**Note**

**Effect of Processing on Functional Properties of Yam Beans (Sphenostylis stenocarpa)**

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The proximate and functional properties of yam bean were determined in five-flour form as raw, boiled, fermented, roasted and malted. The functional properties determined were water absorption, fat absorption gelation, emulsion and foam capacities as well as foam stability. An improvement was observed in protein under all the processing conditions. Protein content ranged from 20.43% in raw flour to 23.63% in malted flour. Fermentation significantly \((p<0.05)\) increased the fat content of the flour. The emulsifying and foaming capacities \((50.7\% \text{ and } 40.20\%)\), respectively observed for raw flour were significantly higher than for the processed flours. Gelation was significantly \((p<0.05)\) increased and decreased respectively, by fermentation and malting. The water absorption capacity ranged from 131.9% in raw flour to 218.8% in boiled flour. There was no significant \((p>0.05)\) difference in the fat absorption capacity of the flours except the fermented flour \((0.40 \text{ ml/g})\) which was significantly lower than the value \((0.73 \text{ ml/g})\) obtained for boiled flour. Though a high foaming capacity was observed for raw flour, this was less stable compared with the processed flours. Yam bean flour was found to exhibit good functional properties and can offer a great potential in various food systems.

Keywords: lesser legume, processing conditions, functional properties, denature, protein modification

The African yam bean is a lesser-known grain legume of tropical origin that has attracted research interest in recent times (Nwokoko, 1987). The plant is found growing wild throughout tropical Africa and most commonly in central and western Africa, especially in southern Nigeria. It is also reported to be cultivated in Ivory Coast, Ghana, Togo, Gabon, Congo, Ethiopia and parts of east Africa (Okigbo, 1973). It grows well in acid and highly leached sandy soils of the humid lowland tropics where other major food legumes do not flourish, and yields more than most other pulses. The seeds are delicious and are usually eaten alone, or with yams, maize, rice, or in soups.

Yam beans (YB) have attracted research interest due to their nutrient content (Evans & Boulter, 1974). Amino acid analyses indicate that the lysine and methionine levels in the protein are equal to or better than those of soybeans. The characteristic problem of the hard-to-cook phenomenon that has hindered the extensive use of YB has been substantially reduced by prickling treatments (Njoku et al., 1989). The ultimate success of utilizing plant protein in food formulation depends largely upon the functional attributes. The beans have been processed into flour and paste used locally for moin-moin (cooked paste) and “A kara” (fried bean balls). There is still a limited amount of information about the food uses of the YB seeds; therefore, the objective of this study was to investigate the effect of processing on the functional properties of YB flour for food formulations.

**Material and Methods**

Yam beans Dried yam beans (mixed varieties) were obtained from Institute of Agricultural Research and Training, Moor Plantation, Ibadan, Nigeria. Before processing, beans were hand-sorted to remove foreign materials then subjected to various processing methods before making flour.

Processing of yam bean grains

Malted flour Malting was carried out as described by Kulkan et al. (1991). The grain was soaked for 24 h in a volume of tap water three times its weight and drained using a woven basket. The seeds were then spread in a wide wooden box covered with a jute bag for germination under ambient temperature for 72 h. Seeds were watered 2 times daily. The germinated grains were cleaned of sprouts, dried in an oven (Theuco model 28) set at 60°C for a period of 16 h and hammer milled (Glenmills DCFH-48) into flour.

Fermented flour YB grains were soaked in distilled water for 12 h. The water was drained and the grains spread in a covered calabash in layers (3 cm deep). The calabash was wrapped in two layers of dried jute bag and kept in a warm \((34±2°C)\) place for 48 h to create the appropriate condition for lactic bacteria fermentation. The fermented samples were oven (THELCO-28) dried at 60°C and milled (Glenmills DCFH48) into flour.

Roasted flour An aluminum frying pan on a hot plate (Corning PC-520) was heated to 60°C and 50 g of YB grain was added. Roasting continued until the temperature reached 120°C, then was stopped; thereafter the grains were continuously stirred until the temperature dropped to 50°C.

Boiled flour YB grains were boiled for 8 h with sufficient water until tender. Excess water was decanted; grains were oven dried (THELCO-28) at 60°C before milling into flour as described above.

