Effect of fermentation on the proximate composition and functional properties of defatted coconut (Cocos nucifera L.) flour

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Accepted 3 September, 2014

The proximate composition and functionality of the fermented defatted coconut meat flour at different period of 24 h (FCMₐ), 48 h (FCMᵥ) and 72 h (FCM₇) were investigated and compared with unfermented flour at 0 h (UCMₐ). The result revealed that the protein content, crude fat and crude fiber of the defatted coconut flour increased significantly from 12.31 - 15.00% , 0.58 - 0.67% and 9.47 - 13.23% respectively, while the moisture content and ash content decreased significantly from 5.27 - 2.67 % and 2.76 - 1.02% as the fermentation period increased. The carbohydrate calculated by difference ranged from 67.37 - 67.41 % in decreasing order. Fermentation also significantly (p < 0.05) decreased some functional properties; bulk density (0.51 - 0.46 gmL⁻¹), oil absorption capacity (OAC) (2.70 - 2.00 gmL⁻¹), emulsification capacity (50.00 - 45.83 gmL⁻¹) and foaming capacity (0.04 - 0.01%) while water absorption capacity, least gelation and viscosity at all speed rate (6, 12 and 30) significantly (p < 0.05) increased with fermentation time.

Key words: Cocos nucifera L, flour, fermentation, proximate, functional properties.

INTRODUCTION

Coconut (Cocos nucifera L.) has been described as the most important and extensively grown palm tree worldwide providing food for millions of people especially in the tropical and sub-tropical regions. The most important coconut producing countries in the world include the Philippines, Ceylon, India, Malaysia, Oceania and parts of West Africa including Nigeria (Kisun et al., 1995; Prades et al., 2012). Every part of the plant is useful and in many ways support human life (Chan and Elevitch, 2006; Bourdeix et al., 2005). The fruit has multifarious utility, the tender coconut water is a sweet refreshing drink taken directly from the inner parts of coconut fruit (Sterner and Desser,2008) and it contains a calorific value of 17.4/100 g, vitamin B group, nicotinic acid (B₃), pantothenic acid (B₅), biotin, riboflavin, folic acid, trace amount of thiamine (B₁) and pyridoxine (B₆) (USDA, 2009). Also, it includes sugar (sucrose, sorbitol, glucose and fructose), sugar alcohol, vitamin C, folic acid and free amino acids (Yong et al., 2009). Coconut water is used as a natural beverage (Bourdeix et al., 2005), medicine (Nanda Kumar, 1990; Effiong et al., 2010), wine (Augustine, 2007) and biocatalyst (Bustamante, 2004; Da Fonseca et al., 2009). The kernel (wet meat) is used in making curries, chutney, and toffee, sweet and for other cooking purposes (NMCE, 2007).

Coconut is not only known for providing meat, juice, milk and oil but it is also a good source of flour and it can be used as substitute to wheat flour. Coconut meat flour is a soft flour-like product made from the pulp of coconut and it is actually a by-product made during the coconut milk making process. Coconut flour can be used much like wheat flour to make a multitude of delicious breads, pies, cookies, cakes, snacks and desserts. It contains more calorie free fiber than other wheat alternatives and provides a potential source of protein with good nutritional value (Trinidad et al., 2001; Fife, 2005).

Functionality is the first concern in the formulation and processing steps of a food. Thus, the basic functionality...
of any food ingredient can be used to obtain an indication of their performance in end products. The success in transforming proteins, particularly new proteins raw materials into attractive, nutritious food depend largely on their physiochemical or functional properties. These are the properties of proteins, which contribute some performance in aqueous dispersion to influence the flavor, structure and texture of food formulation. The functional properties of food can be used to define how proteins can be supplemented into existing foods, and how they can replace more expensive proteins in traditional foods. The nutritional value of any plant foods can be enhanced through fermentation as it improves the amino acid balance and increases the protein content and carbohydrate accessibility. Many researchers have used fermentation technology in processing foods (Opara et al., 2013; Gernah et al., 2012) but scanty literature is available on coconut meat fermentation. Therefore, the present study was carried out to investigate the effect of fermentation period on the proximate composition and functionality of defatted coconut flour.

