### Abstract:
The assessment of nutritive and anti-nutritive compositions of fermented and unfermented seeds of *Annona senegalensis* from Niger State, Nigeria was carried out using standard analytical methods. The proximate parameters determined were moisture, protein, ash, fat, and fibre of the unfermented seed were 18.07±0.03, 16.90±0.14, 3.62±0.23, 27.54±0.45 and 7.34±0.11%, respectively; while the moisture, protein, ash, fat and fibre of the fermented seed for 24 and 48 h were 21.00±0.51 and 22.78±0.21, 18.42±0.32 and 25.89±0.05, 4.00±0.50 and 4.22±0.32, 23.00±0.10 and 21.76±0.31, 5.35±0.16 and 4.05±0.14%. The carbohydrate content was lowest in the seed fermented for 24 h (21.30±0.46%) and highest in the unfermented seed (26.60±0.54%). Energy values obtained in this work were 1757.29±33, 1616.34±14 and 1573.35±0.52 Kcal/100g for the unfermented, 24 and 48 h fermented samples, respectively. The fermentation generally improved the mineral contents but decreased the anti-nutrient contents of the seeds. The amino acid profiles makes the studied seed protein of high nutritive. Thus, large-scale production of fermented A. *senegalensis* seeds will be a valuable source of nutrients for humans and animals.

**Keywords:** *Annona senegalensis*, fermented, unfermented, nutrient, anti-nutrient

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### Introduction
In northern Nigeria, malnutrition and vitamins deficiency are quite common among infants and children. This is largely manifested in their greater susceptibility to infections and poor nutrition. Vitamins deficiency impairs growth and development as a result of their involvement in metabolic functions (Franzo et al., 2013). Fruits and vegetables are low in fat, salt and sugar but are good sources of dietary fibre. Thus, they are a part of a well-balanced regular diet and a healthy, active lifestyle. A high intake of fruits and vegetables has been found to reduce obesity, maintain a healthy weight, lower cholesterol, lower blood pressure, reduce the risks of colon cancer and other cancers (Bello, 2014). Fruits are excellent sources of healthy phytochemical, antioxidants, and fibre too. Therefore, taking high contents of catechins and anthocyanins from plants helps to protect body against death from many diseases, especially cardiovascular diseases (Ebert, 2014).

African custard apple plant is a wild growing shrub or small tree up to 7 meters or more in height. It is not a resilient plant and dies as a result of their involvement in metabolic functions. It has a curved inner whorl of stamens and ovary and several stamen (Coates, 2002). This plant is common and quite wild in the shrubbery, open bush and along rivers and streams in Nigeria. It is found throughout Northern Nigeria, primarily in the Nasarawa, Kaduna, Kano, Plateau and Niger States and Federal Capital Territory (FCT), Abuja (Alqasim, 2013). Although many of these plants have been identified, scanty data are available on their chemical composition for the prospect of their utilization despite the fact that some could have good nutritional application (FMH, 2016). The objective of this study was to determine the effect of fermentation on the nutritents and anti-nutritient contents of the seed of African custard apple (*A. senegalensis*).

### Materials and Methods

#### Sample preparation
The sample was collected between July and September, 2016. The seeds were separated, washed, rinsed with clean water and dried at room temperature for some days. After drying, they were ground into fine powder with porcelain mortar and pestle; sieved with mesh size of 0.5 mm. The traditional methods of African locust beans fermentation was adopted in this work with modification. 200 g of African custard apple (*A. senegalensis*) seeds powder was weighed into 1000 cm$^3$ conical flask, 50 cm$^3$ of distilled water was added while 0.5 g of commercial baker’s yeast (*Saccharomyces cerevisiae*) was added to the mixture. It was stirred, covered and allowed to ferment for 24 h. The same process was repeated for the fermentation at 48 h. The resultant mixture was dried in a freeze dryer and kept for further analysis.

#### Methods

**Proximate analyses**
The moisture, ash, fat and protein contents of the *Annona senegalensis* seed flour were determined out as described by the AOAC (2006). Total carbohydrate content was determined by subtracting percentage moisture, ash, crude fibre, protein, and fat from 100%. The energy value (kcal/100g) was estimated by multiplying the percentage of crude protein, crude lipid and carbohydrate by 4, 9 and 4 respectively as conversion factors (AOAC, 2006).

