</td>
<td>4.1±0.0^e</td>
<td>0.9±0.0^ab</td>
<td>8.3±0.1^b</td>
<td>59.5±0.8^a</td>
<td>15.6±0.8^b</td>
<td>11.6±0.1^d</td>
</tr>
</tbody>
</table>

Results are expressed as mean ± deviation of triplicate samples. Mean values of different superscript letters within the same column differs significantly at (P< 0.05). P; pared and UP; un-pared.

The moisture content of the flour samples ranged from 4.1 % to 12.7 % with un-pared coconut flour and wheat flour containing the lowest and highest moisture content, respectively. Both pared (4.6 %) and un-pared (4.1 %) coconut flour contained a much lower moisture content compared to wheat flour (12.7 %), cassava flour (10.6 %) and corn flour (11.1 %). However, the moisture content of all the flour samples showed mutual significant differences (P< 0.05). The deviation seen could be due to the fact that the processing methods, temperature and duration of drying differed (Hossain et al., 2016). The moisture content (12.7 %) for wheat flour obtained in this result is consistent with that obtained by Suresh et al. (2014) who reported 13.3 %. Ezeokeke and Onuoha (2016) published a moisture content of 8.3 % for maize flour which is lower than the result of this current study. The moisture content of both coconut flour samples deviate slightly from the findings of Lai and Vo Thi, (2017) who showed 6.1 % moisture content for the pared coconut flour. Similarly, Yalegama and Chavan (2004) reported 9.3 % moisture content for coconut flour. The
moisture content of the individual flours are within the recommended level of not more than 14 % for proper and safe storage. This criterion plays an important role in the prevention of microbial deterioration, chemical changes and by consequence leads to extension of shelf life and overall quality of flour products (Shahzadi et al., 2005). This suggests that all the flour samples may have good keeping quality and will be stable during storage. The keeping quality of cereals flours is not solely dependent on moisture content. However, it is also important to state that the lower the moisture content of these flour, the more easily they will take up moisture from the surrounding air if proper storage is not ensured.

The data pertaining to the ash content of the flour samples is presented in Table 4.1. The ash content fell within the range of 0.6 % to 1 %. The lowest ash content was recorded for wheat flour while the highest was for pared coconut flour. Cassava flour, corn flour and un-pared coconut flour were all less than 1 %. The ash content of wheat flour was significant different (P< 0.05) from pared and un-pared coconut flour. However, it is evident from Table 4.1 that there is an insignificant difference in the ash content of both coconut flours. This implies that the process of paring of the coconut did not influence this parameter. The results obtained in this study are quite different from the findings of Etong et al. (2014) who reported that wheat and cassava flours contains 4.9 % and 2.1 % ash, respectively. Similarly, for the coconut flours samples, Daniela (2016) and Gunathilake and Abeyrathne (2007) reported ash content of respectively 1.7 % and 6.0 % which are higher than the results obtained in this study. However, Lai and Vo Thi, (2017) study showed that coconut flour contains 1.2 % ash content which is similar to the range 0.9 % - 1 % that was presented in this study. The differences in the ash content values for the coconut flour samples may be due to different varieties and the retention of components after the extraction process of coconut milk (Gunathilake and Abeyrathne, 2007). Therefore, based on this study, pared coconut flour was only found to have a higher mineral content than wheat flour and maize flour. Ash content provides an indication of the mineral content of any food sample. It is the residue left after complete combustion of organic compounds (Usman et al., 2015). Minerals play a role for the maintenance of the overall mental physical wellbeing and the development and maintenance bones, tissues teeth, and muscles (Ohzua et al., 2016). However, the bioavailability of the minerals in the flour samples may be impeded by the fibre matrix which was found to be higher in the coconut flour samples (Barbara, 1989).
The crude protein content of the flour samples varied from 1.4 % to 10.6 % where cassava and wheat flour have the lowest and highest value, respectively. The protein content of all the flour samples were significantly different from each other (P< 0.05). Similar results have been obtained for wheat flour in the study conducted by David et al. (2015) who reported 10.2 % protein content. However, Etong et al. (2014) reported a higher crude protein content for cassava flour (7.2 %) and wheat flour (20.9 %). For the coconut flour samples, a similar finding was presented by Daniela (2016). The latter reported that coconut flour contain 6.9 % crude protein which is consistent with 6.3 % protein content for pared coconut flour in this study. However, Lai and Vo Thi, (2017) reported 5.8 % for coconut flour which was lower than the result for both pared and un-pared coconut flour. The difference between the protein content of the pared and un-pared coconut flour may have been influenced by the process of removing the outer brown coat of coconut kernel for the pared sample. Furthermore, the difference may have resulted due to different geographical locations of cultivation, as soil with higher nitrogen levels positively affects the protein content of the crop grown (David et al., 2015). The protein content of coconut flours as obtained in this research suggests that they have potential applicability in food formulation and they can be used in the enrichment of other staple flours that are nutritionally poor. A higher protein intake to an extent helps in the prevention and reverse of protein-energy malnutrition (Canan, 2016). Protein is a source of amino acids and it plays an important role in determining the functionality of flours (Usman et al., 2015). Protein’s influence on flour functionality may be due to the presence of hydrophilic and hydrophobic parts and as such depending on the type of amino acid present; whether polar or non-polar, it could determine the hydration properties of flour (Suresh et al., 2015).

The fat content of the flour samples as presented in Table 4.1 were found to range from 0.5 % to 59.5 % with cassava flour and un-pared coconut flour having the lowest and the highest value, respectively. For all the flour samples, the fat content are significantly different from each other (P< 0.05). Wheat flour, cassava flour and corn flour showed that the staple flours have lower fat content compared to any of the coconut flours including the pared coconut flour which contains 52.6 % fat. This is confirming that these staple flours are not oil-rich (Iwe et al., 2017). The fat content for wheat flour in this present study was found to be lower than 1.3 % reported by Opong et al. (2015). However, Etong et al. (2014) reported a much higher fat content for wheat flour (9.8 %) but a similar result for cassava flour (0.5 %). Daniela (2016) published a similar result of 63.9
% fat content for coconut flour while the findings of Lai and Vo Thi (2017) and Gunathilake and Yalebama (2009) showed respectively 29.8 % and 9.2 % coconut flour fat content which differ from the results in this study. Furthermore, Yalebama et al. (2013) reported 42.6 % fat content for the residue which was obtained after coconut milk extraction. In this present study, the significant difference between the fat content of the pared and un-pared coconut flour samples was due to the removal of the external brown coating of the coconut kernel (Figure 3b) for the pared flour while the brown coating of the kernel (Figure 3c) was left intact for the un-pared flour. However, the high fat content in both coconut flour samples was mainly due to the fact that no further physical or chemical treatment was done to reduce the fat content of the coconut residue. The varying results of coconut flour fat content may be due to the different types of products obtained from coconut kernels and the different processing methods that are applied (Lai and Vo Thi, 2017). Raghavendra et al. (2004) reported that it is difficult to reduce the fat content of coconut residue to a very low value through hot water and other physical treatments except with the application of solvent extraction. Fat plays a role in enhancing the flavor and palatability of final food products.

According to the Codex Alimentarius commission, “dietary fibre is an edible, naturally occurring in the food as consumed, non-digestible materials composed of carbohydrate polymer which is neither digested nor absorbed in the small intestine”. The data for the crude fibre content of the flour samples revealed wheat flour to have the lowest (2.8 %), while pared coconut flour have the highest (16.7 %). This is followed by un- pared coconut flour (15.6 %), maize flour (7.7 %) and cassava flour (4.8 %). The fibre contents of all the flours are significantly different from each other (P< 0.05). The findings of Etong et al. (2014) showed that wheat flour and cassava flour have fibre content of 3.4 % and 6.19 % respectively. These were slightly higher than the result obtained in this study. Lai and Vo Thi (2017) reported coconut flour of 19.82 % fibre content which is higher but similar to 16.7 % fibre content of pared coconut flour in this study. Daniela (2016) reported 13.2 % fibre content which is lower than the result for our pared and un- pared coconut flour. These findings show that wheat flour, cassava flour and corn flour are not a good source of dietary fibre compared to coconut flour. One possible implication of using higher fibre coconut flour in food applications particularly in bakery products is that higher amount of water may be needed. Based on these findings, there is potential for the incorporation of coconut flours in food formulations where wheat flour is the main ingredient which will help raise their fibre content of the food products and offer some important health benefits such as prevention of constipation and colon
cancer, reducing low density lipo-protein cholesterol levels (LDL) (Codex, 2004; Hossain et al., 2016).