Raw flour Raw YB grains were milled into flour as noted above.

Proximate analysis The moisture, fats and ash contents of...
the sample were determined by the method of AOAC (1990). Total nitrogen in the sample was determined by the micro Kjeldahl method and the crude protein calculated using the factor N (%)×6.25 (AOAC, 1990).

Functional Properties

Gelation capacity (GC) GC was measured by the least gelation concentration method of Sathe and Salunkhe (1981). Sample suspensions of 2–20% (w/v) were prepared in 5-ml distilled water using test tubes. The test tubes containing these suspensions were then heated for 1 h in a boiling water bath (Grant W28) followed by rapid cooling under cold running tap water. The test tubes were further cooled for 2 h at 4°C; later, each test tube was inverted to evaluate the strength of the coagulum. The least gelation concentration was the sample that formed gel and remained in the inverted test tube.

Foaming capacity (FC) FC was determined by the method of Giami and Bekebain (1992). The sample (2 g) was blended with 100 ml distilled water in a Kenwood blender. The suspension was whipped in an Ace homogenizer (NISEI AM-6) at 1600 rpm for 5 min. The mixture was poured into a 250 ml-graduated cylinder and the volume was recorded after 30 s. The foaming capacity was expressed as percent increase in volume using the formula:

\[
FC = \frac{\text{vol. after whipping} - \text{vol. before whipping}}{\text{vol. before whipping}} \times 100
\]

Foaming stability = foam volume after 120 min / initial foam volume \times 100.

Emulsifying capacity (EC) The method described by Yatsu-matsu et al. (1972) was used for the determination of EC. Samples (1.0 g) were suspended in 50 ml of distilled water, then 50 ml of refined groundnut oil was added. The mixture was emulsified with an Ace homogenizer (NISEI AM-6) at 10,000 rpm for 1 min. The emulsion obtained was divided evenly into two 50-ml centrifuge tubes and centrifuged (Beckman GS-6R) at 4100 rpm for 5 min.

\[
EC = \frac{\text{Height of emulsified layer}}{\text{Height of whole layer}} \times 100
\]

Water absorption capacity (WAC) WAC was determined by the method of Ige (1984). Samples (1.0 g) were suspended in 10 ml of distilled water and were vigorously mixed 4 times with a 10 min rest period between each mixing. Samples were then centrifuged (Beckman GS-6R) and the top layer was decanted off. It was oven dried (THELCO-28) and weighed. WAC was calculated as:

\[
\text{WAC} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Initial weight}} \times 100.
\]

Fat absorption capacity (FAC) FAC was also determined using the method of Ige et al. (1984). A 0.5 g of sample was added to 3 ml of refined groundnut oil. The sample was stirred for 1 min and, after 30 min rest, it was centrifuged (Beckman GS-6R) at 3200 rpm for 25 min. The top oil was decanted.

Statistical analysis The results obtained were subjected to analysis of variance using Duncan multiple range test to determine the significance of differences between means (Duncan, 1955). Significance was accepted at \( p \leq 0.05 \).

Results and Discussion

Proximate composition The results of the proximate analyses of the raw, germinated, fermented, roasted and boiled flour are shown in Table 1. Moisture varied by less than 2% in all the treatments. Crude protein was higher in the malted flour. Other authors (Akpanam & Achinewhu, 1985; Giami, 1993) have reported similar observations of malting. Kylen and McCready (1975) attributed the increase to protein synthesis at the time of sprouting. The increase might also be due to changes resulting from the uptake of tap water during sprouting (Del Rosario & Flores, 1981). The high protein content in the present study can also be attributed to the low moisture content of the malted flour. There was no significant (\( p > 0.05 \)) difference in the fat content of the processed flours except the fermented sample which had a significantly (\( p < 0.05 \)) higher value. This is contrary to the 17.65% decrease in fat content observed by Giami (1993) in cowpea germinated flour. The roasted and malted flours had significantly (\( p < 0.05 \)) higher ash content while boiling significantly reduced the ash content. Other investigations have shown that as protein increases, ash content also increases (Kylen & McCready, 1975, Del Rosario & Flores 1981). Giami (1993) reported a 3.23% increase in total ash content of germinated cowpea flour. The low ash content observed in the boiled sample is attributed to the leaching of some minerals during the long cooking time.