**Mineral analysis**
The sample was digested by weighing in triplicate 1.00 g into beakers and 10 cm$^3$ of the acid mixture (HClO$_4$;H$_2$SO$_4$;HNO$_3$) in the ratio of 1:4:3 was added in each case. The mixture was swirled and left in a fume cupboard overnight. The samples were then digested on a Kjedhal digestion block until the solutions became quite clear. The digests were allowed to cool, diluted with 20 cm$^3$ of water, filtered using Whatman filter papers, made up to mark with deionized water in 100 cm$^3$ volumetric flask and transferred into sample bottles. The samples were analyzed for their mineral contents (Ca, Cu, Fe, Zn, Mn and Mg) using atomic absorption spectrophotometer (AAS) Buck model 210 VGP. A flame photometer (AA-500F, China) was used for the determination.
Results and Discussion

The proximate composition (%) and energy contents (kcal/100g) of fermented and unfermented seeds flour of African custard apple are presented in Table 1. The moisture contents ranged from 18.07±0.03 (unfermented) to 22.78±0.21% (fermented at 48 h). The result obtained from this work was higher than that of pigeon pea flour (7.44±0.04%) reported by Babalola and Giwa (2012). The values obtained for samples fermented of both 24 and 48 h in this work, were lower than the respective 61.50±2.12 and 52.50±3.54% reported for soybean seeds flour by Babalola and Giwa (2012). The moisture contents increased with the fermentation with period probably due to increase in the relative humidity. The shelf life of the fermented samples on the basis of their moisture contents would be lower than those of the raw samples. This is because, high moisture content speed up deterioration since excess water aids microbial activities (Ogunyinka et al., 2017). The mean crude fibre of the seed ranged from 4.23±0.16 (unfermented) to 5.04±0.15% (fermented for 48 h). The crude fibre contents in the present work were low compared to the range of 4.05±0.14 to 7.34±0.11% reported for the raw and fermented soya beans reported by Babalola and Giwa (2012). The fibre contents of the three samples decreased by fermentation as a result of the activities of extracellular enzymes which converted fibres to soluble carbohydrates (Jolasso et al., 2014). The decrease in crude fibre contents was in agreement with the trend (20.08±0.11% for raw) and 18.33±0.17% for fermented soybean seeds reported by Babalola and Giwa (2012); although the values in this work were low relative to those of these authors. The low fibre contents will be of advantage to maintain the health of the gastrointestinal tract although excess fibre may bind trace elements, like zinc, copper and iron leading to deficiency (Mossia, 2017). The mean carbohydrate contents ranged from 21.30±0.46 (fermented for 48 h) to 26.60±0.54% (unfermented). The result obtained for the raw and fermented samples for 24 and 48 h as reported for pigeon pea flour by Mbaeyi-Nwoah and Obetta (2016) were lower than the 54.70±0.11, 52.27±0.01 and 49.82±0.42%, respectively obtained in the present study. The crude fat contents of the samples in the present work ranged from 4.02±0.23 (fermented for 48 h) to 7.00±0.06% (raw seeds). The decrease in crude fat contents of the samples might be attributed to the increase in the activities of the lipolytic enzymes during fermentation which may have hydrolysed fat components into fatty acids and glycerol (Adebowale and Malikii, 2011). The decrease in crude fat was in disagreement with increased values (19 to 23%) for fermented soybeans reported by Thingom and Chhtry (2011). The crude protein values of the samples ranged from 16.90±0.14 (unfermented) to 25.89±0.05 (fermented for 48 h). The increase in protein contents of the plant seeds is in agreement with the result of soybeans seeds reported by Babalola and Giwa (2012). Although, their values were lower compared to those of the present study but in agreement with the value 25% reported for soybeans seeds fermented for 48 h reported by Thingom and Chhtry (2011). The ash contents ranged from 3.62±0.23 (unfermented) to 4.22±0.32% (fermented for 48 h). This result indicates that the ash contents of the samples increased during fermentation which might be attributed to the increase in moisture content. Similar increase was observed by Babalola and Giwa (2012) during the fermentation of soybean flour (3.34±0.44 to 5.38±0.22%). However, the values obtained in this study were lower than the 6.21±0.05 to 6.91±0.53% reported for locust beans seeds by Aremu et al. (2015).
Table 1: Proximate compositions (%) and energy contents (kcal/100g) of the Seeds flour of African custral apple

