NUTRITIONAL VALUE OF DIFFERENTLY PROCESSED SOYBEAN SEEDS

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ABSTRACT

BACKGROUND AND OBJECTIVES: Soybeans have been used in human and animal nutrition because of their favorable agronomic characteristics, relatively low price, high quality and quantity of protein and oil as well as their important functional properties for the development of different types of foods for humans. However, Raw Soybean Seed Meal (RSSM) contain high levels of anti-nutritional factors (ANFs), such as protease trypsin inhibitors, lipase inhibitors, goitrogens, and hemagglutins, which must be deactivated by proper heat treatment prior to inclusion in animal and human diets. The main objective of this study was to determine the nutritional and anti-trypsin content of raw soybean seeds in comparison to the solvent extracted and steam cooked soybeans.

MATERIALS AND METHODS: The proximate composition, minerals and anti-trypsin content of raw soybean seeds and differently processed soybean seeds were determined using standard methods. One way Analysis of Variance (ANOVA) was used in analysing the data.

RESULTS: The moisture content of solvent extracted soybean seeds (SES) (6.7±0.2 %) was significantly higher than Raw Soybean Seed Meal (RSSM) and Extruded Full-Fat Soybean Seeds (EFFS) (P<0.05). EFFS seeds had lower ash content (4.4±0.1%) as compared to the SES and RSSM. SES had significantly very low crude fat content (2.7±0.2%) than EFFS and RSSM (P<0.005). SES had higher crude protein content (48.9±0.6%) than EFFS and RSSM. RSSM had significantly higher calcium content (1.81±0.007 %) than both EFFS and SES seeds (P<0.05). There was a significant difference in phosphorous content among all the soybean seeds with RSSM having the highest content (0.96±0.1) and EFFS seeds having the lowest (0.59±0.06%), (P<0.05).

There was a significant difference in trypsin inhibitor content in raw and differently processed soybeans with RSSM having the highest concentration (54.0±1.5) while EFFS had the lowest concentration (1.0±0.03 mg inhibited Trypsin/g). The highest essential amino acid content in EFFS, SES and RSSM seeds was arginine (8.67±0.3) (8.69±0.5) and (7.77±0.3g/16g N) respectively. While the lowest essential amino in raw and differently processed soybeans was methionine with SES having the lowest concentration (1.46±0.2g/16g N). The results further indicate that EFFSs had the highest concentrations of all the non-essential amino acids apart from cystine which was slightly higher in SES than in EFFSs whilst glutamic acid was the highest non-essential amino acid obtained in EFFSs. RSSM had lower amount of all the non-essential amino acids apart from tyrosine as compared to SES and EFFS though the differences were not significant (P>0.05).

CONCLUSIONS: Soybeans processed by steaming (EFFS) could be used as a protein and energy source at the village level as the method is easier and cheaper to use while it maintains most of the nutrients and removes the anti-nutrient factors.

Key words: Raw Soybean, Solvent extraction, Full-Fat Soybeans, anti-nutritional factors, Proximate analysis
1. INTRODUCTION

Soybeans and soybean products are widely used as a protein and energy source for humans and animals. Soybean production in Zambia has been taken up seriously by farmers in recent years especially in Central and Northern provinces. Soybean seeds in Zambia are sold based on weight irrespective of the quality of seeds in terms of nutritive content while in other countries it is sold based on specifications of protein, fat, moisture content, fibre and urease activity. Therefore there is need to know more about the processing, nutritional quality, usage of soybean products, storage and quality control. The methods of processing and heat treatment of soybeans to combat anti-nutritional factors has been described in addition to nutritional analysis of locally produced soybeans. Soybeans have been used in human and animal nutrition because of their favourable agronomic characteristics, relatively low price, high quality and quantity of protein and oil (Liu, 2000) as well as their important functional properties for the development of different types of foods for humans (Traina and Breene, 1994). Soybeans contain highly valuable proteins and oils (on average ranging from 39-41% crude protein and 18-21%oil) which make them good feed alternatives to animal proteins and oils. According to their digestibility and amino acid composition, soybeans are very similar to proteins of animal origin, except that the sulphur amino acids (cystein and methionine) contents are limited (Anderson and Wolf, 1995). Soybean is the leading protein source used in poultry and livestock diets around the world as it contains high quality protein that is essentially equivalent to milk protein when supplemented with methionine (Liener et al., 1985). It also contains many of the essential amino acids that are deficient in most cereal grain-based diets commonly fed as energy sources to poultry and swine (Bruce et al., 2006). According to Stein et al. (2008) this unique composition of amino acids (AA) complements the AA composition of many cereal grains in complete animal diets.

