Nutrient composition and functional properties of raw, defatted and protein concentrate of sesame (Sesamum indicum) flour

Ogungbenle H.N. and Onoge F.

Abstract
The proximate, functional properties, minerals and anti-nutrients composition of sesame raw, defatted and protein concentrate flours were investigated. The raw flour contained fat (40.97 g/100g), crude protein (33.91 g/100g), ash (4.04 g/100g), moisture (11.69 g/100g), fibre (5.63 g/100g), carbohydrate (3.77 g/100g); defatted sample contained fat (4.54 g/100g), crude protein (35.69 g/100g), ash (4.22 g/100g), moisture (10.32 g/100g), fibre (5.49 g/100g), carbohydrate (12.29 g/100g) and the protein concentrate contained fat (31.99 g/100g), crude protein (51.86 g/100g), ash (2.62 g/100g), moisture (1.69 g/100g), fibre (3.79 g/100g), carbohydrate (35.51 g/100g). The predominant mineral was potassium, while the least was sodium. Water absorption, oil absorption and emulsion capacities were relatively high while foaming capacity and least gelation concentration were moderately good. The results showed that the protein concentrate, defatted and raw flours may be useful in some food formulations.

Keywords: Nutrient, functional, raw, defatted, protein concentrate, sesame

1. Introduction
In the recent century, hustle for survival is the pre occupation of many families and individuals living below the poverty line. This has led to some individuals to rely on non-nutritive and starchy foods for their daily survival, there is need to provide these groups with information about the nutritive status of some underutilized crops readily available in their domain. Sesame seed (Sesamum indicum) is a tropical annual crop and one of the oldest cultivated plants in the world. It is a highly prized oil crop of some countries in the world. The specie has a high % yield of oil which is worthwhile [1]. Sesame is drought-tolerant, due to its extensive root system. However, it requires adequate moisture for germination and early growth [2]. Sesame is adapted to many soil types, but it thrives best on well drained and fertile soil. Sesame seeds are protected by a fibrous hull, which may be whitish brown or black depending on the variety. Foods that are fried in sesame oil have a long shelf life because the oil contains an anti-oxidant called sesamol. The oil can be used in the manufacture of soaps, paints, perfume, pharmaceuticals and insecticides. Sesame meal, obtained after the oil is extracted from the seed, contains high protein content that can be used as feed for poultry and livestock.

2. Materials and Methods
Sesame (Sesamum indicum) seeds were purchased from Ado-Ekiti central market, Ekiti State Nigeria in Africa continent. The seeds were screened to remove the bad ones and the remaining good seeds were blended into fine flour using Excella Marlex grinder. The flour obtained was packaged in polythene bag and kept in freezer prior to analyses. Three samples obtained from the sesame flour were: raw, defatted and protein concentrate. The defatted sample was obtained by using soxhlet extractor to remove the oil while protein concentrate was obtained by following the flow chart scheme in Fig. 1.

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2.1 Proximate analysis
The moisture and ash contents were determined using the air oven and dry ashing method [3]. The sample was analyzed for crude fat and crude protein according to the methods described [4]. Nitrogen was determined by micro-Kjeldahl method described [4] and the percentage nitrogen was converted to crude protein by multiplying by 6.25. The crude fibre was determined by adding 2g (W1) of the sample into 500 ml conical flask; 200 ml of boiling 1.25% of H2SO4 was added and boiled for 30 minutes. The mixture was filtered through muslin cloth and rinsed with hot distilled water. The sample was scrapped back into the flask and 200 ml of boiling 1.25% NaOH was added and boiled for 30 minutes. The mixture was filtered through muslin cloth and rinsed with 10% HCl twice with industrial methylated spirit and allowed to drain and dry. The residue was scrapped into a crucible, dried in the oven at 105 °C, allowed to cool in a desicator and weighed (W2); then placed in muffle furnace at 300 °C for 30 minutes and finally allowed to cool at room temperature and weighed again (W3).

\[
\text{% crude fibre} = \frac{W_2 - W_3 \times 100}{W_1}
\]

The carbohydrate content was calculated by method of difference.