The result for carbohydrate content of the various flour samples ranged from 11.6 % to 81.8 %, respectively for un-pared coconut and cassava flour. According to Table 4.1 wheat and corn flours show insignificant difference from each other while cassava flour was significantly different from the rest of the samples (P<0.05). Chang and Bhat (2015), and Begum et al. (2013) reported 69.3 % and 72.3 % carbohydrate content for respectively whole wheat flour which were similar to that obtained in this study. Etong et al. (2014) reported a cassava flour of 73.7 % while Begum et al. (2013) found that maize flour have carbohydrate content of 74.7 %. The pared coconut flour was found to have a higher carbohydrate content (18.8 %) compared to the un-pared coconut flour (11.6 %) and these values are significantly different from each other (P<0.05). This difference may have occurred due to the parings which could have aided in concentrating the carbohydrate content of the pared coconut flour. Daniela (2016) reported coconut flour carbohydrate content of 10.5 % which is similar to that obtained for the un-pared coconut flour. The staple flour samples exhibited a much higher carbohydrate content than any of the coconut flour samples. The significance of this is that the staple flours will have a higher glycemic index in comparison to the coconut flour samples. Glycemic index is a measure of the rate of release of sugar by the food and absorption of sugar in the human body. This index is less affected by the amount of protein and fat in foods (Nicoletta, 2014). Based on these findings, coconut flour can be described as a low carbohydrate supplier when compared to other staple flours.

4.2 FUNCTIONAL PROPERTIES OF FLOURS

4.2.1 Pasting properties

The result for the pasting parameters of wheat flour, cassava flour, corn flour, pared and un-pared coconut flour are shown in Table 4.2. Pasting properties are used to describe the structural changes that occur in food matrix when heated in the presence of water. Pasting characteristics are majorly influenced by the amount of starch present in the flour sample, the plant source, interactions among the components and the experimental conditions at which the analysis is carried out. (Ocheme et al., 2018). In this regard, the most important parameters to consider in understanding the functionality and quality prediction of flour in food systems are the pasting temperature (PT), peak
viscosity (PV), breakdown viscosity (BDV), setback viscosity (SBV) and final viscosity (FV) (Kinn et al., 2015).

Table 4.2 Pasting properties of the different flour samples.

<table>
<thead>
<tr>
<th></th>
<th>PT (°C)</th>
<th>PV (mPa.s)</th>
<th>BDV (mPa.s)</th>
<th>SBV (mPa.s)</th>
<th>FV (mPa.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat flour</td>
<td>63.8±0.6b</td>
<td>1173.3±18.3c</td>
<td>696.7±12.4b</td>
<td>720.0±14.9c</td>
<td>1190.0±15.3c</td>
</tr>
<tr>
<td>Cassava flour</td>
<td>63.0±0.9b</td>
<td>5819.0±8.4a</td>
<td>3903.3±20.2a</td>
<td>1130.0±13.6b</td>
<td>2890.0±0.1a</td>
</tr>
<tr>
<td>Maize Flour</td>
<td>66.6±0.1a</td>
<td>1683.3±20.3b</td>
<td>696.7±15.3b</td>
<td>1190.0±20.1a</td>
<td>2186.7±20.5b</td>
</tr>
<tr>
<td>Coconut flour (P)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>973.3±5.8d</td>
</tr>
<tr>
<td>Coconut flour (UP)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>546.7±5.6e</td>
</tr>
</tbody>
</table>

Results are expressed as mean ± deviation of triplicate samples. Mean values of different superscript letters within the same column differs significantly at (P< 0.05). P.T; pasting temperature, P.V; peak viscosity, B.V; breaking viscosity, SBV; set back viscosity, F.V; final viscosity, P; pared and UP; un-pared

Pasting temperature gives an indication of the minimum temperature that is needed to cook a particular food product. It is the temperature at which an observable increase in viscosity of the sample is noticed. According to Eriksson et al. (2014), a higher P.T relates positively to a higher gelatinization. The P.T of the different flour samples ranged from 63.0 °C (cassava flour) to 66.6 °C (maize flour). No data was extracted for the P.T of both pared and un-pared coconut flour because a proper pasting curve was not formed (Figure 6b). An observation based on the study of Stevenson et al. (2015) indicated that the higher the moisture content of flour, the higher the pasting temperature. This was not necessarily the case in this study as cassava flour with the lowest moisture content (Table 4.1) had a similar P.T with wheat flour which had the highest moisture content. An earlier visible increase (Figure 6a) as noticed in the viscosity of cassava flour in comparison to the other staple flour (wheat flour and maize flour) did not result in a significant difference except for maize flour. Iwe et al. (2017) reported a higher P.T for wheat flour (95.2 °C) and cassava flour (82.1 °C) which are not in accordance with the finding of this present study. However, Abimbola et al. (2017) revealed a P.T of 59.8 °C for wheat flour which is similar to the result in this study. The higher the P.T, the longer it will take for the onset of gelatinization to take place. The implication of this is that corn flour will have longer cooking period and better paste stability than the rest of the flour samples (Kolawole and Chidinma, 2015).
**Figure 6a:** Pasting curve for wheat flour, cassava flour, maize flour, pared coconut flour and unpared coconut flour.

**Figure 6b:** Pasting curve of pared coconut flour and un-pared coconut flour.
The peak viscosity gives an indication of the strength of paste induced by the swelling of the starch granules (Adebowale et al., 2011). It is the maximum viscosity that is developed during heating (Ohizua et al., 2016). The PV of the flour samples varied from 1173.3 mPa.s to 5819.0 mPa.s where wheat flour and cassava flour have the lowest and highest value, respectively. These values were found to be significantly different from each other (P< 0.05). With respect to the coconut flour samples, the ill-suited pasting curve led to inability to determine their PV. This resulted possibly because of the low carbohydrate content of both pared and un-pared coconut flour. For the staple flours, it can be observed that the PV (Figure 6a) for cassava and maize flour were attained at a lower temperature than that of wheat flour. This may have occurred due to the swelling capacity of the starch granules in the flours (Eriksson et al., 2014). The result obtained for wheat flour is in accordance with 1100 mPa.s reported by Blessing (2014). He further declared that the PV reduces significantly as the proportion of walnut flour (higher fat and lower carbohydrate) was incorporated into the mix. This gives credence to the improper pasting curve for the coconut flours which were characterized by high fat and low carbohydrate. Furthermore, it can be observed (Table 4.1) that the higher the protein content of the staple flours, the lower the attainment of peak viscosity (Figure 6a). Ocheme et al. (2018) published a decreasing PV as more ground protein concentrate flour was added in composite mix with wheat flour. This claim was further stressed by Chandrashekar and Kirleis (1988) who reported sorghum with a higher protein content having a lower degree of starch gelatinization in comparison to sorghum with lower protein. It is important to note that a high PV can be associated with good textural property of paste and this also shows that such flour will be applicable for food products that are requiring high gel strength. Moreover, it is indicative of the water binding capacity of the flour’s starch mixes. This parameter can be used to correlate the final product quality of foods made from flour (Osungbaro et al., 2010). Therefore, coconut flours used in this study was poor in this regard.