**MATERIALS AND METHODS**

**Procurement and sample preparation**

Coconuts used for this study were purchased from railway market in Makurdi, Benue State Nigeria. Coconuts were shelled and the coconut meats/kernels were removed. The brown particles of the coconut kernel were removed with the aid of a peeling knife and then the kernels were sliced (10 mm thickness), washed and divided into four (4) portions (1 kg for each sample). The first portion was kept as control (unfermented kernel slices), while the second, third and fourth portions were allowed to undergo fermentation naturally at ambient temperature for 24, 48 and 72 h respectively and then oven dried at 60°C for 24 h. The dried coconut slices were grinded using electric blender (Phillips, Holland model HR 1702) and coconut oil was extracted using the screw press method as described by Igyor et al. (2008). The residues were re-dried in oven at 60°C (Genlab widnes, UK model T 12H) for 30 min and milled into flours as shown in Figures 1 and 2.

**Proximate analyses of flour samples**

Proximate composition including crude protein content, crude fiber, crude fat and ash were analyzed. Crude protein content was determined by estimating the nitrogen content using the Kjedahl method. Ash content was determined by incineration at 600°C. Crude fat was determined by the Soxlet method and the crude fibers were assayed by acid digestion and alkali digestion. Dried samples were analyzed for the above compositions in triplicate in line with the result, in accordance with the AOAC standards (1995). Carbohydrate content was calculated by difference according to the following.
equation: \%
Carbohydrate = 100 - (\% Protein + \% Moisture + \% Fat + \% Fibre \% Ash)(AOAC, 1995).

**Determination of functional properties of flour samples**

**Bulk density**

Bulk density was determined by the method described by Onwuka (2005). 10 mL capacity graduated measuring cylinder was filled gently with each sample. The bottom of the cylinder was gently tapped on a laboratory bench several times until there was no further diminution of the sample level. Bulk density was calculated as shown below.

\[
\text{Bulk density} = \frac{\text{weight of sample (g)}}{\text{volume of the sample (mL)}}
\]  

**Foaming capacity**

This was determined by the method described by Coffman and Garcia (1977). About 2 g of sample was blended with 100 mL distilled water in a Kenwood blender. The suspension was whipped in an ace homogenizer (NSEIAM-6) at 1600 rpm for 5 min. The mixture was poured into a 250 mL graduated cylinder and the volume was recorded after 30 sec. The foaming capacity was expressed as percentage increase in volume using the formula:

\[
\text{Foam capacity} = \frac{\text{volume after whipping} - \text{volume before whipping}}{\text{volume before whipping}} \times 100
\]

**Viscosity measurement**

The method of Onwuka (2005) was used for the viscosity measurement. Ten grams of sample was weighed and emptied into a beaker after which 100 mL of distilled water was added. The mixture was then stirred properly for 2 h at room temperature. Using Oswald type viscometer, viscosity was measured.

**Water and oil absorption capacities**

The water and oil absorption capacities were carried out according to the method described by Sosulski et al. (1976). 10 mL distilled water or oil was mixed with 1 g of the flour sample, the mixture was allowed to rest at 30 ± 2°C for 30 min and then centrifuged at 200xg for 30 min.
Table 1. Effect of fermentation on the proximate composition of defatted coconut flour.

<table>
<thead>
<tr>
<th>Parameters (%)</th>
<th>UCM&lt;sub&gt;A&lt;/sub&gt;</th>
<th>FCM&lt;sub&gt;B&lt;/sub&gt;</th>
<th>FCM&lt;sub&gt;C&lt;/sub&gt;</th>
<th>FCM&lt;sub&gt;D&lt;/sub&gt;</th>
<th>LSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>12.31±0.08</td>
<td>13.13±0.07</td>
<td>13.75±0.14</td>
<td>15.00±0.03</td>
<td>0.23</td>
</tr>
<tr>
<td>Moisture</td>
<td>5.27±0.01</td>
<td>4.04±0.04</td>
<td>3.19±0.02</td>
<td>2.67±0.05</td>
<td>0.13</td>
</tr>
<tr>
<td>Crude fat</td>
<td>0.48±0.03</td>
<td>0.58±0.00</td>
<td>0.64±0.07</td>
<td>0.67±0.02</td>
<td>0.14</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>11.81±0.03</td>
<td>9.47±0.09</td>
<td>12.91±0.01</td>
<td>13.23±0.05</td>
<td>0.14</td>
</tr>
<tr>
<td>Ash</td>
<td>2.76±0.07</td>
<td>1.38±0.03</td>
<td>0.95±0.11</td>
<td>1.02±0.04</td>
<td>0.19</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>67.37±0.00</td>
<td>71.40±0.23</td>
<td>68.56±0.03</td>
<td>67.41±0.05</td>
<td>0.38</td>
</tr>
</tbody>
</table>

