Effects of Boiling and Autoclaving on the Chemical Composition and Functional Properties of Mucuna Flagellipes Seed Flours

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ABSTRACT
The effects of boiling and autoclaving on the chemical composition and functional properties of Mucuna flagellipes flours were studied. The Mucuna flagellipes seeds were sorted, cleaned and processed into boiled and autoclaved seed flours. The flours obtained were analyzed for proximate, mineral and functional properties using standard analytical methods. The proximate composition of the samples showed that the flours had a range of moisture, 10.22-11.60 %, crude protein, 25.52-27.68%, fat, 7.25-8.29%, ash, 4.42-4.65%, crude fibre, 8.19-12.82%, carbohydrate, 47.84-52.45% and energy, 376.43-378.39 KJ/100g, respectively. The mineral composition of the flours showed that the calcium, potassium, phosphorus, magnesium, iron and zinc contents of the samples varied between 138.20-166.50mg/100g, 132.40-145.00mg/100g, 133.00-137.95mg/100g; 138.80-144.50mg/100g, 28.50-32.60mg/100g and 5.89-6.40mg/100g, respectively. The functional properties of the flours also revealed that the water absorption, oil absorption, gelation, foam and swelling capacities and the solubility index of the samples were significantly (p < 0.05) increased by autoclaving than the boiling treatment. The proximate, mineral and functional properties of the flours evaluated suggested that the flours have the potentials to be used both as nutritional supplements and functional ingredients in the preparation of a number of baked and complementary food products.

Keywords: Mucuna flour, boiling, autoclaving, proximate composition, mineral content, functional properties.

INTRODUCTION
Legumes or pulses are good sources of protein in human and animal food and are protein complements to cereals. Unconventional legumes are promising in terms of nutrition, food security and agricultural development and in crop rotation in developing countries. The wild legume Mucuna consists of about 100 varieties which are in great demand as food, livestock feed and pharmaceutically valued products (FAO, 2011). Mucuna seeds are relatively high in protein, carbohydrate, crude fibre, minerals and vitamins but low in fat content (Adebowale et al., 2005). The seeds also possess good functional properties and in-vitro protein digestibility. The nutritional quality of Mucuna flagellipes protein depends on its essential amino acid content. Like cowpea, it is a good source of lysine, adequate in tryptophan but deficient in methionine and cystine (Udensi et al., 2001). The utilization of Mucuna flagellipes as human food is limited by the presence of naturally occurring anti-nutritional factors such as protease inhibitors, saponins, tannins, oxalates, phytates and haemagglutinins in them which are poisonous to humans or in some cases limit the nutrient availability to the body. However, these anti-nutrients can be drastically reduced or eliminated by the use of simple processing techniques such as boiling in water at high
temperatures, roasting, autoclaving, germination, fermentation, microwave treatment, dehulling and soaking in water, acidic or alkaline solutions (Obizoba, 1990; Tarek, 2002). Several anti-nutritional components of *Mucuna* seeds have been extracted, purified and used for the treatment of certain diseases. In addition, considerable interest has been drawn towards their anti-oxidant properties and potential medicinal values. All the parts of *Mucuna* plant have been reported to possess useful phytochemicals that are of high medicinal value in human and veterinary medicine. They also constitute an important raw material used extensively in folk medicine. *Mucuna* seeds are good sources of several alkaloids, anti-oxidants, anti-tumor and anti-bacterial compounds which have potential health benefits (Dia[llo and Berhe, 2003)

*Mucuna flagellipes* is the most widely cultivated and utilized among the numerous varieties of *Mucuna* family. It contains high level of protein (20.4%), carbohydrate (61%) and fat (9.6) on fresh weight basis (Enwere, 1998). The excellent nutritional value of the legume makes it possible to be used as nutritional supplements in a variety of African diets which are mainly formulated from root and tuber crops (Lazzos,1986). The cotyledons of the seeds are widely used as soup thickener when they have been broken, boiled sufficiently to soften them and milled into powder in the eastern parts of Nigeria. The seeds are sometimes broken, roasted with hot charcoal and ash, milled and used as soup thickener.