Breakdown viscosity is an important parameter which indicates the stability of the paste. It explains the ability of flour to withstand controlled heating and application of shear during food processing (Ohizua et al., 2016). Therefore, the higher the breakdown viscosity, the lesser the ability of the flour to withstand shear and heat during cooking, and vice versa. It explains the weakness of the swollen granules against the high temperature that was being applied during the test period while low breakdown viscosity indicates that the starch in product may possess crosslinking abilities (Chinma et al., 2012). The breakdown viscosity of the flours fell within 696.7 mPa.s for maize
flour and 3903.3 mPa.s for cassava flour. The data presented in Table 4.2 indicated that cassava flour had BDV that was significantly different (P< 0.05) from the rest of the flour samples. Again, data was not presented for coconut flour samples due to their uncharacteristic pasting curve. The difference observed for the cassava flour implied that its starch has the least ability to withstand heat treatment since there was a quick drop in viscosity to more than half of its peak value during the 90 °C temperature mark. It suggested that such flours with minimal drop in viscosity may be quite stable to heat treatment and mechanical stress (Oladele and Aina, 2007).

Figure 7: Images showing the paste formed by the different flours after the pasting procedure was performed. Paste corn flour (a), paste cassava flour (b), paste wheat flour(c), paste pared coconut flour (d), paste un-pared coconut Flour (e).

The setback viscosity can be defined as the difference between the final viscosity and the trough viscosity or strength viscosity. It shows an indication for the potential of retrogradation and gel stability. The higher the setback viscosity value, the higher the tendency for retrogradation during period of cooling (Wani et al., 2016). This by extension has an effect on the staling rate of products made from such flours. The setback viscosity of the flour samples ranged from 720 mPa.s to 1190 mPa.s with wheat flour and maize flour having the least and highest values, respectively. These
values show significant difference (P< 0.05) from each other. The higher setback viscosity seen in maize flour indicate that there will a greater re-association of starch polymer (Darfour et al., 2013). This implies that maize flour will show greater retrogradation and by extension faster spoilage due to staling when used in food application such as in bread making. For wheat and cassava flour, it indicate that their paste will be relatively quite stable during cooking. The increasing trend noticed in the pasting profile particularly for the staple flours during the cooling phase was due to the re-association of the amylose molecules (Sanni et al., 2001). Amylose content is a critical criterion in determining retrogradation characteristic of starch based product (Chinma et al., 2012). It is important to state that fat may also play a part in determining the tendencies of retrogradation of flours. In the presence of lipid, which is a major constituent of the coconut flour, there may be retardation of starch gelatinization due to possible interaction of lipid and starch leading formation of complex which could entrap amylose (Radhika et al., 2008).

Final viscosity is an important parameter that is used to determine the gel forming ability of flour after a period of progressive cooking and cooling (Iwe et al., 2007). The final viscosity varied from 546.7 mPa.s to 2890.0 mPa.s where un-pared coconut flour and cassava flour have the least and highest values, respectively. These values were significantly different from each other (P< 0.05). According to Iwe et al. (2007), the high F.V value (Figure 6a) seen for cassava flour could be due to its higher amylose content (Ohizua et al., 2016). He further stressed that some varieties of cassava flour have a FV higher than their PV. However, this is contrary to the findings for cassava flour in this present study where the final viscosity is less than peak viscosity. Again, coconut flour samples have much lower final viscosity compared to the staple flours which further establishes their poor pasting characteristics which may be attributed to their low carbohydrate content and partly to high fat.

The pasting properties of the different flour samples as shown above clearly indicated that the coconut flour samples (pared or un-pared) as defined in this study have poor and uncharacteristic pasting profile when compared to the three staple flours. A closer look at the pasting profile (Figure 6b) showed that a proper pasting curve was not achieved, rather an increasing set of undulating viscosity values was displayed. This was largely dependent on the compositional profile of the coconut flour samples and that made it difficult to paste or form a gel (Figure 6(d) and (6e)), un-
like the paste that was formed by maize flour, cassava flour and wheat flour (Figures 6 (a), (b) and (c)).

An intermediate conclusion based on the findings is that the coconut flour (in itself) has limited use in bakery products such as breads, cakes *etc.* except when used in combination with food improvers or in composite ratio with other flour samples with better pasting properties.

### 4.2.2 Hydration properties, oil absorption capacity and foaming capacity and stability

Hydration properties such as water absorption capacity and swelling power, alongside oil absorption capacity, foaming capacity and foaming stability were evaluated and the results are presented in Table 4.3. These functional properties collectively help to further understand how these flours (wheat, cassava, maize, pared coconut and un-pared coconut flours) will behave in different food systems and by consequence, providing some information on how best to utilize them.

**Table 4.3: Hydration properties and foaming capacity and stability of wheat flour, cassava flour, maize flour, pared and un-pared coconut flour**

<table>
<thead>
<tr>
<th>Samples</th>
<th>WAC %</th>
<th>SP %</th>
<th>OAC %</th>
<th>FC %</th>
<th>FS %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat flour</td>
<td>60.9±3.27e</td>
<td>502.2±7.70e</td>
<td>88.21±0.95d</td>
<td>11.67±0.58a</td>
<td>33.82±0.84c</td>
</tr>
<tr>
<td>Cassava flour</td>
<td>144.2±1.47d</td>
<td>872.71±7.47a</td>
<td>135.80±2.48c</td>
<td>5.67±0.58b</td>
<td>43.45±6.27bc</td>
</tr>
<tr>
<td>Maize flour</td>
<td>228.2±4.37c</td>
<td>661.69±4.83d</td>
<td>69.76±1.00c</td>
<td>1.33±0.58cd</td>
<td>50.00±0.00ab</td>
</tr>
<tr>
<td>Coconut flour (P)</td>
<td>476.3±2.76a</td>
<td>828.8±1.96b</td>
<td>214.53±4.96a</td>
<td>1.67±0.58c</td>
<td>55.56±9.62ab</td>
</tr>
<tr>
<td>Coconut flour (UP)</td>
<td>292.2±2.19b</td>
<td>699.38±3.70c</td>
<td>164.06±3.26b</td>
<td>0.33±0.58d</td>
<td>61.11±9.62a</td>
</tr>
</tbody>
</table>

Results are expressed as mean ± deviation of triplicate samples. Mean values of different superscript letters within the same columns differs significantly at (P< 0.05). WAC: water absorption capacity; OAC: oil absorption capacity; SP: swelling power; FC: foaming capacity; FS: foaming stability.

Water absorption capacity (WAC) can be described as the ability of flour to bind with water. (Singh, 2001). The most important chemical constituents that improve water adsorption capacity of flours are carbohydrates and proteins, mainly because of their hydrophilic parts. The presence of dietary fibre plays an important role in this regard as it helps in binding with water (Raghavarao *et al.*, 2008). Furthermore, it can be influenced by the presence of polar amino acids which
describes the hydrophilic nature of the protein in the flour (Suresh et al., 2015). The WAC of the flour samples varied from 60.9 % to 476.3 % with wheat and pared coconut flours having the lowest and highest absorptive capacities, respectively. Cassava, maize and unpared coconut flours have water absorption capacities of 144.24 %, 228.21 % and 292 %, respectively. The WAC of these flours are significantly different from each other (P< 0.05). The result obtained in this study for wheat flour was similar to the findings of Naseer et al. (2016) who reported 83 % for whole wheat flour and 63 % upon the application of irradiation. Also, Ajani et al. (2016) reported a WAC of 161 % for wheat flour while the WAC of cassava flour were in the range of 151 % - 167 % (Eriksson et al., 2014). The difference seen in the WAC between the pared and unpared coconut flour may be related to the fact that pared coconut flour contains slightly higher fibre (16.7g/100g) compared to the unpared (15.6g/100g) (Table 4.1) which may have helped in the entrapment of more water since fibre has the capacity to entrap both polar and non-polar substances. Also, higher lipid content in the unpared coconut flour could have reduced its hydration properties (Raghavendra et al., 2004). Furthermore, Lai and Vo Thi (2017), reported a higher WAC (791 %) for coconut flours with particle size of 18 mm which is higher than the result obtained in this study. The higher water absorption capacity of coconut flour (pared) in comparison to other flours suggest that it can be used in food formulation such as sausages and other bakery products. Water absorption capacity plays an important role in bulkiness and consistency of food products (Amandikwa et al., 2015).