Functional properties The functional properties of the raw and processed yam bean flours are given in Table 2. Processing conditions had a significant increasing (\( p < 0.05 \)) effect on WAC compared with raw flour. Of all the processing conditions, malting had the lowest (150.6%) and boiling had the highest (218.8%) WAC. Padmashree et al. (1987) reported that polar amino acids of a protein have an affinity for water and denatured protein binds more water. The long boiling time (8 h) might have caused the yam bean protein to denature, thus the high value obtained for water absorption capacity in the present study. Heat

### Table 1. Proximate composition of raw and processed yam bean flours (%).

<table>
<thead>
<tr>
<th>Process</th>
<th>Moisture</th>
<th>Ash</th>
<th>Protein</th>
<th>Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>7.82</td>
<td>3.92b</td>
<td>20.43b</td>
<td>1.97b</td>
</tr>
<tr>
<td>Boiled</td>
<td>7.49</td>
<td>3.02c</td>
<td>21.30b</td>
<td>1.97b</td>
</tr>
<tr>
<td>Fermented</td>
<td>7.38</td>
<td>3.62b</td>
<td>21.83b</td>
<td>2.23a</td>
</tr>
<tr>
<td>Roasted</td>
<td>6.33</td>
<td>4.38a</td>
<td>21.67b</td>
<td>2.13b</td>
</tr>
<tr>
<td>Malted</td>
<td>6.81</td>
<td>4.42a</td>
<td>23.63a</td>
<td>1.96b</td>
</tr>
<tr>
<td>LSD Value</td>
<td>2.447</td>
<td>0.372</td>
<td>1.37</td>
<td>2.00b</td>
</tr>
</tbody>
</table>

Mean values in the same column with different superscripts are significantly different (\( p < 0.05 \)).

### Table 2. Functional properties of raw and processed yam bean flours.

<table>
<thead>
<tr>
<th>Process</th>
<th>WAC (%)</th>
<th>FAC (ml/g)</th>
<th>GC (%)</th>
<th>EC (%)</th>
<th>FC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>131.9c</td>
<td>0.600ub</td>
<td>14.26b</td>
<td>50.7a</td>
<td>40.20a</td>
</tr>
<tr>
<td>Boiled</td>
<td>218.8a</td>
<td>0.7333a</td>
<td>14.04b</td>
<td>28.0b</td>
<td>1.98d</td>
</tr>
<tr>
<td>Fermented</td>
<td>157.7b</td>
<td>0.400b</td>
<td>16.12a</td>
<td>23.2b</td>
<td>7.81b</td>
</tr>
<tr>
<td>Roasted</td>
<td>167.3b</td>
<td>0.667ab</td>
<td>14.00b</td>
<td>20.0b</td>
<td>4.90c</td>
</tr>
<tr>
<td>Malted</td>
<td>150.6b</td>
<td>0.533ab</td>
<td>11.53c</td>
<td>28.2b</td>
<td>7.84b</td>
</tr>
<tr>
<td>LSD Value</td>
<td>18.65</td>
<td>0.273</td>
<td>1.31</td>
<td>10.31</td>
<td>2.112</td>
</tr>
</tbody>
</table>

Mean values in the same column with different superscripts are significantly different (\( p < 0.05 \)).
Treatment has been reported to improve water absorption capacity of some other legumes (Del Rosario & Flores, 1981; Narayana & Narasinga, 1982; Giami, 1993; Pawar & Ingle, 1988). Giami (1993) reported that water absorption indicates the ability of a product to associate with water under a condition where water is limited. Therefore, the high WAC observed for boiled yam bean flour suggests the usefulness of the flour in bakery products. The WAC value observed for raw YB flour is higher than that observed for raw mung bean flour (Del Rosario & Flores 1981).