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Moisture (%)</th>
<th>Crude Protein (%)</th>
<th>Ash (%)</th>
<th>Crude Fibre (%)</th>
<th>Crude Fat (%)</th>
<th>Carbohydrate (%)</th>
<th>Calories (kcal/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfermented</td>
<td>18.07±0.03</td>
<td>16.90±0.14</td>
<td>3.62±0.23</td>
<td>7.34±0.11</td>
<td>27.54±0.45</td>
<td>26.53±0.35</td>
<td>1757.29±0.33</td>
</tr>
<tr>
<td>Fermented for 24 h</td>
<td>21.00±0.51</td>
<td>18.42±0.32</td>
<td>4.00±0.50</td>
<td>5.35±0.16</td>
<td>23.00±0.10</td>
<td>26.60±0.54</td>
<td>21.30±0.46</td>
</tr>
<tr>
<td>Fermented for 48 h</td>
<td>22.78±0.21</td>
<td>25.89±0.05</td>
<td>4.22±0.32</td>
<td>4.05±0.14</td>
<td>21.76±0.31</td>
<td>21.30±0.46</td>
<td>157.35±0.52</td>
</tr>
</tbody>
</table>

Mean within a row with same superscripts were not significantly different at (p≥0.05)

Table 2: Mineral compositions of African custral apple (mg/100g)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Na</th>
<th>K</th>
<th>P</th>
<th>Ca</th>
<th>Fe</th>
<th>Mg</th>
<th>Zn</th>
<th>Cu</th>
<th>Mn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfermented</td>
<td>126.13±0.15</td>
<td>160.29±0.80</td>
<td>105.60±0.26</td>
<td>7.05±0.66</td>
<td>15.30±0.45</td>
<td>11.30±0.26</td>
<td>5.33±0.21</td>
<td>9.55±0.13</td>
<td>3.35±0.24</td>
</tr>
<tr>
<td>Fermented for 24 h</td>
<td>129.30±0.82</td>
<td>170.32±0.50</td>
<td>111.43±0.39</td>
<td>9.22±0.36</td>
<td>12.01±0.52</td>
<td>8.11±0.41</td>
<td>6.98±0.62</td>
<td>5.20±0.60</td>
<td>2.97±0.43</td>
</tr>
<tr>
<td>Fermented for 48 h</td>
<td>130.98±0.11</td>
<td>172.42±0.42</td>
<td>114.27±0.51</td>
<td>11.02±0.40</td>
<td>10.63±0.12</td>
<td>7.02±0.20</td>
<td>8.07±0.55</td>
<td>4.30±0.16</td>
<td>5.17±0.34</td>
</tr>
</tbody>
</table>

Mean within a row with same superscripts were not significantly different at (p≥0.05)

The mineral contents (mg/100g) of fermented and unfermented of African custral apple seed flowers are presented in Table 2. Calcium is an essential mineral for bone development (Mathew et al. 2014). The calcium contents of the flours ranged from 7.05±0.66 (unfermented) to 11.02±0.40 (fermented for 48 h). These values were higher than 5.81 mg/100g (unfermented) to 6.36 mg/100g (fermented for 48 h) range for C. alitissium seed reported by Jolaoso et al. (2014) except for the value for the unfermented samples. However, the values were low compared to 18.33±0.01 mg/100g reported for mug beans by Adamu et al. (2015). The phosphorus contents of the samples ranged from 105.60±0.26 (unfermented) to 114.27±0.51 mg/100g (fermented for 48 h). This increase compared well with the result of Jolaoso et al. (2014) who reported an increase in the level of phosphorus during the fermentation of C. atitissium which ranged from 560 mg/100g to 720 mg/100g. The phosphorus content of the fermented seeds in the present study is desirable since the element is needed in the formation of strong bones and teeth. It also plays a role in energy metabolism of the cells (Jolaoso et al., 2014).