*values are means ± SD of triplicate determinations.
*values with common superscript letters in each row are not significantly different (p>0.05)
UCMA – Unfermented coconut meat flour (0 h)
FCMB – Fermented coconut meat flour (24 h)
FCMC – Fermented coconut meat flour (48 h)
FCMD – Fermented coconut meat flour (72 h)

Least gelation capacity

The method by Onwuka (2005) was used to determine the least gelation capacity. Sample suspensions of 2 - 20% (w/v) were dissolved respectively in a boiling test tube containing 5 mL of distilled water and heated for 1 h in a boiling water bath. The heated dispersion were cooled rapidly under running cooled water and then cooled further at 4°C for 2 h. Gelation was determined either by its ability to flow or not in test tube when slanted. The gelation capacity is the least gelation concentration determined as the concentration when the sample from the inverted test tube will not fall or slip.

Emulsification capacity (EC)

Emulsification capacity was determined by the method described by Onwuka (2005). 2 g of each sample was blended with 25 mL of distilled water at room temperature for 30 s in a warring blender at 1600 rpm x g. After complete dispersion, 25 mL vegetable oil was added and the blending was continued for another 30 s. The mixture was transferred into a centrifuge tube and centrifuged at 1600 rpm x g for 5 min. The volume of oil secreted from the sample after centrifugation was read directly from the tube.

Calculation: emulsion capacity is expressed as the amount of oil emulsified and held per g of sample.

$$\text{Emulsion capacity} = \dfrac{X}{Y} \times 100$$ \hspace{1cm} (3)

Where X= Height of emulsified layer
Y= Height of whole solution in the centrifuge tube

Statistical analysis

All results were subjected to analysis of variance (ANOVA) using a prepackaged computer statistical software (MINITAB 15).

RESULTS AND DISCUSSION

Proximate analysis of defatted flour samples

The effect of fermentation on the proximate composition of defatted coconut flour is presented in Table 1. The protein, moisture, crude fat, crude fibre, ash and carbohydrate content of the four different samples showed a significant difference (p < 0.05) with increased fermentation time. The protein content of defatted coconut flour increased significantly (p < 0.05) with increase in the fermentation time. The values ranged from 12.31 ± 0.08 % at 0 h to 15.00 ± 0.03 % at 72 h. This trend is similar to the observations of Egounlety (1994) who observed a significant increase in protein content of soybean (Glycine max), Cowpea (vigna Unguiculata) and ground bean (Macrotylooma geocarpa). Michodjehoun et al. (2005) also observed an increase in protein content from 7.9 – 10% during fermentation of millet. This increase could be attributed to the increase in microbial mass during fermentation, causing extensive hydrolysis of the protein molecule to amino acid and other simple peptides.

Moisture content decreased with significant difference (p < 0.05) as fermentation time increased, the peak moisture content was obtained at 0 h. Values for moisture ranged from 5.27 ± 0.01 % to 2.67 ± 0.02 % at 0 hour and 72 h respectively. The decrease in moisture content with fermentation time may be probably due to the soft texture of the coconut which allowed leaching of soluble mineral element into the processing water.
Table 2. Effect of fermentation on some functional properties of defatted coconut flour.

<table>
<thead>
<tr>
<th>Parameters (%)</th>
<th>UCMa</th>
<th>FCMb</th>
<th>FCMc</th>
<th>FCMD</th>
<th>LSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Density (gmL⁻¹)</td>
<td>0.51±0.02</td>
<td>0.50±0.04</td>
<td>0.49±0.03</td>
<td>0.46±0.02</td>
<td>0.04</td>
</tr>
<tr>
<td>WAC (mLg⁻¹)</td>
<td>2.00±0.05</td>
<td>2.00±0.12</td>
<td>2.50±0.07</td>
<td>2.70±0.14</td>
<td>0.36</td>
</tr>
<tr>
<td>OAC (mLg⁻¹)</td>
<td>2.70±0.04</td>
<td>2.69±0.08</td>
<td>2.40±0.23</td>
<td>2.10±0.11</td>
<td>0.23</td>
</tr>
<tr>
<td>EC (%)</td>
<td>50.00±0.20</td>
<td>47.50±0.34</td>
<td>46.83±0.27</td>
<td>45.83±0.12</td>
<td>0.70</td>
</tr>
<tr>
<td>FC (mLg⁻¹)</td>
<td>0.04±0.00</td>
<td>0.03±0.00</td>
<td>0.02±0.00</td>
<td>0.01±0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