Boiled YB flour had the highest (0.73 ml/g) fat absorption capacity which was significantly (p<0.05) higher than that obtained for fermented YB flour (Table 2). The processing conditions did not result in any significant (p>0.05) increase or decrease compared to the raw flour. The physical entrapment of oil has been attributed to the fat absorption capacity (Padmashree et al., 1987). The ability of a food crop to entrap oil is an important characteristic in food formulation. This is because fat acts as a flavor retainer and enhances the mouth feel of foods (Kinsella, 1976). The increase in fat absorption has been attributed to heat treatment just as with water absorption. The same has been observed for heated mung bean (Del Rosario & Flores, 1981). Increase in fat absorption is associated with heat-dissociation of the proteins and denaturation, which is expected to unmask the nonpolar residue from the interior of the protein molecules (Kinsella, 1976).

Least gelation concentration of about 14% was observed for raw, boiled and roasted flour while values of 16% and 11.5% were observed for fermented and malted, respectively. The GC value of fermented YB observed in the present study is similar to that of fermented dried cowpea flour (16%), as reported by Henshaw and Lawal (1993) and higher than mung bean flour (Del Rosario & Flores, 1981). Gelation capacity of legumes has been attributed to the globulin fraction and aggregation of denatured protein molecules (Fleming et al., 1975). The significant decrease in GC value observed in malted flour might be due to interaction of amylase and starch in YB during malting (Obatolu & Cole, 2000). This property is required for food systems that require thickening and gelling.

All processing conditions resulted in significant (p<0.05) reductions in EC of the YB flour. This might be a result of repulsion of the protein and oil phase during processing (Beuchat, 1977). The results show the direct effect of heating (boiling and roasting), malting and fermentation on modification of the YB protein. The degree of heating has been identified as the primary determinant in the reduction of EC of some other legumes (McWaters & Holmes, 1979; Eke & Akobundu, 1993). The reduced EC observed in the present study for malted and roasted YB grains is consistent with the findings of Eke and Akobundu (1993), but higher than that observed for roasted yam beans. Similarly, Padmashree et al. (1987) observed a lower EC for processed cowpea flour except fermented flour. The present study agrees with Eke and Akobundu (1993) that none of these processing conditions is appropriate for YB intended for spread formulations that require high emulsifying capacity.

The foaming capacity value (40.20%) obtained for raw flour was significantly (p<0.05) higher than those obtained for the processed flours. A lower foaming capacity of 25–33% had been reported for raw cowpea flour (Henshaw & Lawal 1993). The fermented (7.81%) and malted (7.84%) flours had a significantly (p<0.05) higher foam capacity than the boiled and roasted flours. The value obtained for roasted flour (4.90%) was significantly higher than that obtained for the boiled sample (1.98%). Padmashree et al. (1987) reported the decreasing effect of processing conditions on foam capacity with processed cowpea flour. Giami (1993), however, reported an increasing effect of germination while fermentation and heat treatment had a decreasing effect in his study on processed cowpea flour. As in the present study, Eke and Akobundu (1993) reported the reducing effect of roasting on foam capacity of African yam bean; Narayana and Narasinga (1982) found a similar effect on winged bean flour. The more pronounced reduction of foaming capacity in heat-treated (boiling and roasting) samples has been reported to be due to protein denaturation (Lin et al., 1974). It is also an indication of precipitation of proteins due to the temperature and time of the heat treatment used in the present study. Raw yam bean flour had the best whipping property of 130 ml which produced less stable foam than those of the processed flours. The stability of the foam after 2 h was 88.7%, 97.5%, 93.7%, 94.6% and 93.6%, respectively, for raw, boiled, fermented, roasted and malted yam bean flour. A contrary result of effect of heat treatment on foaming stability of cowpea flour (Giami, 1993, Padmashree et al., 1987) and mung bean flour (Del Rosario & Flores, 1981) have been reported. Lin et al. (1974) reported that foaming stability is related to the amount of native protein, which gives higher foam stability than denatured protein (Yatsumatsu et al., 1972). Cherry and McWaters (1981), however, proposed that both non-protein nitrogen compounds and carbohydrates could stabilize foams.

Conclusion

The present study shows the great potential of yam beans (Sphenostylis stenocarpa) for incorporation into human food products, not only as protein supplements in the diets of the poor populace but also as a functional agent in fabricated foods. The flour under different processing conditions exhibited different functional properties, which could be a basis for selection in food application. There is a need for further studies on reaction of the protein in the processed flours with other constituents (starch, lipid) of food products.

References