However, Raw Soybean Seed Meal (RSSM) contain high levels of anti-nutritional factors (ANFs), such as protease trypsin inhibitors, lipase inhibitors, goitrogens, and hemagglutins, which must be deactivated by proper heat treatment prior to inclusion in animal and human diets. ANFs contained in soybeans may cause unfavourable physiological effects (Buttle et al. 2001) and may decrease weight gain in animals (Palacios et al. 2004). This is an indication of the indigestibility of RSSM for both animals and humans. Proper processing is required to inactivate the ANFs to an acceptable level without reducing the availability of nutrient (Van der Poel et al. 1995). Processing of RSSM by means of heat and mechanical treatment destroys the ant-nutrients contained therein, thus making the beans fit for use in monogastric diets for example in chickens, pigs, pets as well as humans. The problem relating to the availability of the amino acids in the heat-treated beans arises due to the fact that only an optimum level of heat treatment will produce the maximum availability of the amino acids to the animal. Under-processing of the Full Fat Soybeans (FFSB) tend to limit amino acid availability due to the partial destruction of the anti-nutrient factors. Over-processing on the other hand, decreases the amino acid availability as a result of the Maillard reaction that occurs between aldehyde groups of sugar and free amino groups (Stein, 1989). Experiments conducted by Renner and Hill (1960) and Rackis (1965) revealed that RSSM that contained high levels of trypsin inhibitor activity (TIA) reduced protein absorption in young chicks and to a certain extent fat absorption by increasing the fecal excretion of bile acids (Serafin and Nesheim, 1970). This study therefore determined the nutrient and anti-nutrient contents of Raw Soybean Seed Meal (RSSM), Extruded Full-Fat Soybean Seeds (EFFS) and Solvent Extracted Soybeans (SES).The full-fat soybeans method used in this study was devised so as to be used even at village level.

2. MATERIALS AND METHODS

Soybeans collected for analysis were divided into three categories, namely RSSM, EFFS and SES. The RSSM were analysed for nutritional and anti-nutritional factors without further processing while the EFFS were prepared by placing already milled soybeans into a cut drum. A lid was placed on top of the drum. A stirrer was placed inside the drum to mix the soybeans completely. The drum of boiling water was connected by a pipe to the drum containing the milled soybeans. The pipe was not immersed in water but just above the boiling water so as to collect the steam into the sample drum. The temperature of the boiling water was maintained at 100 degrees Celsius. The soybeans were left to boil for 90 minutes until
the pulp turned to light brown or tan indicating complete cooking. The EFFSs were taken out and left to dry and then packed.

SES were processed by placing milled soybeans into a container of a solvent which in this case was hexane. Hexane was maintained at room temperature. A stirrer was used to mix the milled soybeans in hexane to ensure complete mixing. Dissolved fat from soybeans was collected on top and was poured off and thereafter the soybeans were placed onto another container with a fine sieve so that residues collected on top and oil goes down through the sieve and collects into the container. This process was repeated several times so as to ensure that most of the oil was removed from the soybeans. The residues were then dried on sacks and packed for analysis.

All the laboratory assays were done at Agriculture University of Norway; Department of Animal Sciences (Nutritional Unit Laboratory), Aas, Norway.

2.1 PROXIMATE ANALYSIS
The moisture content was determined by using the oven drying method as described by AOAC (1990). The total ash was determined as described by Kirk et al. (1991). Fat content was determined using the procedure of AOAC (1990) and n-hexane as solvent. The crude protein content was determined using macro kjeldahl method as reported by Kirk et al. (1991). The gram nitrogen obtained was multiplied by 6.25 to obtain the crude protein content calorimetrically using the spectronic 20 (Gallenkamp, UK) (Kirk and Sawyer, 1991) with KH₂PO₄ as the standard. The gross energy was determined using Gallenkamp Ballistic Bomb Calorimeter and Metabolizable energy was estimated by the method outlined by Panzenga (1985):
ME (kcal/Kg) = 37 X % protein+81.8 X % fat+35 X % NFE

2.2 MINERAL DETERMINATION
Phosphorus (P) was determined calorimetrically using the spectronic 20 (Gallenkamp, UK) (Kirk and Sawyer, 1991) with KH₂PO₄ as the standard. Calcium (Ca) was determined using Atomic Absorption Spectrophotometer (AAS model SP9). All values were expressed in mg%.