Table 3: Amino acid profile of the samples (g/100g Protein)

<table>
<thead>
<tr>
<th>Parameters</th>
<th><em>Leucine</em></th>
<th><em>Lysine</em></th>
<th><em>Isocitcine</em></th>
<th><em>Phenylalanine</em></th>
<th><em>Tryptophan</em></th>
<th><em>Valine</em></th>
<th><em>Methionine</em></th>
<th><em>Histidine</em></th>
<th><em>Cysteine</em></th>
<th><em>Proline</em></th>
<th><em>Arginine</em></th>
<th><em>Tyrosine</em></th>
<th><em>Glycine</em></th>
<th><em>Serine</em></th>
<th><em>Aspartic acid</em></th>
<th><em>Glutamic acid</em></th>
<th><em>Alanine</em></th>
<th>%TAA</th>
<th>%TEAA</th>
<th>%TCEAA</th>
<th>%TNEAA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfermented</td>
<td>9.57±0.00</td>
<td>4.35±0.04</td>
<td>3.21±0.09</td>
<td>3.72±0.08</td>
<td>1.05±0.02</td>
<td>3.68±0.11</td>
<td>1.23±0.09</td>
<td>3.13±0.06</td>
<td>1.09±0.07</td>
<td>3.62±0.09</td>
<td>5.68±0.02</td>
<td>3.53±0.33</td>
<td>3.99±0.02</td>
<td>3.83±0.06</td>
<td>9.40±0.05</td>
<td>11.96±0.08</td>
<td>4.70±0.06</td>
<td>40.31±0.33</td>
<td>22.38±0.10</td>
<td>37.29±0.11</td>
<td></td>
</tr>
<tr>
<td>Fermented for 24 h</td>
<td>10.66±0.09</td>
<td>5.02±0.10</td>
<td>3.89±0.05</td>
<td>4.63±0.07</td>
<td>1.09±0.07</td>
<td>4.76±0.09</td>
<td>1.36±0.07</td>
<td>3.51±0.06</td>
<td>2.00±0.05</td>
<td>4.20±0.02</td>
<td>6.10±0.08</td>
<td>3.72±0.02</td>
<td>4.37±0.07</td>
<td>4.25±0.02</td>
<td>8.96±0.04</td>
<td>13.53±0.08</td>
<td>5.32±0.09</td>
<td>41.92±0.06</td>
<td>21.47±0.10</td>
<td>34.33±0.09</td>
<td></td>
</tr>
<tr>
<td>Fermented for 48 h</td>
<td>10.52±0.05</td>
<td>4.97±0.05</td>
<td>3.60±0.09</td>
<td>4.26±0.08</td>
<td>1.06±0.02</td>
<td>4.60±10</td>
<td>1.36±0.07</td>
<td>3.58±0.07</td>
<td>3.62±0.02</td>
<td>1.92±0.02</td>
<td>6.02±0.06</td>
<td>3.72±0.04</td>
<td>4.04±0.08</td>
<td>4.20±0.06</td>
<td>9.71±0.04</td>
<td>13.39±0.03</td>
<td>5.30±0.07</td>
<td>41.92±0.06</td>
<td>21.47±0.10</td>
<td>35.95±0.05</td>
<td></td>
</tr>
</tbody>
</table>

Mean within a row with same superscripts were not significantly different at (p≥0.05). Represent essential amino acids and "represent conditionally amino acids, TEAA: Total essential amino acids, TCEAA: Total conditionally essential amino acids, TNEAA: Total non-essential amino acids.

The amino acid compositions (g/100g protein) of the fermented and raw seed sample are presented in Table 3. The physiological role of dietary proteins is the provision of substrates required for the synthesis of body proteins and other metabolically important nitrogen-containing compounds. Therefore, the contents of the nutritionally indispensable amino acids in food proteins are usually the primary determinants of nutritional quality of proteins reported by Mbaeyi-Nwaoha and Obetta, (2016). Potassium plays important role in the human