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

2.2 Determination of minerals
The minerals were analyzed by dry ashing the sample at 550 °C to constant weight and dissolving the ash in 100 ml standard flask using distilled deionized water with 3 ml of 3 M HCl. Sodium and potassium were determined by using a flame photometer (model 405, corning, U.K). All other minerals were determined by Atomic Absorption Spectrophotometer (Perkin & Elmer model 403, USA).
2.3 Determination of anti nutrients
Oxalate: 1g of the sample was taken into 100 ml conical flask, 75 ml of 1.5N H₂SO₄ was added and the mixture was stirred for 1 hour and then filtered. 25 ml of sample filtrate was titrated against 0.1N KMnO₄ solution until faint color persisted for 30 seconds [5].

Tannins: 200 mg of the sample was added to 10 ml of 70% aqueous acetone and properly covered. The mixture was put in an ice bath and shaken for 2 hours at 30⁰C. The mixture was later centrifuged at 3,600 rpm; 0.2 ml of the mixture was pipetted into test tubes and 0.8 ml of distilled water was added. Standard tannic acid solutions were prepared from a 0.5 mg/ml stock and the solution made up to 1ml with distilled water. 0.5 ml Folin reagent was added to both sample and standard solutions and then followed by the addition of 2.5 ml of 20% Na₂CO₃. The solutions were then vortexed and allowed to incubate for 40 minutes at room temperature after which absorbance was measured at 725 nm [6].

Phytate was determined on Spectronic 20 colorimeter (Gallenkamp, UK) using the method described [7, 8]. The amount of phytate in the sample was calculated as hexaphosphate equivalent using the formula:

\[ \text{Phytate} = \frac{28.2 \times A \times X}{0.282 \times 1000} \]

Whereas, 
K is the absorbance, mean K = standard P.

2.4 Determination of functional properties
The water and oil absorption capacities of the sample were determined using the method [9]. 10cm³ of water was added to 1.0 g sample in a centrifuge tube. The suspension was mixed vigorously using vortex mixer. This was then centrifuged at 3500 rpm for 25minutes and the volume of the supernatant left after centrifuging was noted. Water bound was calculated from the difference in the initial volume of the solvent used and the final volume after centrifuging. The same procedure was used for oil absorption capacity but oil replacing water in above process.

The slight modified procedure of [10] was used to determine least gelation concentration. Sample slurries of 2, 4, 6, 8, 10, 12, 14 and 16 were prepared in 5ml of distilled water. The test tubes containing these slurries were heated for one hour in boiling water followed by rapid cooling under running tap water. The test tubes were then cooled for 2 hours at 4 ºC. The least gelation concentration was determined as concentration which did not fall or slip when the test tubes were inverted. The emulsion capacity and stability determined by [10].

The method [11] was employed to determine foaming capacity and stability. 1 g of the sample was whipped with 50 ml distilled water for 5 minutes in a Kenwood blender and later poured into a 100 ml graduated flask to study the foaming stability at 2 hrs. The foaming capacity was calculated using the equation below:

\[ \text{Volume increase} \% = \frac{\text{volume after whipping} - \text{volume before whipping}}{\text{Volume before whipping}} \times 100 \]

2.5 Protein solubility
The dependence of protein solubility on pH of sample was determined by method described [12]. 2g of flour was mixed with 50cm³ distilled water for 5 mins. in a magnetic stirrer at room temperature (25⁰C). The pH of resulting solution was adjusted to the desired value using either 0.1M HCl or 0.1M NaOH: samples were centrifuged for 30 mins and the protein content of the supernatant determined by micro-Kjeldahl method [4].