*Mucuna flagellipes* is one of the lesser known and under utilized legumes in the tropical regions of the world. It is a legume known to originate from Asia and was introduced into the hemisphere via Mauritius (Bau et al., 1997). It is known as “horse eye bean” and with other local names in respect to different tribes and ethnic groups. It is called ‘Ukpo’ by Ibos, Karasuu by Hausas and Yerepe by Yorubas. Despite its utilization as a soup thickener, it has been used also as additives in other foods to impart desirable texture and functional qualities in different food products (Okaka, 1997).

Nutritionally, the importance of “Ukpo” lies in its high content of lysine but is usually limited in the sulphur containing amino acids particularly methionine. The high content of lysine in *Mucuna flagellipes* makes it to be suitable complement to cereals which are relatively low in lysine (Enwere, 1998). The flour also possesses appreciable good functional properties like water absorption capacity, emulsifying capacity and foam capacity which make it to be useful as functional ingredient agents in the preparation of a number of food products. The objective of this study, therefore, is to investigate the effects of boiling and autoclaving on the chemical composition and functional properties of *Mucuna flagellipes* seed flours.

**MATERIALS AND METHODS**

Mature dried *Mucuna flagellipes* seeds used for the study were purchased from Enugu Main Market, Enugu State, Nigeria. The seeds were sorted, decorcted, cleaned and divided into three equal portions of 500g each. Two portions were subjected to different processing treatments (boiling and autoclaving) while the third batch was processed raw.

**Preparation of Raw *Mucuna flagellipes* seed flour**

The raw *Mucuna flagellipes* flour was prepared according to the method of Udensi et al. (2001). During preparation, five hundred grammes (500g) of *Mucuna flagellipes* seeds which were free from extraneous materials were cleaned with 1.5liters of potable water and dehulled manually by cracking them with stones followed by winnowing to remove the hulls. The dehulled seeds were spread on trays and dried in a hot air oven (Model DHA 9101 ISA) at 60°C for 6 h with occasional turning of the seeds at intervals of 30 min to ensure uniform drying. The dried seeds were milled in an attrition mill and sieved through a 500 micron mesh sieve. The flour produced was packaged in an airtight plastic container, labeled and kept in a cool dry place until needed for analysis.

**Preparation of Boiled *Mucuna flagellipes* seed flour**

The boiled *Mucuna flagellipes* flour was prepared according to the method of Enwere (1998). During preparation, five hundred grammes (500g) of *Mucuna flagellipes* seeds which were free from extraneous materials were cleaned with 1.5 liters of potable water and dehulled manually by cracking them with stones followed by winnowing to remove the hulls. The dehulled seeds were boiled with 2 liters of potable water in a hotplate at 100°C for 30 min. The boiled seeds were drained, spread on the trays and dried in hot air oven (Model DHA 9101 ISA) at 60°C for 8 h with occasional turning of the seeds at
intervals of 30 min to ensure uniform drying. The dried seeds were milled in an attrition mill and sieved through a 500 micron mesh sieve. The flour produced was packaged in an airtight plastic container, labeled and kept in a cool dry place until needed for analysis.

**Preparation of Autoclaved Mucuna flagellipes seed flour**

The autoclaved *Mucuna flagellipes* flour was prepared according to the method of Udensi *et al.* (2001). During preparation, five hundred grammes (500g) of the seeds which were free from extraneous materials were cleaned with 1.5 liters of potable water and dehulled manually by breaking them with stones followed by winnowing to remove the hulls. The dehulled seeds were placed in a beaker and autoclaved at a temperature of 121°C and pressure of 6 atmospheres for 40 min in an autoclave (Model 75HG, Britain, UK). The autoclaved seeds were dried in a hot air oven (Model DHG 9101 ISA) at 60°C for 6 h. The dried seeds were milled in an attrition mill and sieved through a 500 micron mesh sieve. The flour produced was packaged in an air tight plastic container, labeled and kept in a cool place until needed for analysis.