body and sufficient amounts of it in the diet protect against heart disease, hypoglycaemia, diabetes, obesity and kidney dysfunction (Mathew et al., 2014). Adequate intake of this mineral from the diets has been found to lower blood pressure by antagonizing the biological effects of sodium (Mathew et al., 2014). The mean copper concentrations of the samples ranged from 4.30±0.16 (fermented for 48 h) to 9.55±0.13 mg/100g (raw). The copper contents were higher than 0.90±0.00 mg/100g and 0.46±0.00 mg/100g reported for beans and soybean respectively by Adamu et al. (2015). This might have been as a result of the breaking down of some complex metallic compounds in the sample during fermentation. The mean zinc contents of the samples ranged from 5.33±0.21 (unfermented) to 8.07±0.55 mg/100g (fermented for 48 h). These were higher than 5.81 mg/100g (unfermented) to 6.36 mg/100g (fermented for 48 h) range for C. alitissium seed reported by Jolaoso et al. (2014) for which an increase in the level of phosphorus during the fermentation of C. atitissium which ranged from 560 mg/100g to 720 mg/100g. The phosphorus content of the fermented seeds in the present study is desirable since the element is needed in the formation of strong bones and teeth. It also plays a role in energy metabolism of the cells (Jolaoso et al., 2014).
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(Mohanty et al., 2014). Leucine is the only dietary amino acid that stimulates muscle protein synthesis and has important therapeutic role in stress conditions like burn, sepsis and trauma (Wu, 2010). Leucine is an essential amino acid, in this present study it had concentrations that ranged from 9.57±0.08 (unfermented) to 10.66±0.09 (fermented for 24 h) g/100g protein. There were increases in the leucine contents of samples as the period of fermentation increased. The increases might have been as a result of the formation of intermediate compounds which during metabolism, reacted with ammonia and were converted to a amino acids which in turn were useful in the formation of other amino acids (Okechukwu et al., 2012). These values were high when compared with the 2.89±0.05 g/100g protein of Astyanax fasciatus leucine content reported by Furuya et al. (2015). Also, Buang and Taib (2014) recorded increase in leucine values during the fermentation of groundnut [1.74±0.04 g/100g protein (fermented for 18 h)] to 2.55±0.01 g/100g protein (for 30 h fermentation), although the values reported were lower than the values for the present study. These values for this study were however, lower than the 64.50±2.33 g/100g (fermented for 48 h) for Ricinus communis seed reported by Igwe et al. (2012). Therefore, leucine in the plant seeds can greatly contribute to the nutritional requirements of man and his animals.