Swelling power can be described as a hydration property of flour after dispersing it in excess water for a specified period (Yagalema et al., 2013). Furthermore, it is used to measure the ability of undisrupted granules to absorb water at high temperature. The swelling capacities of the flour samples are presented in Table 4.3 and were recorded to be in the range 502.2 % to 872.7 % in which wheat and cassava flours had the lowest and highest value, respectively. The results for all the flours show significant variations from each other (P< 0.05). Kusumayanti et al. (2014) reported a different result for cassava flour (1380 %) which is significantly higher compared to that of this study. However, Raghavendra et al. (2004) reported a similar swelling capacity for coconut flour with a high fat content (50-62 g)/100 g that ranged from 800 % to 1100% depending on the particle size of the coconut fibre. A higher swelling capacity for pared coconut flour (828.0 %) and unpared coconut flour (699.4 %) in comparison to maize and wheat flour could be mainly related to their fibre content. According to Yagalema et al. (2013), fibre contains free polar groups which make them to bind easily with water and swells. However, the extent of swelling was influenced
by the fat composition of the flour which could have blocked the matrix of the fibre, thereby reducing access to water. This explains the reason why un-pared coconut flour with a higher fat content (Table 4.1) had a lower swelling power compared to the pared coconut flour. In agreement with this finding, Raghavarao et al. (2008) revealed a decrease in the swelling capacity of coconut fibre as the fat content increases.

Oil absorption capacity (OAC) describes the ability of a food material to be bound to oil. This parameter may also be influenced by the characteristic of the constituents of flour in terms of their hydrophobic components which aid in the absorption of oil (Muhammad et al., 2013). OAC of the flour samples showed a slightly different pattern from that of the water absorption capacity. It ranged from 69.8 % to 214.5 %, where maize and pared coconut flour were observed to have the lowest and highest values, respectively. The data further revealed that all the flour samples showed significant difference from each other (P< 0.05). The OAC of wheat flour (88 %) is in agreement with the findings of Amandikwa et al. (2015). Muhammad et al. (2013) reported a slightly lower OAC for wheat flour (72.5 %). However, this result was found to be different from that of Suresh et al. (2015) who reported an OAC of 146.0 %. Muhammad et al. (2013) reported an OAC of 107.0 % for full fat maize flour and 216 % for defatted maize flour which suggested that higher fat content reduces OAC. These results are higher than the oil absorption capacity of maize flour (69.8 %) in this present study. There is a notable difference between the coconut flour samples. The pared coconut flour (214.5 %) has a much higher oil absorption capacity when compared to the un-pared coconut flour (164.1 %). This variation could be related to the higher fat (Table 4.1) content in the un-pared coconut flour which may have reduced the absorptive capacity of oil compared to the pared which contains lower amount of oil (Igbabul et al., 2014). Overall, the coconut flours showed a much higher oil absorptive capacity compared to wheat, maize and cassava flour. This might be related to the higher fibre content in the coconut flour samples which helped in entrapping more fat. Furthermore, the presence of non-polar amino acid side chains could have aided a stronger hydrophobic interaction with the hydrocarbon chains of the lipid. (Singh and Kaur, 2005). The oil absorption characteristic of food products helps in the improvement of mouthfeel and retention of flavour. Therefore, coconut flour could be potentially useful in food application of some bakery products where palatability and flavour retention are important (Suresh et al., 2015).
Foam can be described as a colloidal of several gas bubbles which can be trapped in a liquid or semi-solid phase (Suresh et al., 2015). By consequence, foaming capacity and stability are a function of surface active substance such as protein which can be estimated upon the application of whipping. They are important parameters that are enhanced due to protein-protein interactions and the concentration of these surface-active solutes (Kaur and Singh, 2005). In this regard, foaming stability describes how stable the surface-active substance can be in the presence of gravitational stresses (Suresh et al., 2015).

The foaming capacity of the flour samples in this present study ranged from 0.3 % to 11.7 % with un-pared coconut and wheat having the lowest and the highest values, respectively. Cassava flour, maize flour and pared coconut flour were found to have 5.7 %, 1.3 % and 1.7 % foaming capacity, respectively. There was no significant difference (P< 0.05) between the FC of maize and pared coconut flour as well as between maize flour and un-pared coconut flour. However, there was a significant difference (P< 0.05) between the pared and un-pared coconut flour. The result obtained for wheat flour is similar to the finding of Suresh et al. (2015) who reported a FC of 12.9 %. Contrary to this, Peter et al. (2004) reported a foaming capacity of 40 % for wheat flour. Etong et al. (2014) reported a FC of 8 % for cassava flour which is slightly higher than the 5.7 % obtained in this study. A possible reason for the variation in foaming capacity is the type of protein contained in the flour. Flexible protein molecules triggers a stronger interaction at the air – water interface to form foams while well-structured globular proteins provide a weak air – water interface which leads to low foamability (Xiaying et al., 2012). The low foaming capacity of both pared and un-pared coconut flour make them to be less applicable in food systems requiring high FC such as breads, cakes and sponges. However, they may be more applicable in chapatti, cookies and biscuits making where formation foam is less needed (Janica et al., 2013) and (Iwe et al., 2017).

The foaming stability shows an inverse trend of the foaming capacity where flours with higher foaming capacity exhibited lower foaming stability. The highest foaming stability was recorded for un-pared coconut flour (61.1 %). This is followed by pared coconut flour (55.6 %), maize flour (50 %), cassava flour (43.5 %) and lastly wheat flour (33.8 %). The result shows that there are insignificant variations among cassava flour, pared and un-pared coconut flour (P< 0.05). Maize flour showed no significant difference from both pared and un-pared coconut flour. However, there was significant difference between the two coconut flour samples. Horsfall et al. (2017) reported a
higher foaming stability of 63.2 % for wheat flour. In similar pattern, Peter et al. (2004) documented a FS of 60.0 % for wheat flour. Both findings deviate from the result obtained in this study. Generally, flours with larger bubbles of air which is surrounded by a less flexible protein film tend to have lower foam stability since the air bubble easily collapse thereby lowering its stability compared to flours with much lesser foaming capacity (Suresh et al., 2015). This explains the reason why wheat flour has the highest foaming capacity and lowest foaming stability and unpared coconut flour has lowest foaming capacity and highest foaming stability.

4.3 CHAPATTI

4.3.1 Physical properties of chapatti

4.3.1.1 Weight, width, thickness and spread ratio

The physical properties of baked chapatti such as weight, diameter, thickness and spread ratio were measured and reported in Table 4.4.

Table 4.4 Physical properties of chapatti made from different levels of substitution of pared and un-pared coconut flour into wheat flour.

<table>
<thead>
<tr>
<th>WF:CF</th>
<th>Weight (g)</th>
<th>Width (cm)</th>
<th>Thickness (cm)</th>
<th>Spread ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>100:0</td>
<td>76.0±1.0a</td>
<td>19.3±0.8a</td>
<td>0.28±0.0a</td>
<td>68.9±2.8a</td>
</tr>
<tr>
<td>90:10P</td>
<td>76.3±0.6a</td>
<td>18.5±0.7ab</td>
<td>0.28±0.0a</td>
<td>66.1±1.9a</td>
</tr>
<tr>
<td>80:20P</td>
<td>76.3±0.6a</td>
<td>17.2±0.5c</td>
<td>0.29±0.0a</td>
<td>59.3±1.3c</td>
</tr>
<tr>
<td>90:10UP</td>
<td>76.3±0.6a</td>
<td>18.8±0.3ab</td>
<td>0.28±0.0a</td>
<td>67.1±0.9</td>
</tr>
<tr>
<td>80:20UP</td>
<td>76.7±1.2a</td>
<td>18.2±0.3b</td>
<td>0.29±0.0a</td>
<td>62.8±0.6b</td>
</tr>
</tbody>
</table>

Results are expressed as mean ± deviation of triplicate samples. Mean values of different superscript letters within the same column differs significantly at (P< 0.05). WF; wheat flour, CF; coconut flour, P; pared coconut flour, UP; un-pared coconut flour

The weights of the chapatti samples fell within a narrow range of 76.0 g to 76.7 g and all the samples showed no significant difference from each other (P< 0.05). This may have occurred due to the equal weight measurement (84 g) of the dough prior to sheeting and baking of each chapatti. Daniela (2016) reported a gradual increase in the average weight of cookies as increasing ratio of
coconut flour was added into the composite mix of whole rice-coconut flour cookies. Afroza et al. (2014) revealed that there was no significant difference in the weight of chapatti upon the increase in the addition of jack fruit seed and Bengal gram flours.