**Chemical Analysis**

The moisture, crude protein, fat, ash and crude fibre contents of the samples were determined in triplicate according to standard analytical methods (AOAC, 2006). Carbohydrate was calculated by subtracting the difference of moisture, crude protein, ash and fat from 100 percent (Onwuka, 2005). The energy content of the flours was calculated by multiplying the percentages of crude protein, fat and carbohydrate by the Atwater factors of 4, 9 and 4, respectively (Tarek, 2002). The potassium and iron contents of the samples were determined after wet extraction by the use of a flame photometer (Model 405, Corning, UK) according to the method of Onwuka (2005). The calcium, magnesium and zinc contents of the flours were determined using atomic absorption spectrophotometer (Perkin-Elmer Model 1033, Norwalk, CT, USA) according to the method of AOAC (2006). Phosphorus was determined by the vanadomolybdate colorimetric method of Bau *et al.* (1997)

**Functional Properties**

The water absorption, oil absorption, foam and gelation capacities of samples were determined in triplicate according to the method of Onwuka,(2005). Swelling capacity was determined by the method of Udensi *et al.* (2001) whereas the solubility index was determined according to the cold water extraction method of Henshaw and Sobowale (1996).

**Statistical Analysis**

The data were analyzed using a one way experimental design and the mean, standard deviation and analysis of variance were calculated on the data obtained using special package for social science (SPSS version 21) to detect significant differences among the sample means. Results were recorded as mean ± SD and the significant differences were determined at p≤ 0.05. Significant means were separated using Turkey’s Least Significance Difference (LSD) test.

**RESULTS AND DISCUSSION**

**Proximate Composition**

The proximate composition *Mucuna flagellipes* seed flours are presented in Table 1. The moisture content of the samples was significantly (p ≤ 0.05) higher in boiled flour than in autoclaved sample. The increase could be attributed to the inhibition of large quantity of water by the seeds as a result of boiling during processing. This observation is in agreement with the report of Udensi *et al.* (2001) for boiled and soaked *Mucuna flagellipes* flours. The higher moisture content affects the storage stability of legume and other flour products. The crude protein content of the raw sample was 27.68%. The crude protein content of the processed flours was significantly (p ≤ 0.05) reduced by boiling than the autoclaving treatment. The reduction in the protein content of the boiled sample could be attributed to progressive solubilization and leaching out of some soluble nitrogenous substances into boiling water during processing (Adebowale *et al.*, 2005). The fat content of the samples ranged from 7.25 to 8.29% with boiled and autoclaved samples having the highest and the least values, respectively. The values obtained in this study were lower than the values (9.22-10.08%) reported by Onweluzo and Nwabugwu (2009) for boiled *Mucuna flagellipes* flour. The ash content of the flours was significantly (p≤ 0.05) lower in boiled flour than in the sample...
processed by autoclaving. The decrease in the ash content of the sample may be due to leaching of soluble inorganic salts into the boiling water during processing. The observation is in agreement with the report of Obizoba (1990) for boiled cowpea flour. The crude fibre content of the raw flour was the highest, while the crude fibre content of the processed samples which ranged from 8.19 to 8.34% was significantly (p≤0.05) reduced by autoclaving than the boiling treatment. The observed decrease in crude fibre content of the sample could be attributed to the thermal decomposition of some fibre components of the seeds due to high during autoclaving temperature(≥121°C) (Onweluzo and Nwabugwu, 2005).

The carbohydrate content of the flours was significantly (p≤0.05) lower in autoclaved flour than in the sample processed by boiling. The decrease could be attributed to the breakdown of complex carbohydrates which were bound in the raw sample as a result of autoclaving during processing. The observation is in consonance with the report of Udensi et al. (2001) for boiled and roasted Mucuna flours. The energy content of the samples was significantly (p≤0.05) reduced by autoclaving than the boiling treatment. The lower energy value may be a reflection of the low fat content of the autoclaved sample since fat has a high physiological energy value (Udensi et al., 2001; Obatolu et al., 2007). The boiled and autoclaved Mucuna flagellipes flours could be used as nutritional supplements in the preparation of beverages, complementary foods and baked products due to their high nutrient density. However, autoclaving gave product of higher protein and ash contents than the boiling treatment.

Mineral Composition

The mineral composition of Mucuna flagellipes seed flours are shown in Table 2. The calcium content of the raw sample was 166.50mg/100g. The calcium content of the processed samples was significantly (p≤0.05) higher in autoclaved flour compared to the sample processed by boiling. The increase could due to its less sensitivity to heat during autoclaving. The high calcium content of the sample is an indication that it has the ability to provide the body with reasonable amount of dietary calcium. Calcium in conjunction with magnesium, phosphorus and protein are involved in bone formation (Okaka et al., 2006).