2.3 AMINO ACID ASSAY
The concentration of each of the assayed amino acids was determined as described by Einarsson et al. (1983). In summary, the assay involved acid hydrolysis with 6M HCl at 110°C for 24h and precolumn derivatisation of amino acids with 9-fluorenylmethyl chloroformate. The amino acids were extracted with pentane and separated by gradient elution on a chromatograph. The Chromatograph consisted of a Spectra System P4000 Quaternary HPLC equipped with a Spectra System FL3000 fluorescence detector and Rheodyne 7125 valve with 20µL injection loop. The eluent was varied with a concave curve from sodium citrate buffer (pH 2.95)-acetonitrile (70:30) to sodium citrate buffer (pH 4.5)-methanol-acetonitrile (14:6:70) and a flow rate of 1.4MI min⁻¹. A varian-omniSper 5 C18 150 X 4.6 analytical column and guard column were used for the separation of the amino acids. Identification of the amino acids was done at an excitation wavelength of 264nm and an emission wavelength of 340nm. A personal computer equipped with TSP software was used for quantification. Quantification was performed by using an external calibration procedure.

2.4 TRYSIN INHIBITORS
Trypsin inhibitors are low molecular weight proteins capable of binding to and inactivating the digestive enzyme, trypsin (Dave Oomah et al., 2011). Trypsin Inhibitor Activity (TIA) was determined using the casein digestion method (Kakede et. Al 1974).

All the analytical procedures were done in triplicate and the mean data recorded. The data were analyzed using SPSS version 16.00. The mean and standard error of means (SEM) of the triplicate analyses were calculated. The analysis of variance (ANOVA) was performed to determine significant differences between the means (p< 005).

3. RESULTS

3.1 PROXIMATE COMPOSITION
Data on the proximate composition of raw and differently processed soybeans are shown in Table 1.

The moisture content of SES (6.7±0.2 %) was higher than RSSM and EFFS. There was no significant difference in moisture content between EFFS and RSSM (P>0.05). EFFS had lower ash content (4.4±0.1%) as compared to the SES and RSSM. SES had very low crude fat content (2.7±0.2%) than EFFS and RSSM and there was no significance difference between EFFS and RSSM crude fat content. Crude fibre content in RSSM was higher than both EFFS and SES. SES had higher crude protein content (48.9±0.6%) than EFFS and RSSM. There was a significant difference (P<0.05) between raw and
differently processed soybeans with EFFS having the highest energy content than the RSSM and SES.

**TABLE 1: PROXIMATE COMPOSITION OF RAW AND DIFFERENTLY PROCESSED SOYBEAN SEED MEALS.**

<table>
<thead>
<tr>
<th></th>
<th>EFFS</th>
<th>SES</th>
<th>RSSM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture %</td>
<td>4.4±0.1a</td>
<td>6.7±0.2b</td>
<td>5.3±0.2a</td>
</tr>
<tr>
<td>Ash %</td>
<td>4.4±0.1a</td>
<td>6.0±0.1b</td>
<td>7.3±0.3b</td>
</tr>
<tr>
<td>Crude fat %</td>
<td>22.0±0.3b</td>
<td>2.7±0.2a</td>
<td>22.7±0.5b</td>
</tr>
<tr>
<td>Crude fibre %</td>
<td>5.4±0.1a</td>
<td>4.5±0.3a</td>
<td>7.5±0.2b</td>
</tr>
<tr>
<td>Crude Protein %</td>
<td>37.6±0.8a</td>
<td>48.9±0.6b</td>
<td>36.6±0.7a</td>
</tr>
<tr>
<td>MEn Kcal/kg</td>
<td>3223±1.8a</td>
<td>2241±1.4b</td>
<td>2734±1.6c</td>
</tr>
</tbody>
</table>

All values expressed as means ± SE on dry weight basis.
*Values on the same row followed by the same letter are not significantly different (p >0.05)

EFFS: Extruded full fat soybean Seeds  SES: Solvent Extracted Soybean Seeds
RSSM: Raw Soybean Seed Meal  MEn: Metabolizable nitrogen corrected energy

**3.2 MINERAL COMPOSITION**

The result of mineral composition of raw and differently processed soybean is shown in Table 2. RSSM had the highest amount of both calcium and phosphorous (1.81±0.07 and 0.96±0.1%) respectively. There was no significant difference in the calcium content of both EFFS and SES (0.21±0.02 and 0.29±0.02 %) respectively. The lowest amount of phosphorous was found in EFFS (0.59±0.06%).