3. Results and Discussion

Table 1: The proximate composition of raw, defatted and protein concentrate of sesame flour (Sesamum indicum)

<table>
<thead>
<tr>
<th>Samples (g/100g)</th>
<th>Ash</th>
<th>MC</th>
<th>CP</th>
<th>Fat</th>
<th>Fibre</th>
<th>CHO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw₁</td>
<td>4.03</td>
<td>11.70</td>
<td>33.54</td>
<td>40.37</td>
<td>5.65</td>
<td>4.71</td>
</tr>
<tr>
<td>Raw₂</td>
<td>4.05</td>
<td>11.68</td>
<td>34.27</td>
<td>41.56</td>
<td>5.61</td>
<td>2.83</td>
</tr>
<tr>
<td>Average</td>
<td>4.04</td>
<td>11.69</td>
<td>33.91</td>
<td>40.97</td>
<td>5.63</td>
<td>3.77</td>
</tr>
<tr>
<td>Defatted₁</td>
<td>4.20</td>
<td>10.35</td>
<td>35.67</td>
<td>32.42</td>
<td>5.48</td>
<td>39.74</td>
</tr>
<tr>
<td>Defatted₂</td>
<td>4.24</td>
<td>10.29</td>
<td>35.71</td>
<td>31.54</td>
<td>5.50</td>
<td>39.74</td>
</tr>
<tr>
<td>Average</td>
<td>4.22</td>
<td>10.32</td>
<td>35.69</td>
<td>31.99</td>
<td>5.49</td>
<td>39.29</td>
</tr>
<tr>
<td>PC₁</td>
<td>2.65</td>
<td>1.68</td>
<td>51.64</td>
<td>4.56</td>
<td>3.78</td>
<td>7.83</td>
</tr>
<tr>
<td>PC₂</td>
<td>2.58</td>
<td>1.70</td>
<td>52.08</td>
<td>4.52</td>
<td>3.80</td>
<td>8.30</td>
</tr>
<tr>
<td>Average</td>
<td>2.62</td>
<td>1.69</td>
<td>51.86</td>
<td>4.54</td>
<td>3.79</td>
<td>8.05</td>
</tr>
</tbody>
</table>

MC = Moisture Content, CP = Crude Protein, CHO = Carbohydrate
PC = Protein Concentrate

Table 1 shows the proximate composition of raw, defatted and protein concentrate of sesame flour. The low moisture contents in the samples would enhance their shelf lives by preventing the growth of micro organisms during storage. Accurate knowledge of moisture content of any food sample will dictate the amount of water to be incorporated during processing and industrial utilization of their products. The value obtained for the protein concentrate was the lowest among the samples. This indicates that the shelf life of protein concentrate is better than those of raw and defatted
samples. The protein concentrate has the highest value of crude protein (51.86 g/100g). This high value of crude protein in the protein concentrate indicates that it would have potential for food formulation and fortification. This result is highly expected for the protein concentrate. The value of crude protein in the protein concentrate was lower than that of Adenopus breviflorus benth seed flour concentrate (76.5 g/100 g) but higher than those of African mango raw (10.6 g/100 g) [10], velvet tamarind (24.3 g/100 g) [15] and kidney bean seed (28.5 g/100 g) [16]. The crude protein of the defatted sample (35.69 g/100 g) was higher than those of cashew kernel (31.5 g/100 g) [17] and Parinari curatellifolia (12.7 g/100 g) [18], quinoa flour (13.5 g/100 g) [19], six varieties of dehulled African yam bean flour that ranged from 20.18 to 25.78 g/100 g and soy protein concentrate (SPC) (68.25%) [20]. The crude fibre in the raw, defatted and protein concentrate were: 5.63 g/100g, 5.49 g/100g and 3.79 g/100g respectively. The moderate fibre makes them suitable for easy colon digestion and also helps to reduce the risk of bowel cancer and gall stones when consumed. The ash content was low in the protein concentrate but high in the defatted sample. The fat contents in raw and protein concentrate of sesame flour were lower than those of Adenopus breviflorus whole (47.67%), dehulled full fat (54.76%) [13], and Colocynthis citrullus L. (52%) [21] but higher than those of kidney bean (14.48%), kersting’s groundnut (5.9%), scarlet runner bean (7.5%) [22] and date palm fruit (1.54%) [23]. This indicates that sesame flour is a better source of oil than kidney bean, kersting`s groundnut, scarlet runner bean, cowpea and date palm fruit. The fat contents in raw and protein concentrate were high while that of defatted sample was low.