The potassium content of the flours which ranged from 132.40-145.00mg/100 was significantly (p≤0.05) higher in the autoclaved sample than in the boiled flour. The values obtained in this study were higher than the values (124.2-131.8mg/100g) reported by Obizoba (1990) for cooked and germinated cowpea flours. Potassium is very essential in blood clotting and muscle contraction.

The phosphorus content of the samples was significantly (p≤0.05) increased by autoclaving than the boiling treatment. The decrease in phosphorus content of the boiled sample could be due to the leaching of the mineral element into the boiling water during boiling. The observation is in agreement with the report of Wanjakeche et al. (2003) for soaked and boiled Mucuna flours. Phosphorus helps in the formation of Adenosine Triphosphate (ATP) in the body (Okaka et al., 2006). The magnesium content of the raw flour was 144.50mg/100g, while the magnesium content of the processed flours ranged from 138.80 to 140.00mg/10g with boiled and autoclaved flours having the least and highest values, respectively. The decrease in magnesium of the boiled flour could be due to leaching out of the mineral element during boiling. Magnesium helps in the maintenance of the electrical potential of nerves. The iron content of the samples was significantly (p≤0.05) higher in autoclaved sample compared to the sample processed by boiling treatment. Iron is an important component of haemoglobin which is an oxygen carrying pigment in the blood. The zinc content of the flour was significantly (p≤0.05) lower in boiled sample than in the sample processed by autoclaving. The reduction could attributed to leaching of the mineral element into boiling water during boiling. The result, however, is in agreement with the report of Vadivel and Janardhanan (2000) for boiled and autoclaved velvet bean flours. Zinc acts as an activator of many enzyme systems in humans. Generally, autoclaving had a greater effect in enhancing the micro-nutrient content of Ukpo seed flour than the boiling treatment.

Functional Properties

The functional properties of Mucuna flagellipes seed flours are presented in Table 3. The water absorption capacity of the samples was significantly (p≤0.05) higher in autoclaved flour than in the sample processed by boiling. The disparity could be due to the modification of starch components of the flour during autoclaving. Flours with good water absorption capacity will be desirable for use in the
preparation of complementary foods. The oil absorption capacity of the flours were significantly (p≤0.05) reduced by autoclaving than the boiling treatment. The decrease could be attributed to the low fat content of the sample. The result is in agreement with the report of Diallo and Berhe (2003). Flours with excellent oil absorption capacity may be useful in the preparation of pastries and doughnuts. The gelation capacity of the samples was significantly (p≤0.05) higher in autoclaved sample than in the sample processed by boiling. The variation may be due to differences in carbohydrate content of the flours (Onimawo and Asugo, 2004). Flours with good gelation capacity will be desirable for use as soup thickeners. The gelatinization capacity of the flours was significantly (p≤0.05) lower in boiled sample than in the autoclaved flour. The values obtained in this study were higher than the values (152.52-158-10%) reported by Henshaw and Sobowale (1996) for cowpea flour. Flours with good foam capacity are desirable for use in the preparation of whipped cream and salad dressing. The swelling capacity of the flours which ranged from 155.3 to 157.5% was significantly (p≤0.05) reduced by boiling than the autoclaving treatment. The variation in the swelling capacity of the flours could be due to differences in the amylose and amylopectin contents of their starch (Adebowale et al., 2005). The excellent swelling capacity of the flours suggests that they may be useful as thickening and binding agents in the preparation of soaps, sauces and gravies. The solubility index of the flours was significantly (p≤0.05) higher in autoclaved sample than in the boiled flour. The observation is in agreement with the report of Obizoba (1990) for cowpea flour. Flours with good solubility index will be useful in the preparation of ice cream and frozen desserts. Generally, the functional properties of the flours were drastically enhanced by autoclaving than the boiling treatment. This showed that autoclaved Mucuna flagellipes flour could be more desirable for use as functional ingredients in food preparations than the boiled sample.

CONCLUSION
This study showed that boiling and autoclaving treatments had significant effects on protein, ash, carbohydrate, energy and mineral contents of Mucuna flagellipes seed flours. Of the two heat processing treatments used in this study, autoclaving seems to have more beneficial effect in enhancing both the nutrient content and the functional properties of Mucuna flour than the boiling treatment. It is, therefore, recommended that nutritional intervention programmes involving the use of boiled and autoclaved Mucuna flagellipes seed flours should be encouraged especially in developing countries where there is acute shortage of protein to minimize the problem of protein-energy malnutrition. Also, further studies should be carried out to determine the vitamin and amino acid profiles and storage stability of boiled and autoclaved Mucuna flagellipes flours.