**TABLE 2: MINERAL COMPOSITION OF RAW AND DIFFERENTLY PROCESSED SOYBEANS.**

<table>
<thead>
<tr>
<th></th>
<th>EFFS</th>
<th>SES</th>
<th>RSSM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium %</td>
<td>0.21±0.02a</td>
<td>0.29±0.02a</td>
<td>1.81±0.07b</td>
</tr>
<tr>
<td>Phosphorus %</td>
<td>0.59±0.06a</td>
<td>0.77±0.1b</td>
<td>0.96±0.1c</td>
</tr>
</tbody>
</table>

All values expressed as means ± SE on dry weight basis.
*Values on the same row followed by the same letter are not significantly different (p >0.05)

EFFS: Extruded full fat soybean seeds  SES: Solvent extracted soybean seeds
RSSM: Raw soybean seed meal

**3.3 TRYSPI-N INHIBITOR ACTIVITY (TIA)**

Data for TIA in raw and differently processed soybeans are presented in Table 3. There was a significant difference in trypsin inhibitor content in raw and different processed soybeans with RSSM having the highest concentration (54.0±1.5) , with EFFSs having the lowest content (1.0±0.03 mg inhibited trypsin/g).

**TABLE 3: ANTI-TRYPSIN CONTENT IN DIFFERENT PROCESSED SOYBEANS.**

<table>
<thead>
<tr>
<th></th>
<th>EFFS</th>
<th>SES</th>
<th>RSSM</th>
</tr>
</thead>
<tbody>
<tr>
<td>mg inhibited trypsin/g</td>
<td>1.0±0.03a</td>
<td>10.0±0.5b</td>
<td>54.0±1.5c</td>
</tr>
</tbody>
</table>

All values expressed as means ± SE on dry weight basis.
All values expressed as means ± SE on dry weight basis.
*Values on the same row followed by the same letter are not significantly different (p >0.05)
EFFS: Extruded full fat soybean seeds  SES: Solvent extracted soybean seeds  RSSM: Raw soybean seed meal

3.4 AMINO ACID COMPOSITION

Results for essential and non-essential amino acid composition in raw and differently processed soybeans are shown in table 3 and 4 respectively. The highest essential amino acid content in EFFS, SES and RSSM was arginine (8.67±0.3), (8.69±0.5) and (7.77±0.3g/16g N) respectively. While the lowest essential amino in raw and differently processed soybeans was methionine with SES having the lowest concentration (1.46±0.2g/16g N). However, there was no significance difference in methionine concentration in raw and differently processed soybean seeds (P>0.05).

The results further indicate that EFFS had the highest concentrations of all the non-essential amino acids apart from cystine which was slightly higher in SES than in EFFSs whilst glutamic acid was the highest non-essential amino acid obtained in EFFSs. RSSM had lower amount of all the non-essential amino acids apart from tyrosine as compared to SES and EFFS though the differences were not significant (P>0.05).