Table 2: Mineral composition of raw, defatted and protein concentrate of sesame flour (Sesamum indicum)

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Raw</th>
<th>Defatted</th>
<th>Protein concentrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>87.21</td>
<td>59.88</td>
<td>35.33</td>
</tr>
<tr>
<td>K</td>
<td>96.33</td>
<td>72.61</td>
<td>91.48</td>
</tr>
<tr>
<td>Ca</td>
<td>61.37</td>
<td>63.42</td>
<td>15.42</td>
</tr>
<tr>
<td>Mg</td>
<td>64.79</td>
<td>55.68</td>
<td>33.48</td>
</tr>
<tr>
<td>Zn</td>
<td>19.29</td>
<td>17.29</td>
<td>24.32</td>
</tr>
<tr>
<td>Fe</td>
<td>7.29</td>
<td>7.26</td>
<td>3.74</td>
</tr>
<tr>
<td>Mn</td>
<td>3.32</td>
<td>6.81</td>
<td>1.25</td>
</tr>
<tr>
<td>Pb</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Cu</td>
<td>6.48</td>
<td>6.35</td>
<td>0.39</td>
</tr>
<tr>
<td>P</td>
<td>39.19</td>
<td>37.56</td>
<td>33.41</td>
</tr>
</tbody>
</table>

N.D = Not detected

Table 1 shows the mineral composition of raw, defatted and protein concentrate of sesame flour. Potassium was found to be the most abundant mineral with the values of 96.33 mg/100g, 72.61 mg/100g and 91.48 mg/100g for raw, defatted and protein concentrate respectively. The levels of K, Na, Mg and Ca were relatively high in all the samples. The large amount of potassium relative to sodium in the three samples could be a disadvantage to hypertensive patients because of the mineral imbalance [24]. Zn, Fe, Mn, Cu and P were evenly distributed but Pb was not detected in any of the samples. It was generally observed that raw sample contained high quantity of minerals than those of defatted and protein concentrate while the values of Ca, Na and Cu were significantly different from one another. The phosphorus levels in the samples: raw (39.19 mg/100g), defatted (37.56 mg/100g) and protein concentrate (33.41 mg/100g) were similar. The raw sample contained the highest amount of minerals than others. This value was lower than that of raw Adenopus breviflorus (116 mg/100g) [13], sorghum flour (225.23 mg/100g), soy protein concentrate (SFC) (469.63 mg/100g) [20]. The values obtained for the essential minerals in the samples may satisfy the nutritional needs of the consumers [25]. Magnesium and copper values in protein concentrate were lower than those obtained for other samples determined. The value of calcium in defatted sample was significantly higher than others while iron contents in raw (7.29 mg/100g) and defatted (7.26 mg/100g) samples were similar but higher than that of protein concentrate (3.74 mg/100g). Iron is good for the formation of blood. From the results, it was evident that the protein concentrate had the highest mineral values.