* Values are means ± SD of triplicate determinations.
*Values with common superscript letters in each row are not significantly different (p>0.05)

UCMA – Unfermented coconut meat flour (0 h)
FCMB – Fermented coconut meat flour (24 h)
FCMC – Fermented coconut meat flour (48 h)
FCMD – Fermented coconut meat flour (72 h)
WAC – Water absorption capacity, EC= emulsification capacity
OAC – Oil absorption capacity, FC= foaming capacity

Crude fat showed a significant increase (p < 0.05) with an increase in fermentation time. Values ranged from 0.48±0.03 % at 0 h to 0.67 ± 0.05 % at 72 h. Usha et al. (1996) reported a similar trend in fat content of fermented millet. This increase could be attributed to extensive break down of large fat molecule to simpler fatty acid units.

Crude fibre content reduced from 11.81 ± 0.03 % at 0 h to 9.47 ± 0.09 after 24 h of fermentation while it later increased from 12.91 ± 0.01 % to 13.23 ± 0.05 % after 48 and 72 h respectively. This trend is in agreement with the work of Udensi and Okoronkwo (2006) that showed an increase in crude fibre of fermented *Mucuna cochinchinensis*.

Ash content decreased significantly (p < 0.05) from 2.76 ± 0.07 % at 0 h to 1.02 ± 0.04% at 72 h. However at 48 h and 72 h, ash content showed no significant difference (p > 0.05), which is probably due to the long fermentation time. This is similar to the observation of Atti (2000) who reported a decrease in ash content of millet with increase in time of fermentation (2.70 to 2.68 %). Michodjehoun et al. (2005) also reported a decrease in ash content during fermentation of “Gowe”, a traditional food made from sorghum, millet or maize (1.7 to 1.8 % on dry basis). The decrease in ash content is attributable to the leaching of soluble mineral element from the coconut into water.

Carbohydrate content ranged from 67.37 ± 0.00 % at 0 h to 71.40 ± 0.23 % at 24 h and later reduced to 68.56 ± 0.03 % to 67.41 ± 0.05 % after 42 and 72 h of fermentation respectively. This decrease in carbohydrate content could be attributed to the decrease in the moisture content of coconut flour as the fermentation time increased.

Functional properties of defatted coconut flour

The effect of fermentation on the functional properties of defatted coconut flour is presented in Table 2. The bulk density of defatted coconut meat flour decreased with increase in fermentation time, the values ranged from 0.51 ± 0.02 gmL⁻¹ to 0.46 ± 0.02 gmL⁻¹ however there was no significant difference (p>0.05) with increase in fermentation time from 0 to 72 h respectively. Peleg (1983) reported that bulk density depends on the combined effects of interrelated factors such as the intensity of attractive inter-particle forces, particle size, and number of contact points. The result is similar to that of Igbal et al. (2012) on sweet detar and hamburger bean flour. Also Onimawo and Akubor (2005) reported that germination and fermentation leads to decrease in the bulk density of foods.

Fermentation significantly (p < 0.05) increased the water absorption capacity of coconut flour, the values ranged from 2.00 ± 0.05 to 2.70 ± 0.14 mLg⁻¹ with increased fermentation time from 0 h to 72 h. The increase in water absorption capacity could be attributed to the presence of high hydrophilic constituents as the fermentation time increased (Badifu and Akubor, 2001).

The oil absorption capacity of fermented defatted coconut meat flour decreased significantly (p > 0.05) from 2.70 ± 0.04 to 2.10 ± 0.11 mLg⁻¹ with increase in fermentation time from 0 h to 72 h. The result is in disagreement with that of El Khalifa et al. (2005) who reported increase in oil absorption capacity in the fermentation of sorghum flour. The result however agrees with the work of Abulude (2004) who observed a significant decrease in oil absorption capacity of rice. The decrease observed could be attributed to the increase in the fat content during the fermentation process, which probably decreases the hydrophobicity of the system.

The emulsification capacity decreased significantly with increase in fermentation time with values ranging from 50.00 ± 0.20 to 45.83 ± 0.12 % after 72 h of fermentation. This decrease in emulsification capacity could be attributed to the ability of the protein to lower the tension at the interface of water and oil. The stability effect of protein on emulsion is due to the protective barrier
Table 3. Effect of fermentation on viscosity of defatted coconut meat flour.