**TABLE 4: ESSENTIAL AMINO ACID CONTENT IN DIFFERENT PROCESSED SOYBEANS. (g/16g N)**

<table>
<thead>
<tr>
<th></th>
<th>EFFS</th>
<th>SES</th>
<th>RSSM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arginine</td>
<td>8.67±0.3³</td>
<td>8.69±0.5⁴</td>
<td>7.77±0.3⁵</td>
</tr>
<tr>
<td>Histidine</td>
<td>3.10±0.11²</td>
<td>2.98±0.25²</td>
<td>2.97±0.3²</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>4.96±0.3³</td>
<td>4.69±0.2⁴</td>
<td>4.88±0.3⁵</td>
</tr>
<tr>
<td>Leucine</td>
<td>8.31±0.3³</td>
<td>7.93±0.3⁴</td>
<td>7.82±0.4⁵</td>
</tr>
<tr>
<td>Lysine</td>
<td>6.31±0.4²</td>
<td>6.51±0.3⁴</td>
<td>6.80±0.2⁴</td>
</tr>
<tr>
<td>Methionine</td>
<td>1.63±0.1²</td>
<td>1.46±0.2²</td>
<td>1.59±0.2²</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>5.37±0.3³</td>
<td>5.20±0.4³</td>
<td>4.93±0.3⁴</td>
</tr>
<tr>
<td>Threonine</td>
<td>4.22±0.3³</td>
<td>3.99±0.2⁴</td>
<td>4.14±0.5⁵</td>
</tr>
<tr>
<td>Valine</td>
<td>5.02±0.18²</td>
<td>4.79±0.22²</td>
<td>5.00±0.21⁴</td>
</tr>
</tbody>
</table>

**TABLE 5: NON-ESSENTIAL AMINO ACID CONTENT IN DIFFERENT PROCESSED SOYBEANS (g/16g N).**

<table>
<thead>
<tr>
<th></th>
<th>EFFS</th>
<th>SES</th>
<th>RSSM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alanine</td>
<td>4.67±0.05³</td>
<td>4.55±0.02²</td>
<td>4.53±0.02³</td>
</tr>
<tr>
<td>Cystine</td>
<td>1.66±0.03³</td>
<td>1.78±0.05³</td>
<td>1.52±0.03³</td>
</tr>
<tr>
<td>Glutamic acid</td>
<td>21.07±2.1³</td>
<td>20.44±1.8⁴</td>
<td>19.96±1.5⁴</td>
</tr>
<tr>
<td>Glycine</td>
<td>4.80±0.3³</td>
<td>4.00±0.2³</td>
<td>4.54±0.3³</td>
</tr>
<tr>
<td>Proline</td>
<td>5.33±0.2³</td>
<td>5.20±0.3³</td>
<td>4.93±0.2³</td>
</tr>
<tr>
<td>serine</td>
<td>5.68±0.2³</td>
<td>5.43±0.3³</td>
<td>5.38±0.2³</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>4.12±0.1³</td>
<td>3.89±0.2²</td>
<td>5.00±0.3³</td>
</tr>
</tbody>
</table>

All values expressed as means ± SE on dry weight basis.

*Values on the same row followed by the same letter are not significantly different (p >0.05)
4. DISCUSSION

The results in this study shows that the moisture content in EFFS seeds was significantly lower than in the RSSM and SES. This could be attributed to the fact that steam was used to boil the milled soybeans and hence the water contained in the milled seeds could have evaporated during drying. These results are in agreement with Davies (2008), who found lower moisture content in full-fat soy beans than in solvent extracted soybean seeds. The main advantage of having lower moisture content is that preservation period is increased due to less risk of microbial deterioration and spoilage when even when stored longer. The results obtained for ash content is in agreement with Saulawa et al., (2014), who obtained higher ash content in raw baobab seed meal than differently processed baobab seed meal. There is a consensus among researchers that ash content of a given sample correlates the minerals contents of the sample. The study further reveals that the crude fibre content of raw soybean seeds was significantly reduced by all the processing methods. The reason for this could be due to the destruction of cellulose contained in raw soybean seeds by the processing methods and consequently reduction in fibre content among the differently processed soybean seed meal. The crude fibre values observed in this study were lower than the value of 16.2% crude fibre reported by Magdi (2004) in raw and differently processed baobab seed meal. The value of crude fibre observed in raw baobab seed in this trial is similar to 9.02% crude fibre reported by Okoye et al. (1980) for raw baobab seed obtained from Maiduguri in north-eastern Nigeria. The low fibre content in different processed soybeans accords the results obtained by Akinmutimu (2004) who reported 50% reduction in crude fibre in soybeans when subjected to cooking.

The crude protein content in raw soybean seeds was much lower than in different processed soybeans and this could be due to the fact that in raw soybeans seeds, crude proteins are enclosed in fibre and hence not readily available. These results are in conflict with Saulawa et al. (2014) who obtained decreased amount of crude proteins in different processed baobab seed beans than in raw seed beans however the results were in agreement with Emiola et al. (2002) who reported an increase in crude protein content of raw kidney beans when subjected to boiling. The highest crude fat content in this study was found in raw soybeans while the lowest was found in SES seed meal and there was no significance difference between crude fat content of raw soybean seed meal and EFFS. The lower fat content in SES could be due to the removal of fat as a result of the solvent used during processing. There was a significant difference in the Metabolizable energy content between the raw soybeans and differently processed soybeans with EFFS and SES having the highest and least metabolizable energy content respectively. Fat tend to release more energy than any other source hence the availability of fat in the RSSM and EFFS leads to higher metabolizable energy content than in SES which had fat removed by the use of solvent during processing.