The width of the chapatti samples were measured to be in the range of 17.2 cm to 19.3 cm with sample (80:20P) and the reference sample (100:0) having the lowest and highest values, respectively. The data presented in Table 4.4 indicated that sample 80:20P was significantly different (P< 0.05) from the rest of the samples while the reference chapatti showed insignificant difference when compared to samples 90:10P and 90:10UP. The increase in the level of substitution from 10 % to 20 % of the pared coconut flour resulted in a significant difference (P< 0.05) in the width measurement of the chapatti. Likewise, upon the increase in the addition of un-pared coconut flour from 10 % to 20 %, the width reduces. It is important to note that fat or oils which was higher in the coconut flour enriched chapatti may have played a role in the lubrication of dough and by extension resulted in the easy of dough sheeting which may have contributed to the values recorded for width (Debi, 2004). In addition, the application of manual sheeting method during this experiment may have slightly affected the results for the chapatti. Daniela (2016) reported a similar finding which showed that an increase in the addition of coconut flour reduces the width of whole rice-coconut composite flour cookies. The possible reason for this could be that the inclusion of coconut flour which contained higher fibre compared to wheat flour, had disrupted the starch-gluten network, resulting in a reduction in its extensibility during sheeting and by extension led to a decrease in the width of the chapatti. This was also evident in the poor pasting profile of the coconut flours in comparison to wheat flour which had a much better pasting characteristics than coconut flour. Another explanation is that due to the higher water absorptive capacity of fibre, the added coconut flours; with significantly higher fibre content compete for water which should have used by the gluten protein and then causes a lesser strength of the gluten network (Yadav et al., 2012).

The thicknesses of the chapatti samples were recorded to have no significant difference (P< 0.05). The chapatti samples had thickness that fell within a narrow range from 2.8 mm to 2.9 mm. The implication here is that the inclusion of coconut flour (pared or un-pared) up to 20 % in the making of chapatti does not affect the thickness of the chapatti in comparison to the reference sample. A similar observation was reported by Raihan and Saina (2017). The study revealed that there was no statistical difference in the thickness of the cookies upon the enrichment of the multi grain flour in
wheat flour. On the other hand, Afroza et al. (2014) reported a steady increase in the thickness of chapatti upon the addition of jackfruit seed and bengal seed flours in the composite mix.

Spread ratio is an important parameter in assessing the quality of many bakery products. It helps in determine the product yield. The higher the spread ratio, the higher the products yield (Daniela, 2016). The spread ratio of the chapatti varied from 59.3 to 68.9 where sample (80:20P) and the reference chapatti (100:0) have the lowest and highest values, respectively. Generally, the results showed that there was insignificant difference (P< 0.05) in the spread ratio of all the chapatti samples with 10 % addition of coconut flour when compared to the reference chapatti. However, upon the increase in addition of coconut flour (both pared and un- pared) from 10 % to 20 % into the composite mix for the chapatti production, the spread ratio significantly reduced. This result is in accordance with the findings of Daniela (2016) who observed a decrease in spread ratio of cookies made from composite whole rice and coconut flour as the addition of coconut flour increases. Contrary to this, Afroza et al. (2014) reported an increase in the spread ratio of chapatti made by enriching wheat flour with jackfruit seed flour and Bengal gram flour. This may have been possible due to increase in the overall protein content of the composite mix in comparison to the reference. Mudgil et al. (2017) suggested that baking time and moisture level may have an effect on spread ratio. He further stressed that fibre components such as pectin, hemicellulose and cellulose play a role in the reduction of spread ratio.

4.3.1.2 Texture analysis

The textural characteristics of the chapatti are presented in Table 4.5. Parameters such as force and extensibility were determined. Force is described as the measure of chapatti’s hardness while extensibility is the measure of the chapatti’ ability to stretch (Suresh and Kaur, 2013). These parameters have a notable effect on the quality and by extension the acceptability of chapatti (Yadav et al., 2008).

The peak force measurement as presented in Table 4.5 ranged from 4.0 N to 5.3 N. Statistically, there was no significant difference in the force required to break or tear all the chapatti samples. The findings of Cheng and Bhat (2015) is in agreement with the result of this study as it revealed a peak force of 3.3 N for chapatti made from 100 % wheat flour while there was no significant difference in the peak forces obtained for other chapatti samples made by incorporating jering flour up to 20 %. Yadav et al. (2012) reported a significant increase in the peak load of chapatti made
from composite wheat-rice flour at 25% addition of rice flour. In this present study, the insignificant variation in the peak force for all the chapatti samples may have been due to high gluten content in the wheat flour which helped in entrapping the incorporated coconut flour without leading to any significant hardness. Also, the fat content of the coconut flours could have played a role as a lubricant and as such led to a reduction in the hardness that would have been introduced due to the higher fibre content of the coconut flours. Dar et al. (2013) reported an increasing tearing force of chapatti as the level of supplementation of bran increases. He stated that the differences in the cutting force for chapatti is usually dependent on the protein content or level of replacement of wheat flour with other types of flours.

Extensibility of flat breads is an important quality parameter. The reference chapatti sample (100:0) had highest extensibility (17.9 mm) and was significantly different (P< 0.05) from the results obtained for the other chapatti samples (Table 4.5). The higher extensibility for the reference chapatti sample implied that the chapatti was soft and can be easily folded and stretched (Suresh and Kaur, 2013). Upon the incorporation of pared coconut flour at sample 90:10P, there was a significant reduction in extensibility to 11.4 mm. A further increase in the level of incorporation up to 20% in sample 80:20P led to an insignificant variation in extensibility (11.2 mm) when compared to sample 90:10P. A similar trend was observed in the chapatti samples 90:10UP and 80:20UP. The difference noticed between the coconut flours (pared and un-pared) enriched chapatti especially at 20% level of incorporation, could be due to possible variation in the particle size of both coconut flours. In a situation where the un-pared coconut flour has larger particle size compared to the pared coconut flour, then, it shall have less surface area available for water absorption which is needed for increase extensibility (Yadav et al., 2012). Cheng and Bhat (2015)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Reference 100:0</th>
<th>Pared coconut flour 90:10P</th>
<th>80:20P</th>
<th>Un-pared coconut flour 90:10UP</th>
<th>80:20UP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force (N)</td>
<td>4.00±0.1a</td>
<td>4.5±1.1a</td>
<td>5.3±0.9a</td>
<td>4.4±1.1a</td>
<td>4.6±0.4a</td>
</tr>
<tr>
<td>Extensibility (mm)</td>
<td>17.9±4.0a</td>
<td>11.4±1.6b</td>
<td>11.2±4.3b</td>
<td>9.6±2.3bc</td>
<td>4.3±1.1c</td>
</tr>
</tbody>
</table>

Results are expressed as mean ± deviation of triplicate samples. Mean values of different superscript letters within the same rows differs significantly at (P< 0.05). P; pared coconut flour, UP; un-pared coconut flour.