Table 1: Proximate composition of Mucuna flagellipes seed flours.

<table>
<thead>
<tr>
<th>Parameters (%)</th>
<th>Raw</th>
<th>Boiled</th>
<th>Autoclaved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>11.60± 0.21</td>
<td>10.54± 0.55</td>
<td>10.22± 0.14</td>
</tr>
<tr>
<td>Crude protein</td>
<td>27.68± 0.69</td>
<td>25.52± 0.42</td>
<td>26.03± 0.30</td>
</tr>
<tr>
<td>Fat</td>
<td>8.29± 0.04</td>
<td>7.36± 0.14</td>
<td>7.25± 0.42</td>
</tr>
<tr>
<td>Ash</td>
<td>4.65± 0.04</td>
<td>4.24± 0.02</td>
<td>4.47± 0.07</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>12.82± 0.18</td>
<td>8.34± 0.27</td>
<td>8.19± 0.10</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>47.84± 0.59</td>
<td>52.45± 0.26</td>
<td>51.92± 0.30</td>
</tr>
<tr>
<td>Energy (KJ/100g)</td>
<td>376.43± 1.20</td>
<td>378.39± 0.26</td>
<td>378.04± 0.42</td>
</tr>
</tbody>
</table>

Values are mean ± SD of triplicate determinations. Means in the same row with different super scripts are significantly different (p ≤ 0.05).
Table 2: Mineral composition of *Mucuna flagellipes* seed flours.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Raw</th>
<th>Boiled</th>
<th>Autoclaved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium (mg/100g)</td>
<td>166.50±2.07</td>
<td>138.20±0.67</td>
<td>150.10±15.13</td>
</tr>
<tr>
<td>Potassium (mg/100g)</td>
<td>145.00±0.84</td>
<td>132.40±5.47</td>
<td>138.20±0.84</td>
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<tr>
<td>Phosphorus (mg/100g)</td>
<td>137.95±0.59</td>
<td>133.00±0.38</td>
<td>135.45±1.34</td>
</tr>
<tr>
<td>Magnesium (mg/100g)</td>
<td>144.50±2.27</td>
<td>138.80±0.67</td>
<td>140.00±0.38</td>
</tr>
<tr>
<td>Iron (mg/100g)</td>
<td>32.60±0.14</td>
<td>28.50±0.14</td>
<td>29.90±0.21</td>
</tr>
<tr>
<td>Zinc (mg/100g)</td>
<td>6.40±0.03</td>
<td>5.89±0.10</td>
<td>6.18±0.18</td>
</tr>
</tbody>
</table>

Values are mean ± SD of triplicate determinations. Means in the same row with different super scripts are significantly different (p ≤ 0.05).

Table 3: Functional properties of *Mucuna flagellipes* seed flours.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Raw</th>
<th>Boiled</th>
<th>Autoclaved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water absorption(mg/g)</td>
<td>6.11±0.04</td>
<td>6.10±0.03</td>
<td>6.33±0.17</td>
</tr>
<tr>
<td>Oil absorption(mg/g)</td>
<td>6.26±0.02</td>
<td>6.15±0.04</td>
<td>6.42±0.14</td>
</tr>
<tr>
<td>Gelation capacity(ml/g)</td>
<td>5.75±0.10</td>
<td>65.73±0.01</td>
<td>5.86±0.03</td>
</tr>
<tr>
<td>Foam capacity (%)</td>
<td>165.8±0.88</td>
<td>161.6±1.20</td>
<td>164.0±0.67</td>
</tr>
<tr>
<td>Swelling capacity (%)</td>
<td>157.5±1.66</td>
<td>155.3±1.37</td>
<td>156.7±1.37</td>
</tr>
<tr>
<td>Solubility index (%)</td>
<td>2.89±0.04</td>
<td>3.11±0.04</td>
<td>3.21±0.01</td>
</tr>
</tbody>
</table>

Values are mean ± SD of triplicate determinations. Means in the same row with different super scripts are significantly different (p ≤ 0.05).

REFERENCES