Table 3 shows the level of anti-nutrients in the samples. Phytate values were: 25.96 mg/100 g, (23.75 mg/100 g) and (10.14 mg/100 g) for raw, defatted and protein concentrate respectively. It can be seen that processing of foods greatly reduced the anti-nutrients values. The presence of toxic substances otherwise known as anti-nutrients in any food sample can limit the nutritional quality. Phytate which represents about 89% of the total phosphorus concentration is widely distributed in food grains. The sample was very low in tannin which ranged between 0.25 and 0.95%. Phytic acid assumed the highest position among the anti-nutrients. Phytic acid values in the three samples were: raw (25.96%), defatted (23.73%) and protein concentrate (10.14%). The values obtained for defatted and protein concentrate were lower than that of the raw sample. The phytic acid in raw sample was higher than those of Afzelia africana (13.69%) [26] and Legarania vulgaris (20.0%) [8] but lower than that of kidney bean (40.8%) [16]. The cyanide values in raw, defatted and protein concentrate were lower than that of Afzelia Africana (2.19 mg/g) reported by [26] while the tannin value of the sesame protein concentrate (0.25%) was lower than those for sesame raw (0.95%), defatted (0.87%), kidney bean (0.77%) [16], lima bean (0.59%) [27] and black cowpea variety (0.75%) [28]. This implies that foods are required to be processed further to reduce the toxicity components.
Tannic acid has been reported to decrease protein quality by decreasing digestibility and palatability. Other negative nutritional effect of tannin is that it can damage the intestinal tract, interfere with the absorption of iron and possess carcinogenic effects in the body [29]. The phytin-phosphorus value of raw (7.31 mg/g), defatted (6.69 mg/g) and protein concentrate (2.86 mg/g) were all higher than those reported for kidney bean flour (4.08 mg/g) [16], pigeon pea flour (3.29 mg/g) and cowpea (5.75%) [30]. The phytin-phosphorus value for the protein concentrate of sesame flour (2.86 mg/g) was lower than those of pigeon pea and cowpea reported [30]. Moreover, with the low values of anti-nutrients in the samples, they are expected to have high nutritive qualities. From the results, it can be deduced that the sesame raw, defatted and protein concentrate flours contain low levels of anti-nutrients, which make them suitable for consumption. The general trend in anti-nutrients values were: raw > defatted > protein concentrate.

The Fig 2 shows the protein solubility against pH of raw, defatted and protein concentrate of sesame flours. The raw sample had minima protein solubilities at pH 5 and pH 10, defatted sample had minima at pH 4 and pH 10 while the protein concentrate had only one minimum protein solubility which was at pH 4. The three samples had maximum at pH 8. The profile shows that the protein solubilities of raw, defatted and protein concentrate increased/decreased when the pH values changed. It can be inferred from Figure 2 that the protein was least soluble in all the samples in both acidic and basic pH regions. The low solubility of the protein in raw flour at all pHs which compared favourably with defatted flour and protein concentrate may be an indication that the hull is inhibiting the solubility of the protein and this may occur when the seeds are consumed with the hull as some consumers do, and may influence the maximum body utilization of the protein in the seed [13]. The defatted sample protein solubility in the acid region was very low compared with the basic region. This pattern is similar to those reported for some oil seeds [12, 13, 21, 26, 31, 32, 33, 34].

Figure 2 further depicts that the protein concentrate had a minimum solubility at a pH of 4.0 and its protein was soluble in both the acidic and basic regions. The high solubility of the protein concentrate sample flour at acid pH indicates that the protein concentrate may be used in the formulation of acid foods such as milk analogue products and protein – rich carbonated beverages [35]. The result obtained for other functional properties determined are shown in Table 4. The water absorption and oil absorption capacities of sesame flour depend on the types of products.

### Table 3: Anti nutrients of raw, defatted and protein concentrate of sesame flour (Sesamum indicum)

<table>
<thead>
<tr>
<th>Anti-nutrients</th>
<th>Raw</th>
<th>Defatted</th>
<th>Protein concentrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tannin (%)</td>
<td>0.95</td>
<td>0.87</td>
<td>0.25</td>
</tr>
<tr>
<td>Phytic acid (mg/g)</td>
<td>25.96</td>
<td>23.75</td>
<td>10.14</td>
</tr>
<tr>
<td>Phytin phosphorus (mg/g)</td>
<td>7.31</td>
<td>6.69</td>
<td>2.86</td>
</tr>
<tr>
<td>Oxalate (mg/g)</td>
<td>3.42</td>
<td>2.98</td>
<td>1.24</td>
</tr>
<tr>
<td>Cyanide (mg/g)</td>
<td>1.34</td>
<td>0.96</td>
<td>0.56</td>
</tr>
</tbody>
</table>

Table 4: Functional properties of raw, defatted and protein concentrate of sesame flour (Sesamum indicum)