Table 4.5 Texture of reference and composite chapatti with different levels of substitution.
reported a much lower extensibility of 4.6 mm for reference chapatti while there was significant
difference between the reference and 20 % addition of jering seed flour in the composite mix.
However, Yadav et al. (2012) reported an extensibility of 11.2 mm for the 100 % wheat chapatti.
He further revealed a significant decrease in the extensibility of chapatti made by incorporating 25
% of rice flour. This varying result may have been affected by the differences in the protein content
of the wheat flours used as gluten plays an important role in determining the elasticity of doughs
and by extension the textural profile of chapatti and other food product made from wheat flour.

4.3.2 Chemical composition of chapatti
The nutritional composition for the chapatti samples which were made by incorporating different
levels of pared and un-pared coconut flours into wheat flour are showed in Table 4.6.

The moisture content ranged from 17.4 % to 26.6 % with samples 80:20P and 100:0 chapatti having
the lowest and highest moisture content values, respectively. There was a significant difference
between the moisture content of the reference and the rest of the chapatti (P< 0.05). However, the
moisture content of the 90:10P and 90:10UP chapatti samples only slightly differ from the reference
sample while on the other hand, chapatti samples 80:20P and 80:20UP showed much larger
deviation from reference sample. One possible explanation for this variation could be the longer
time that was required to bake the 20 % coconut flour (pared and un-pared) incorporated chapatti
which may have led to more moisture loss compared to the other samples.

Table 4.6 Chemical composition of chapatti with different levels of coconut flour substitution

<table>
<thead>
<tr>
<th>WF:CF</th>
<th>Moisture (%)</th>
<th>Ash (%)</th>
<th>Protein (%)</th>
<th>Fat (%)</th>
<th>Fibre (%)</th>
<th>Carbohydrates (%)</th>
<th>Energy (Kcal/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100:0</td>
<td>26.6±0.0a</td>
<td>1.0±0.0d</td>
<td>7.5±0.0a</td>
<td>12.8±0.5c</td>
<td>2.8±0.1c</td>
<td>52.1±0.3a</td>
<td>341.3±2.0cd</td>
</tr>
<tr>
<td>90:10P</td>
<td>24.4±0.5b</td>
<td>1.0±0.0cd</td>
<td>7.5±0.2a</td>
<td>15.0±0.0d</td>
<td>4.2±0.0c</td>
<td>47.9±0.4b</td>
<td>353.7±3.7c</td>
</tr>
<tr>
<td>80:20P</td>
<td>17.4±0.0d</td>
<td>1.1±0.0c</td>
<td>7.2±0.1a</td>
<td>22.7±0.2b</td>
<td>6.2±0.0a</td>
<td>45.4±0.4c</td>
<td>407.9±2.9b</td>
</tr>
<tr>
<td>90:10UP</td>
<td>24.0±0.0b</td>
<td>1.1±0.0b</td>
<td>7.0±0.0a</td>
<td>16.3±0.1c</td>
<td>3.5±0.3d</td>
<td>48.1±1.0b</td>
<td>357.3±4.0c</td>
</tr>
<tr>
<td>80:20UP</td>
<td>18.1±0.1c</td>
<td>1.1±0.0a</td>
<td>7.5±0.2a</td>
<td>25.8±0.0a</td>
<td>5.1±0.1b</td>
<td>42.4±0.5d</td>
<td>421.0±3.5a</td>
</tr>
</tbody>
</table>

Results are expressed as mean ± deviation of triplicate samples. Mean values of different superscript letters
within the same column differs significantly at (P< 0.05). P; pared coconut flour, UP; un-pared coconut
flour
According to Wani et al. (2016) the presence of polysaccharides and fibre substances leads to increased water absorption and by extension longer baking time is observed. Another reason could be because coconut flour (pared and un-pared) was found to contain much lower moisture content (4.1 % to 4.6 %) as against 12.7 % in wheat flour. Afroza et al. (2014) reported the reference chapatti moisture content as 23 % and those with enriched composite flours to have moisture in the range of 22 % to 24 %. This finding is in the narrow range of the observation in this current study. Cheng and Bhat (2015) reported a slightly higher moisture content in the range of 25.5 % to 32.3 % in which the reference chapatti (100 %wheat flour) had the highest value. Moisture content of above 10 % tend to promote increase microbial action (Okoye and Obi, 2017).

The ash content of all the chapatti sample are not significantly different from each other (P< 0.05). It ranged from 1.0 % to 1.1 %. Afroza et al. (2014) reported a similar ash content of 1.2 % for whole wheat chapatti. Cheng and Bhat (2015) published a slightly higher ash content for chapatti made from composite wheat flour and jering seed flour. It ranged from 1.8-2.3 % where the value increases as the percentage inclusion of jeering seed flour increases in the formulation. Yadav et al. (2012) observed a higher ash content (2.1 %) of defatted rice flour enriched chapatti in comparison with the reference (100 % wheat flour) which had 0.9 %. Ash content provides an indication of the mineral component of the food samples.

The data presented in Table 4.6 indicated that there is no significant difference (P< 0.05) in the protein content of all the chapatti samples. The values fell within 7.0 % to 7.5 %. Mehfooz et al. (2018) reported a reference chapatti (100 % wheat flour) with protein content of 9.78 %. At 5 % to 20 % incorporation of barley husk flour, the protein content which ranged between 9.0 to 9.6 % showed not much deviation from the reference. Also, Cheng and Bhat (2015) reported a protein content of 11.5 % for the reference chapatti (100 % wheat flour) which is higher than the result of this present study, while upon the addition of jeering seed flour (5 % to 20 %), the protein content increases gradually. The result of this present study indicates that at up to 20 % coconut flour addition in chapatti making, the protein content is not affected. According to Bressena and Wilson (2012), it is important to note that wheat flour and some other cereals flours are limited in essential amino acid such as lysine. However, Sujirtha and Mahendran (2015) suggested that incorporating coconut flour in biscuit formulation can help increase its lysine content. This by extension increases its nutritional value.
The data pertaining to the fat content of the chapatti sample in Table 4.6 indicated that there are significant differences in fat content of all the samples which ranged from 12.7 % to 25.7 % with samples 100:0 and 80:20UP having the lowest and highest value, respectively. Increase in the addition of coconut flour (pared and un-pared) led to a corresponding increase in the fat content of the chapatti compared to the control. This is related to the high fat content of the coconut flour samples. A similar increase in fat content of cookies made from composite rice and coconut flour was reported by Daniela (2016). Furthermore, Sujirtha and Mahendran (2015) reported a change in the fat content from 16.8 % in the reference sample (100 % whole wheat flour) to 21 % in the treatment biscuit (70 % whole wheat and 30 % defatted coconut flour). On the other hand, the study of Cheng and Bhat (2015) showed a significant decrease in the fat content of chapatti made by incorporating jering seed flour. This was attributed to the lower fat content of the jering seed flour. Dietary fat plays important roles in the retention of flavor, absorption of fat soluble vitamins and increase in the calorie of food product; which implies that coconut flours can be utilized to produce high-calorie foods. However, the potential limitation for the coconut flour incorporated chapatti is the susceptibility of the sample to rancidity due to their significantly higher fat content. Theoretically, coconut oil are less prone to oxidation in comparison to other commercial oils due to their low content of unsaturated fats. The peroxide value was reported to be very low to initiate quick oxidation (Diana et al., 2012). However, proper storage must be applied to reduce or prevent the spoilage which may result from oxidation of fat as the period of storage increases (Blessing, 2014).

The fibre content of the chapatti samples made by incorporating coconut flour in the composite mix were significantly higher than the reference. The results ranged from 2.8 % to 6.2 % with samples 100:0 and 80:20P having the lowest and the highest values, respectively. All the chapatti samples showed significant variation from each other (P< 0.05). The data indicated that upon the increase in the addition of coconut flour (pared and un-pared), the fibre content of the chapatti increases. This is comparable with the findings of Mehfooz et al. (2018) who showed that the fibre content of traditional flat bread increases significantly upon the addition of barley husk. However, Cheng and Bhat (2015) observed a decreasing fibre content in composite wheat-jering seed flour chapatti upon the increase in the level of substitution of jering seed flour. Fibre plays many important health roles in the human body. Inclusion of fibre in diet has been shown to reduce the frequency of constipation, the risk of colon cancer among other benefits (Usman et al., 2015).
According to the European Union Food Safety Authority, foods which contain more than 3 g/100g dietary fibre can be labelled to be a source of dietary fibre while those with more than 6 g/100g of fibre can be labelled as high-fibre containing foods and as such possess certain health benefits. In this regard, we can say that sample 80:20P which is 20 % addition of pared coconut flour into chapatti formulation is a high fibre containing food. Whereas, other coconut flour substituted chapatti samples can be described as source of dietary fibre. The reference chapatti fell below any of these categories. This implies that the daily requirement of fibre can be reached by population whose major staple is chapatti by incorporating coconut flour in the formulation. 