<table>
<thead>
<tr>
<th>Parameters (%)</th>
<th>UCMa</th>
<th>FCMb</th>
<th>FCMc</th>
<th>FCMd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity at speed 6(Nm⁻²s)</td>
<td>1810 ± 78.65</td>
<td>1891 ± 20.00</td>
<td>1918 ± 11.55</td>
<td>1923 ± 45.28</td>
</tr>
<tr>
<td>Viscosity at speed 12(Nm⁻²s)</td>
<td>908 ± 12.44</td>
<td>948 ± 9.72</td>
<td>962 ± 24.67</td>
<td>995 ± 5.00</td>
</tr>
<tr>
<td>Viscosity at speed 30(Nm⁻²s)</td>
<td>364 ± 7.79</td>
<td>375 ± 14.28</td>
<td>385 ± 10.21</td>
<td>397 ± 23.00</td>
</tr>
</tbody>
</table>

*Values are means ± SD of triplicate determinations.

UCM – Unfermented coconut meat flour (0 h)
FCMB – Fermented coconut meat flour (24 h)
FCMC – Fermented coconut meat flour (48 h)
FCMD – Fermented coconut meat flour (72 h)

Table 4. Effect of fermentation on the least gelation capacity of defatted coconut meat flour.

<table>
<thead>
<tr>
<th>Samples (%)</th>
<th>Least gelation capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCMa</td>
<td>10</td>
</tr>
<tr>
<td>FCMb</td>
<td>20</td>
</tr>
<tr>
<td>FCMc</td>
<td>20</td>
</tr>
<tr>
<td>FCMd</td>
<td>20</td>
</tr>
</tbody>
</table>

around fat droplet that prevents their coalescence (Onimawo and Akubor, 2005).

Foaming capacity showed no significant difference (p > 0.05) with increase in fermentation time. Foaming capacity ranged from 0.04 g mL⁻¹ at 0 h to 0.01 g mL⁻¹ after 72 h but did not vary significantly (p > 0.05) with increased fermentation time, however a decrease in values was observed as fermentation time increased from 0 h to 72 h. The slight decrease in foaming capacity may be explained on the basis of presence of globular proteins which makes denaturing of the surface difficult (Okpala et al, 2013). This trend is also similar to the observations of Adebowale et al. (2005) who reported 0.94 g mL⁻¹ at 0.5 h to 0.70 g mL⁻¹ at 24 h for mucuna vera cruz mottle. The decrease in the foaming capacity of coconut flour could be attributed to the relative increase in the fat content during the fermentation period. Lipids are known to destabilize foams by displacing proteins from the air-water inter-phase. The negative influence of lipid content on foaming character of whey protein has been recognized by researchers, according to kunze (2005) in beer production the greatest negative effect is the foam destroying effect of lipids.

Table 3 shows the viscosity measurements which were carried out at three different speeds 6, 12 and 30 which increased as fermentation time increased. Values of viscosity at speeds 6, 12 and 30 ranged from 1810 ± 78.65 44 Nm⁻²s at 0 h to 1923 ± 45.28 Nm⁻²s at 72 h, 908 ± 12.44 Nm⁻²s at 0 h to 995±5.00 Nm⁻²s at 72 h and 364 ± 7.79 Nm⁻²s at 0 h to 397 ± 23.00 Nm⁻²s at 72 h respectively. This increase could be attributed to an increase in the effective volume of the protein which generally results from increased molecular asymmetry brought about by a change from highly compact to an elongated random coil (Onimawo and Akubor, 2005).

The least gelation capacity data is presented in Table 4. The least gelation capacity of coconut flour increased as the fermentation period increased. The values obtained were 10% at 0 h and 20% at 24 h, 48 h and 72 h i.e. at the concentration of 0.5g/5mL and 1.0g/5mL respectively. This could be due to the increase in the concentration (Iwe, 2003) which resulted in the rapid change in the consistency of the protein when heat was applied to form a 3-dimensional continuous network which traps and immobilizes the liquid within it to form a rigid structure that is resistant to flow under pressure.

Conclusion

Fermentation processing technology was successfully used in producing defatted coconut flour. The result of the study showed that the nutrient content increased after 72 h fermentation. There is also a general increase in the water absorption capacity and viscosity and very slight decrease in foaming capacity and oil absorption capacity with increased fermentation time. This implies that coconut flour has good functional properties and can be of good applicability in different food systems such as bread, cake and biscuit production. Fermentation has increased the nutrient content and improved the functionality of coconut flour; therefore, it is an adequate processing technique for coconut meat which could be utilized in different food systems for different age groups.
REFERENCES