Lysine is an essential amino acid extensively required for optimal growth and its deficiency leads to immunodeficiency. It is also used for preventing and treating cold sores (Wu, 2013). The lysine contents ranged from 4.35±0.04 (raw) to 5.02±0.10 g/100g protein (fermented for 24 h). Prolonged fermentation up to 48 h showed significant decrease in the lysine contents of the samples. These values were however higher than the 0.99±0.13 g/100g protein (raw) to 1.64±0.01 g/100g protein (fermented for 30 h) range reported for garbanzo beans by Buang and Taib (2014). However, the lysine contents were low compared to the 40.60±1.10 (raw) to 47.20±0.30 g/100g (fermented for 72 h) range reported for P. africana by Igwe et al. (2012).

Isoleucine is a branched chain amino acid needed for muscle formation and proper growth. Chronic renal failure patients on haemodialysis have low plasma level of the branched chain amino acids such as leucine, valine and isoleucine (Monirujja et al., 2014). The contents of isoleucine ranged from 3.21±0.09 (unfermented) to 3.89±0.05 g/100g protein (fermented for 24 h). There were significant decreases as fermentation reached 48 h in the concentrations of isoleucine which might have been as a result of reactions of intermediate compounds formed during metabolism with ammonia and were thus, converted to amino acids which, in turn, were useful in the formation of other amino acids (Okechukwu et al., 2012). The concentrations of this amino acid in the samples of the present study were high when compared with the 0.84±0.05 g/100g protein (raw) to 1.28±0.05 g/100g protein (fermented for 48 h) reported for groundnut seeds by Bujang and Taib (2014). Although, the values were lower than 5.41 g/100g protein reported for African oil beans by Okechukwu et al. (2012). Also, the values were lower than the 10.40 g/100g protein isoleucine content reported for Stolephorus waitii by Mohanty et al. (2014). The phenylalanine contents ranged from 3.72±0.08 (unfermented) to 4.63±0.07 g/100g protein (fermented for 24 h). Extension of fermentation period showed significant decreases in the phenylalanine contents of the samples. The phenylalanine contents of the samples in this work were higher than 1.78±0.02 g/100g protein to 2.17±0.03 g/100g protein for the unfermented and fermented samples reported for garbanzo beans by Bujang and Taib (2014). Also, Okechukwu et al., (2012) reported 3.03 g/100g protein (raw) to 2.62 g/100g protein (fermented for 48 h) phenylalanine contents for African oil beans which are lower than the values obtained in this study. However, these values were lower than the 6.30±0.20 g/100g protein reported for Anabas testudineus by Mohanty et al. (2014). In addition, 41.60±3.01 (raw) to 67.20±1.21 g/100g protein (fermented for 72 h) range was reported for Prosopis africana by Igwe et al. (2012) which are higher than the range obtained in this study. Tryptophan which is a precursor for serotonin, melatonin and tryptamine is a brain neurotransmitter theorized to oppress pain (Richard et al., 2009). Free tryptophan enters the brain cells to form serotonin. Thus tryptophan supplementation has been used to increase serotonin production in attempt to increase tolerance to pain (Richard et al., 2009). The tryptophan contents obtained ranged from 1.05±0.02 (unfermented) to 1.09±0.07 g/100g protein (fermented for 24 h). These values were however higher than 0.65 g/100g dietary protein reported for A. fasciatus by Furuya et al. (2015). These were however, lower than the 2.10±0.50 g/100g protein reported for Stolephorus waitii by Mohanty et al. (2014). Methionine is used for treating liver disorders, improving wound healing and treating depression, alcoholism, asthma, radiation side effects, allergies, copper poisoning, drug withdrawal, Parkinson’s disease and schizophrenia (Mohanty et al., 2014). The contents of methionine ranged from 1.23±0.09 (fermented) to 1.96±0.07 g/100g protein (fermented for 24 h). The increase in the methionine concentrations during the fermentation period might have been as a result of formation of intermediate compounds during metabolism which might have reacted with ammonia and converted to amino acids which in turn were useful in the formation of other amino acids (Okechukwu et al., 2012). These values obtained for the samples were low compared to reported value for P. africana (10.40±0.10 to 13.10±10 g/100g protein for unfermented and fermented for 48 h) by Igwe et al. (2012). These were however, higher than the 1.04±0.01 g/100g protein methionine reported Astyanax fasciatus by Furuya et al. (2015). Valine is needed for muscle metabolism tissue repair and the maintenance of proper nitrogen balance in the body. It is helpful in treating liver and gall bladder disorders, and it is good for correcting the type of severe amino acid deficiencies caused by drug addiction (Wu, 2013). The concentrations of valine in the samples ranged from 3.68±0.11 g/100g protein (unfermented) to 4.76±0.09 g/100g protein (fermented for 24 h). The values obtained in this study were lower than the 5.36 (raw) to 6.89 g/100g protein (fermented for 48 h) valine level reported for African oil beans by Okechukwu et al. (2012). However, the values were high compared to the 1.00±0.13 (unfermented) to 1.58±0.06 g/100g protein (fermented for 30 h) valine values reported for groundnut by Bujang and Taib (2014). They were however, low when compared with the 40.30±0.80 (raw) to 53.20±0.60 g/100g protein (fermented for 72 h) P. africana seeds reported by Igwe et al. (2012). Histidine plays important roles in protein interaction and is also needed for growth and repair of tissue, for maintenance of the myelin sheaths and in removing heavy metals from the body (Liao et al., 2013). The histidine concentrations in the samples ranged from 2.17±0.10 (unfermented) to 3.58±0.07 g/100g protein (fermented for 48 h). For 48 hours showed significant decrease (p<0.05) in this amino acid in these plant seeds. These values were however, higher than the 0.79±0.01 (unfermented) to 1.29±0.02 g/100g protein (fermented for 30 h) reported for the garbanzo beans by Bujang and Taib (2014). On other hand, they were, lower than the 7.90±0.60 g/100g protein reported for Rastrelliger kanagurta by Mohanty et al. (2014). In a similar observation, Okechukwu et al. (2012) recorded decreased histidine concentrations after the fermentation of African oil beans (1.81 for the raw to 1.43 g/100g protein for...
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fermented for 48 h). This amino acid is very important for the growing and development of infants, therefore incorporation of these plant seeds into infant foods would enhance the growth and development of children particularly in developing nations where animal based-complementary foods are expensive.