<table>
<thead>
<tr>
<th>Functional properties (%)</th>
<th>Raw</th>
<th>Defatted</th>
<th>Protein Concentrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water absorption capacity</td>
<td>38.48</td>
<td>41.55</td>
<td>25.70</td>
</tr>
<tr>
<td>Oil absorption capacity</td>
<td>66.88</td>
<td>70.54</td>
<td>35.41</td>
</tr>
<tr>
<td>Foaming capacity</td>
<td>18.00</td>
<td>20.00</td>
<td>6.53</td>
</tr>
<tr>
<td>Foaming stability</td>
<td>8.00</td>
<td>10.00</td>
<td>3.25</td>
</tr>
<tr>
<td>Emulsion capacity</td>
<td>31.45</td>
<td>35.60</td>
<td>27.43</td>
</tr>
<tr>
<td>Emulsion stability</td>
<td>85.00</td>
<td>90.55</td>
<td>30.50</td>
</tr>
<tr>
<td>Least gelation concentration (w/v)</td>
<td>4.00</td>
<td>2.00</td>
<td>2.00</td>
</tr>
</tbody>
</table>

The water absorption capacity of the raw flour was 38.48% while those of the defatted and protein concentrate were 41.55% and 25.70% respectively. The water absorption capacity value for defatted sample was higher than those of raw defatted sesame flour but lower than those of soy flour (130%) [36], pigeon pea (138%) [12] and kidney bean (165%) [16].

The oil absorption capacities of the sesame raw flour, defatted and protein concentrate were: 66.88%, 70.54% and 36.41% respectively. The absorption capacity of defatted sample was the highest among the sample studied. The value for the protein concentrate was lower than those of *Adenopus breviflorus* protein concentrate (175.7%) [13], sunflower protein concentrate (254.9%) [30] and full fat fluted pumpkin (142.5%) [37]. The oil absorption capacity is an important functional parameter, since oil acts as a flavor retainer and improves the mouth feel of foods [33]. The foaming capacity and stability of the samples are shown in Table 4. The foaming capacity and foaming stability were: raw (18.00%, 8.00%) defatted (20.00%, 10.00%) and protein concentrate (6.53%, 3.25%). These values were lower than those for soy flour (70%) and sunflower (220%) [36]. The foaming capacities of raw and defatted samples were higher than those of dehulled full fat *Adenopus breviflorus* (8.02%) and protein concentrate (17.57%) [13].

The foaming stabilities after 2 hrs for raw and defatted samples were comparatively better than those of soy protein concentrate (5%) and *Adenopus breviflorus* benth protein concentrate (9.50%) [13] but the value for sesame protein concentrate (3.25%) compared favorably with that of *Afzelia africana* (3.5%) reported by [26]. The least gelation
concentration (10%) for sesame raw flour, defatted and protein concentrate were: 4.00% w/v, 2.00% w/v and 2.00% w/v. Both the defatted and protein concentrate had similar least gelation concentration. The least gelation concentration of 4.00% w/v for the raw flour was lower than those for *Afzelia africana* (6.00% w/v) [26], great northern bean protein concentrate (10% w/v) [38] and lima bean (8.00% w/v) [39].

It has been reported that variation in the gelling properties of different legume flours may be linked to the relative ratios of different constituents (protein, carbohydrates and lipids), the interaction between such components may affect functional properties. This may be linked to the observed least gelation concentrations of the different forms of sesame flour in Tables 4 and 1 respectively. The emulsion capacity and stability for the samples were: raw (31.45%, 85.00%), defatted (35.60%, 90.55%) and protein concentrate (27.43%, 30.50%). The defatted sesame flour had the highest value of emulsion capacity and stability among the samples determined. These values were higher than those for soy flour (18%) and wheat flour (7-11%) reported [36] but lower than those for Africa nutmeg (42.0%, 50.0%) [34], pearl millet (89.60%), quinoa (104.0%) [33] and *Adenopus breviflorus* protein concentrate (62%, 54%) [13].

4. Conclusion
It has been shown that sesame seed is nutritionally rich in protein, fats and essential minerals. The food properties are significantly improved when the flour is defatted and the protein concentrated. The seed is not detrimental to human health because of its low levels of anti-nutrients; and also has potential for baby food fortification/formulation in food industries.

5. References
2. Sesame http://corn.agronomy.wisc.edu/crops/sesame.asp x. 16 Sept, 2014