This study reveals that arginine was the most abundant amino acid in all the three soybeans analysed. It is an essential amino acid which may be beneficial in patients with certain cardiovascular diseases. The administration of exogenous L-arginine, a precursor of Nitric oxide (NO) has been found to improve endothelium-dependent vasodilatation (Creager et al., 1992). The highest content of arginine was in EFFS and SES than in RSSM and therefore EFFS could therefore when used as a food ingredient or supplement potentially increase the body’s physiological pool of L-arginine thereby offering some degree of cardiovascular protection. The lowest essential and non-essential amino acids obtained in raw and differently processed soybeans were methionine and cystine respectively. The results accords that of Anderson and Wolf (1995), who hypothesized that the amino composition of soybeans is similar to proteins of animal origin except that sulphur amino acids (methionine and cystine) contents are limited.

This study further reveals that raw soybeans had the highest amount of trypsin inhibitor activity (TIA) than the differently processed soybeans. EFFS processed soybeans had significantly low TIA because of denaturing of these enzymes due to steaming process that was used during preparation. The results are in consistent with Saulawa et al. (2014), who found higher anti-trypsin inhibitors in raw baobab seeds than in boiled baobab seeds. The results also accords those of Udousoro et al. (2013) who found that heating conditions resulted in a reduction of all the anti-nutrients that were studied. The results are also in agreement with Quintela et al., (1998), who found significantly higher TIA in raw soybeans than in peas seeds and fava beans. Therefore EFFSs were far much better than SES and RSSM because low TIA content was found in EFFS processed seeds. Trypsin
inhibitors are a unique class of proteins found in raw soybeans that inhibit protease enzymes in the digestive tract by forming indigestible complexes with dietary protein. These complexes are indigestible even in the presence of high amounts of digestive enzymes. Protease inhibitors reduce trypsin activity and, to a lesser extent, chymotrypsin; therefore impairing protein digestion by monogastric animals and some young ruminant animals (Liener, 1994). Since the pancreas is responsible for the production of most digestive enzymes any substance that affects the pancreatic function will evidently influence nutrient digestibility and availability (Mushtaq, 1987). Herkelman et al. (1992) reported that feeding soybean meal with high levels of trypsin inhibitors to poultry caused pancreatic hypertrophy and a reduction in nutrient digestibility. Previous research has shown that trypsin inhibitors do not appear to account for all the growth inhibition caused by feeding raw soybeans. Kakade et al. (1974) removed the trypsin inhibitor activity of the soybean meal and found that the inhibitor free extract still resulted in growth inhibition and pancreatic hypertrophy in rats. Therefore, they suggested that 40% of the growth inhibition and pancreatic hypertrophy could be attributed to trypsin inhibitors. The other 60% of the growth inhibition could be attributed to other antinutritional factors that include: lipase inhibitors, goitrogens, and hemagglutins. The mechanism by which the trypsin inhibitors stimulate pancreatic enlargement is not fully understood; therefore additional research is necessary.

Raw soybean seeds had moderately higher calcium and phosphorous content than differently processed soybean seeds. The reason for the high content of minerals in raw soybean seeds can be attributed to an increase in phytates and oxalates which tend to form insoluble complexes, which are not readily absorbed by the gastrointestinal tract (Akande et al., 2010; Agbaire and Oyewole, 2012). The results obtained in this study are consistent with those obtained by Magdi et al. (2004) who found high calcium and phosphorous in raw baobab seeds than in different processed baobab seeds.

5. CONCLUSION

Soybeans processed by steaming (EEFS) was found to be of better quality as the crude protein content, fat and amino acid content were maintained. In addition, the anti-nutritional factors such as trypsin inhibitor were found to be lower as compared to the raw and solvent extracted soybeans. Therefore the processing procedure described in this study could be used at the village level to process soybeans for human and animal consumption.

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