The carbohydrate content of the chapatti ranged from 42.4 % to 52.1 % with samples 80:20UP and the reference sample having the lowest and the highest values respectively. All the chapatti samples showed mutual significant difference (P< 0.05) from each other except for samples 90:10P and 90:10UP which were found to be insignificantly different from one another. The decreasing trend of carbohydrate content with increasing level of substitution of coconut flour is comparable with the finding of Afroza et al. (2014), who reported that the carbohydrate content of chapatti enriched with jackfruit seeds flour and bengal gram flour slightly decreases from 65.1 % to 58.2 % with increasing level of substitution. Furthermore, according Sujirtha and Mahendran (2015), soluble carbohydrate of biscuit decreases from 65.7 % to 44.7 % by increasing the level of incorporation of defatted coconut flour in the composite wheat-coconut flour. Based on this study, the reduction in carbohydrate content of the chapatti samples may have occurred mainly because both pared and un-pared coconut flour contained much lower carbohydrate content compared to wheat flour.

The energy value of the chapatti indicated that the 20 % coconut flours substituted chapatti had a significantly higher calorie value than the reference chapatti while insignificant difference (P< 0.05) existed between the reference chapatti and the 10 % coconut flours incorporated chapatti. They were reported to vary between 341.3 kcal/100g to 421.0 kcal/100g. It is therefore important to note that according to Table 4.1, the coconut flour samples were documented to have a significantly higher fat content than wheat flour and the rest of the staple flours. This must have contributed to the higher energy value of some of the coconut flour chapatti. According to the findings of Daniela (2016), the result (which is in agreement with this present study) revealed that increasing substitution of coconut flour (from 25 % to 75 %) in the production of whole rice-coconut flour cookies led to a corresponding significant increase in the energy value of the cookies.
On the contrary, Makinde and Akinoso (2014) reported an insignificant difference in the energy value of bread made by incorporating 20 % of black sesame flour (high fat content) into wheat flour. This was attributed to the higher carbohydrate content of wheat flour.

### 4.3.3 Summary of the sensory evaluation result

The sensory characteristic of composite wheat-coconut flour chapatti are shown in Table 4.7. The subjective sensory evaluation was based on characteristics such as appearance, texture, smell, taste and its overall acceptability.

The results as presented in Table 4.7 showed that the appearance of the reference chapatti received a score that was found to be insignificantly different from samples 90:10P and 80: 20P. This may have occurred due to the paring performed on the coconut kernel prior to the making of the coconut flour which had an off white colour. However, upon the addition of un-pared coconut flour at 10 % and 20 % level of substitution, the allotted scores decreased significantly. A closer look at the images of the chapatti samples revealed that samples 90:10UP and 80:20UP in Figure 7d and 7e possessed an uncharacteristic deep brown colouration which some of the panelists highlighted as their reason for a lower score.

**Table 4.7** Sensory scores of chapatti containing different levels of substitution of pared and un-pared coconut flour.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reference</th>
<th>Pared coconut flour</th>
<th>Un-pared coconut flour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100:0</td>
<td>90:10P</td>
<td>80:20P</td>
</tr>
<tr>
<td>Appearance</td>
<td>7.7±1.1a</td>
<td>7.6±1.1a</td>
<td>7.2±1.2a</td>
</tr>
<tr>
<td>Texture</td>
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<td>6.9±1.4a</td>
<td>6.4±1.2a</td>
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<tr>
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<td>7.4±1.1a</td>
<td>7.1±1.3ab</td>
</tr>
<tr>
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<td>6.9±1.4a</td>
<td>7.1±1.0a</td>
<td>6.8±1.5a</td>
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Results are expressed as mean ± deviation, N=22. Mean values of different superscript letters within the same rows differs significantly at (P< 0.05). P; pared coconut flour, UP; un-pared coconut flour

This result was similar to the findings of Cheng and Bhat (2005) who reported a lower preferential score for much darker chapatti made from composite wheat-jeering seed flour. Similarly, Mehfooz et al. (2018) published a decreasing preference for chapatti made by including barley fibre into
wheat flour. It is important to note that all the chapatti samples were awarded score above 5.0 which implied that none of the chapatti samples was disliked.

Figure 4: Images of chapatti samples made by the addition of different levels of coconut flour substitution. 100 % wheat flour chapatti (a), 10 % pared coconut flour incorporated chapatti (b), 20 % pared flour incorporated chapatti (c), 10 % un-pared coconut flour incorporated chapatti (d), 20 % un-pared coconut flour incorporated chapatti.

The texture scores showed that there was no significant difference (P< 0.05) from all the chapatti samples. These observation is in agreement with the output of the textural analysis (Table 4.5) which indicated no significant variation in the peak force required to tear all the chapatti samples even up till 20 % incorporation of both pared and un-pared coconut flour. However, according to Cheng and Bhat (2015), there was a steady significant decrease in the texture score awarded to chapatti incorporated with jering seed flour. Based on this sensory evaluation results, it can be concluded that incorporation coconut flour (pared or un-pared) into chapatti formulation do not significantly impact the means score for its texture.
In a similar trend, chapatti samples 80:20UP and 90:10P had a smell score of 6.4 and 7.4 representing the least and highest score respectively. These two samples show significant difference from each other (P< 0.05). All other samples were insignificant different from each other. The insignificant variation in the awarded smell score for the coconut incorporated chapatti may be due to the preference for the coconut flavour by the panelists. Yagalema and Chavan (2004) reported a sharp decrease in smell score when the level of substitution of coconut fibre increased to 20 % in wheat flour-coconut fibre cookies. Overall, the smell score for all the chapatti samples fall within the range of “slightly liked” and “moderately liked” and they were all found to be comparable with the reference chapatti.

The taste scores for the chapatti showed no statistical difference from each other (P< 0.05). The peculiar coconut taste which some of the panelists preferred might have been responsible for this insignificant difference in taste in comparison to the reference. Furthermore, it is important to note that the coconut flours incorporated chapatti (pared and un-pared) had higher fat content (Table 4.1) and therefore might have helped in the retention of flavour and improvement in mouth feel. On the contrary, the findings of Cheng and Bhat (2015) published a significant decrease in taste score as jering seed flour is substituted in the chapatti formulation. Surjirtha and Mahendran (2015) reported a decreasing taste score for biscuit upon the increase in the addition of coconut flour due to its dominating taste when used in larger amounts. In this present study it implied that coconut flours addition up to 20 % do not negatively influence the taste of chapatti.

The overall acceptability score gives an indication of the panelists’ product preferences by combining all the product sensorial characteristics and allotting a score that best describe it. Based on the findings documented in Table 4.7, the overall acceptability ranged from 6.3 to 7.1. It is of note that there is an insignificant variation between the samples. Contrary to this, Ameh et al. (2013) reported a significant decrease in the overall acceptability of wheat flour bread as the level of substitution of rice flour increased. However, Obaroakpo et al. (2017) published an increase in the overall acceptability score for biscuits made by incorporation soybean and coconut flour into wheat flour.

The outcome of the sensory evaluation provided an indication that there is a potential for the incorporation of coconut flour (pared or un-pared) up to 20 % in food formulations. In this case where all the panelists were familiar with the sensorial quality attributes of the reference sample,
chapatti made from 10 % to 20 % incorporation of pared and un-pared coconut flour had a comparable overall acceptability score like the reference sample. This result agrees with findings of Butt et al. (2004) who reported that 10 % incorporation of bran for chapatti have comparable sensory attributes as that of the reference chapatti.