Threonine is used for treating various nervous system disorders including spinal plasticity, multiple sclerosis, familial, spastic paraparesis and amyotrophic lateral sclerosis (Costa et al., 2010). The contents of threonine obtained in this work ranged from 3.33±0.06 (unfermented) to 3.80±0.08 g/100g protein (fermented for 24 h). Fermentation for 48 hours significantly (p<0.05) decreased this amino acid in the seeds. The values of threonine in these samples were higher than the 0.73±0.03 (unfermented) to 1.09±0.03 g/100g protein (fermented for 30 h) range reported for groundnut by Bujang and Taib (2014). Also, the values were higher than the 2.54±0.01 (unfermented) to 3.06±0.02 g/100g protein (fermented for 48 h) range reported for African locust beans flour by Ijarotimi and Keshinro (2012). The % total essential amino acids (%TEAAs) ranged from 40.31±0.03 for unfermented to 42.69±0.08 g/100g protein in fermented for 24 h. The TEAAs obtained in this study for the samples were higher than the TEAAs of groundnut (7.80±0.60 for unfermented to 12.29±0.11 g/100g protein for fermentation at 30 hours) reported by Buang and Taib (2014). However, the value was lower when compared with the 59.98 % reported for fermented P. Africana seeds by Igwe et al. (2012). Conditionally essential amino acids are those whose synthesis may be limited under certain pathophysiological conditions, such as infant prematurity or severe catabolic stress which may occur with surgery or trauma (Riggs and Shen, 2012). Glycine plays an important role in metabolic regulation, preventing tissue injury, enhancing anti-antioxidant activity, promoting protein synthesis and wound healing. It also improves immunity and treatment of metabolic disorders in obesity, diabetes, cancer, cardiovascular diseases, ischemia reperfusion injuries and various inflammatory diseases (Wang et al., 2013). The concentration of glycine in the seeds ranged from 3.99±0.02 (unfermented) to 4.40±0.08 g/100g protein (fermented for 24 h). These values showed that this amino acid decreases in concentrations with fermentation period. The glycine values obtained in this work are lower than the 5.92 g/100g protein reported for Parkia biglobosa by Oluwaniyi and Bazambo (2016). However, they were higher compared than the 1.21 (unfermented) to 1.69 g/100g protein (fermented for 48 h) range reported for African oil beans by Okechukwu et al. (2012). Arginine plays important role in cell division, wound healing, ammonia removal, immune function and hormone release. It is also the precursor for biological synthesis of nitric oxide which plays important roles in neurotransmission, blood clotting and maintenance of blood pressure (Sarma et al., 2013). The contents of arginine in the samples in this study ranged from 5.68±0.02 in unfermented to 6.10±0.08 g/100g protein in fermented for 24 h. The increase observed in arginine contents of the samples with the fermentation period, might have been as a result the formation of intermediate compounds during metabolism that reacted with ammonia and were converted to amino acids which in turn were useful in the formation of other amino acids (Okechukwu et al., 2012). Tyrosine concentration ranged from 3.53±0.03 (unfermented) to 3.94±0.02 g/100g protein (fermented for 24 h). These values were higher compared than the 1.8±0.01 g/100g protein reported for A. faciatus by Furuya et al. (2015). Also, the values are higher compared with the 0.20±0.00 g/100g protein for Stolephorus commersonii reported by Mohanty et al. (2014). Although, the values were lower compared with the fermented value of African oil bean reported by Okechukwu et al. (2012). In addition, the values were high than 33.40±0.30 g/100g protein (unfermented) to 40.60±0.51 g/100g protein (fermentation at 48 hours) reported for P. africana by Igwe et al. (2012). The concentration of total conditionally essential amino acids content of 21.47±0.10 (fermented for 24 h) to 22.38±0.10 g/100g protein (unfermented). All these values were much higher than the 16.11 g/100g protein (unfermented) to 17.89 g/100g protein (fermented for 48 h) reported for African locust beans flour by Ijarotimi and Keshinro (2012). The serine concentration was 3.83±0.06 (unfermented) to 4.25±0.02 g/100g protein (fermented for 48 h) were recorded for the samples. The concentration of intermediate amino acids among the analyzed amino acids in this work, was it was recorded that the concentration of this acid decrease on fermentation for 24 h while fermentation exceeded that period the concentration serine decreased. These results were higher than the respective values of the 1.22±0.01 and 1.98±0.01 g/100g protein (for unfermented and fermented for 30 h) reported for groundnut seed by Bujang and Taib (2014). These values were lower than 46.80±0.60 g/100g protein (unfermented) to 64.40±0.11 g/100g protein (fermented for 72 h) reported for Prosporis africana by Igwe et al. (2012). Since these values are high in those samples, they can serve as sources of this amino acid. Glutamic acid plays an important role in amino acid metabolism because of its role in transamination reactions and is necessary for the synthesis of key molecules, such as polyglutamate folate cofactor and glutathione which are required for the removal of highly toxic peroxides (Wu, 2013). The glutamic acid values of 11.96±0.08 (unfermented) to 13.53±0.08 g/100g protein (fermented for 24 h). It was observed that, the glutamic acid concentrations had the highest contents among the analyzed amino acids in this work. The values obtained here are lower than the 102.20±4.10 g/100g protein reported for Prosporis africana by Igwe et al. (2012). Also, the values are lower when compared with the 16.90 g/100g protein recorded for African oil beans by Okechukwu et al. (2012) but these values are higher than the 4.85±0.15


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Conclusion
The results of this study have generally revealed that fermentation, especially after 48 h improved most of the nutritional qualities of the test samples. Also, the anti-nutrient factors of the samples were reduced thereby making them more useful in nutritional applications. The study has also revealed that A. senegalensis seeds if properly processed can be useful for food supplementation.