4.4 Nutritional relevance of this research study
The world has always made great strides to reduce or eliminate the problems of malnutrition and hunger particularly in many developing countries like Nigeria, India and Kenya. Solving these problems will not only require improvement in agricultural production techniques but also there should be conscious effort deployed towards the valorization of agricultural by-products which can contribute to increased food availability and by extension household food security. The processing of coconut residue (by-product of coconut oil industry) in the production of coconut flour with possible food applications may be one of the practicable approaches that could help in this regard.

Wheat flour and some other staple flours such as cassava and corn flour are used in the production of different food products such as breads, cakes and porridges etc. However, these flours are known to be inadequate in their fibre content. In an ideal situation, the meals made from theses staple flours should be consumed along with portions of fruits and vegetables in other to supply dietary fibre, but this rarely happens especially in rural and poorer households. A composite of some of these staple flours with coconut flour will help to improve the fibre intake of the members of these households and by extension reduce the occurrence of diseases or conditions such as constipation and colon cancer that are associated with low consumption of dietary fibre which is fast rising in today’s world such as in Sub-Sahara Africa.

It is becoming much more important to emphasize on the quality of fat consumed rather than focusing on only the amount. It is recommended that a healthy diet should not contain more than 30 % of fat which should be free from trans-fatty acids (Trinidad et al., 2014). Foods with more proportions of polyunsaturated fatty acids are preferred. Coconut flour majorly contains saturated fats which is predominantly lauric acids. Saturated fats have received a negative health connotation (Sack and Katan, 2002; Spady et al., 1993). However, some studies have suggested that lauric acids possess remarkable nutritional and health benefits in comparison to other saturated fatty acids (Enig, 1999; Shamina, 2007). This medium chain fatty acid has been reported to be quickly absorbed and transported to the mitochondria where they are utilized as energy rather than be stored.
as fat. This lauric acid further helps in the formation of monolaurin; a monoesther which was reported to have antibacterial and antiviral activities (Leiberman et al., 2006). Yet, its overall health benefit potentials in these domain remain debatable.

The coconut enriched chapatti as reported in the study was found to have higher energy value (kcal/100g) than the reference (100 % wheat flour) which is primarily due to its fat content. In the case of nutritional intervention, where increase in energy intake may be needed, this type of novel food may be used to raise the population’s calorie intake without necessarily reducing the nutrient content. However, this may contribute to some health concerns when high calorie containing chapatti are consumed by individuals who are already overweight or obese.
CHAPTER 5

CONCLUSION

This study was conducted to understand the nutritional, functional and potential applicability of coconut flour in food systems. Having shown that coconut flour is high in fat, fibre and some amount of protein, the experiment also revealed that in terms of functional properties; the pasting characteristics was poor in comparison to the staple flours. This clearly showed that coconut flour possesses limited ability to function as the main ingredient in bakery food formulation. Contrary to the poor pasting properties, coconut flour indicated better prospect ahead of some of the staple flours in terms of hydration characteristics such as water absorption and swelling power. This strengthens its potential ability to be used in composite proportion with other flours.

An attempt to develop chapatti from composite wheat - coconut flour was made. The coconut flour (pared or un-pared) incorporated chapatti samples up to 20 % had comparable characteristics in terms of physical and sensorial evaluation in relation to the reference chapatti which was made from 100 % wheat flour. However, the textural attribute (extensibility) and appearance of the un-pared coconut flour enriched chapatti samples fell short from the reference chapatti. Additionally, the nutritional composition of coconut flour enriched chapatti indicated higher fibre and fat content when compared to the reference.

The utilization of coconut flour in the making of unleavened breads such as chapatti would enhance and contribute to its proper valorization potentials in countries where coconuts are being cultivated and processed, and consumption of chapatti is popular. This can also provide commercial opportunities for coconut farmers as well as small scale food processing industries. This in the long run may help in reducing the pressure of importing wheat flour.
CHAPTER 6

THE FUTURE PROSPECT FOR COCONUT FLOUR UTILIZATION.

Based on this study, it can be clearly seen that coconut flour has poor pasting properties which makes them rarely useful in some food applications that requires formation of gel or paste and as such, in itself cannot be used to make porridges, bakery products and a few other staple meals. However, the flour still contains important nutrients such as protein, fibre and fat. This nutritional composition of coconut flour enables them to have potential in composite ratio with other flours particularly for those staple flours that are nutritionally poor. However, its valorization options have not been fully maximized.

A number of experimental studies which entail the application of coconut flour in the baking and pastry industries have been carried out (Hosain, 2016; Igbadul et al., 2011; Gunathilake and Yalegama, 2009). They all show that coconut flour can be used to increase the nutritional value of food products such as breads, cakes and cookies. However, to the best of my knowledge, there are no studies which have been carried out to see the possibility of incorporating coconut flour into composite mix as a complementary food.

The problems of undernutrition among children within the ages of 6-24 months are mainly because of inadequate nutrients and energy intake which then exacerbate the prevalence of stunting and wasting especially in many developing countries. The consequences of poor diets among children in poorer households become much more severe at the point where children are introduced to complementary foods (Kulwa et al., 2015). It is a common practice within such households to give children maize, millet, sorghum and cassava based porridges which have being diluted with water into thin consistencies and thereby leading to inadequate supply of energy. The energy densities of these porridges fed to these children have been reported to be low and within the range (0.25-0.50 kcal/g) which do not meet the basic requirement. (Stephenson et al., 1994). According to World Health Organization (2001), the minimum energy density should be 80 kcal/100 g. In a bit to increase the energy value of these porridges, edibles oil are being encouraged to be added in the meals. However, this comes at an extra cost for the households.

Tanzania, Kenya and Nigeria top the list of coconut producing countries in Africa (Uwubanmwen et al., 2011). Based on my experience in Nigeria, the current area of focus in the utilization of
coconut kernel is coconut milk and oil production through which coconut residue is obtained as a byproduct. In-view of this, it may be interesting to investigate the functionality and consumer acceptability of porridges made by combining a nutritional poor staple flour with coconut flour. For example, in the context of maize porridges which require addition of edible oil to raise its energy value, a composite mix of maize-coconut flour porridge will eliminate the need for oil addition in these coconut producing countries since the coconut flour is high in fats. This will proffer a better solution to energy inadequacy while enhancing the dietary fibre intake on the other hand.
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**Web links**


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http://healthtipsinfo.com/ accessed 17th July, 2018

Appendix: Sensory Evaluation Form

Sensory Evaluation Form (Consumer Acceptance Test)

Nationality………………………………………….. Sex…………………………..
Date……/…………/…… Scale: 9 Points Hedonic Scale

Name of Food Product: Chapatti

Panelist Background Information

1) Please indicate by ticking the appropriate box the term that best describe your frequency of chapatti consumption.
   Few times  Often times Occasionally Severally
   □        □           □              □

2) Are you allergic to gluten? Yes □ No □

   If yes, please do not participate in this sensory analysis. If your answer is No, please continue.

Instructions:

i) You are provided with five chapatti samples coded R212, R322, R121, R423 and R112. For each of the food samples, score them using all of the food quality parameters at the same time.

ii) Rinse your mouth thoroughly with the water provided between each product tasting.

iii) Please use the comment section after each sample category to provide extra information (If any).

1) R212

| Instruction: Please circle the number(score) that best fit your description of the sample |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Quality Parameters | Extremely Dislike | Very much dislike | Moderately dislike | Slightly dislike | Neither like or dislike | Slightly like | Moderately like | Very much dislike | Extremely like |
| Appearance | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Texture | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Smell | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Taste | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Over All Acceptability | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

Comment……………………………………………………………………………………………………………………………………………………………...
### 1) R322

**Instruction:** Please circle the number (score) that best fit your description of the sample

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**Comment**


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74
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