References

Table 4: Anti-nutrient compositions (mg/100g) of African custard apple

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unfermented</th>
<th>Fermented for 24 h</th>
<th>Fermented for 48 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phytate</td>
<td>18.02±0.40</td>
<td>15.45±0.34</td>
<td>11.55±0.22</td>
</tr>
<tr>
<td>Oxalate</td>
<td>13.00±0.50</td>
<td>10.32±0.26</td>
<td>7.56±0.16</td>
</tr>
<tr>
<td>Cytanide</td>
<td>9.12±0.33</td>
<td>7.18±0.20</td>
<td>4.00±0.20</td>
</tr>
</tbody>
</table>

Mean within a row with same superscripts were not significantly different (p>0.05)

The levels of the anti-nutrient contents of fermented and unfermented seed flour as presented in Table 4. The fermentation at longer periods reduced the level of the anti-nutritional value obtained in this work was lower than the 0.032±0.007 mg/100g reported for Adegbehingbe 19.23±0.13 mg/100g reported for lima bean seeds by Igwe 2012. These values were however, low when compared with the 3.64±0.01 g/100g protein reported for African locust bean flour by Ijarotimi and Keshinro 2013. The values were however, low compared to the 7.80±1.10 g/100g protein reported for Labeo rohita by Mohanty et al. (2014). The total non-essential amino acids ranged from 34.33±0.09 (fermented for 24 h) to 37.29±11 (unfermented) %. respectively. These values were lower compared to the 43.12% reported for fermented P. africana seeds by Igwe et al. (2012).

The aspartic acid concentration ranged from 9.40±0.05 (unfermented) to 9.86±0.33 (fermented for 48 h) reported for Stone beans by Abdulrahman et al. 2016. Alanine contents ranged from 4.00±0.20 (fermented for 4 days) and 0.01 mg/100g (fermentation for 48 h) reported for Labeo rohita by Mohanty et al. (2014). The total non-essential amino acids ranged from 34.33±0.09 (fermented for 24 h) to 37.29±11 (unfermented) %, respectively. These values were lower compared to the 43.12% reported for fermented P. africana seeds by Igwe et al. (2012).

The lethal dose of oxalates is between 200 and 500 mg/100g. The phytate contents ranged from 11.55±0.22 (fermented for 48 h) to 18.02±0.40 mg/100g for unfermented. These were higher than the 0.04 mg/100g (fermentation for 4 days) and 0.01 mg/100g (fermented for 14 days) reported for African oil beans seed by Balogun (2013). The values were however, low compared to 41.77±0.31 mg/100g (unfermented) to 16.94±0.01 mg/100g (fermentation at 24 h) reported by Abdulrahman et al. (2016). Base on the phytate concentration, the plant seeds both fermented and unfermented could be consumed without much fear of phylic acid toxicity.

The lethal dose of oxalates is between 200 and 500 mg/100g (NRC, 2013). The oxalate contents ranged from 7.56±0.16 (fermented for 48 h) to 13.00±0.50 mg/100g (unfermented). The values were higher than the 1.05±0.07 mg/100g (unfermented) to 1.02±0.21 mg/100g (fermentation at 72 hours) reported for soybeans by Babalola and Giwa (2012) but lower than the value for African bean seed (180.00±1.15 mg/100g) reported by Abdulrahman et al. (2016). The oxalate contents of both fermented and unfermented plant seed flour suggested that, they could be safe for consumption since they all fell below the lethal dose limit. The cyanide contents ranged from 4.00±0.20 (fermented for 48 h) to 9.12±0.33 mg/100g (unfermented). These values were lower than the 19.23±0.13 mg/100g reported for lima bean seeds by Adgebebinghe et al. (2014). However, these values were higher than the 0.032±0.007 mg/100g reported for Citrullus vulgaris by Peter-Ikekukuw et al. (2015).
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