**Impact of Soy Flour Processing Methods on its Functional, Proximate and Antioxidant Properties**

**Abstract**

Assessment on the effect of selected standard processing methods on the functional, proximate and antioxidant properties of soy flours was carried out. Three soy flour samples were prepared using three processing methods (PM1 –PM3). PM1 involves soaking of clean soy bean seeds, dehulling, sundrying (2-3 days), milling, cooling and packaging; PM2 involves soaking with (0.5% NaHCO3), decanting, washing, dehulling, dehusking, sundrying (2-3 days), milling, cooling and packaging; PM3 involves soaking, blanching (100 ᵒC for 5min), draining, cooling, dehulling, sundrying (2-3 days), milling sieving and packaging. The flours were analyzed for functional, proximate and antioxidant properties. Sample means were separated using Duncan’s multiple range comparison test (DMRCT) to determine which sample differed significantly from each of the three (3) soy powder samples. The swelling power, water absorption capacity, oil absorption capacity, bulk density, foam capacity, emulsion capacity, moisture, protein, fat, fibre, ash and carbohydrate contents ranged from 12.50-14.25%, 86.54-88.14%, 70.26-80.63%, 0.70-0.85 g/cm3, 24.50-36.12%, 19.55-24.56%, 7.15- 7.20%, 29.40-36.80%, 7.93-9.11%, 6.51-7.00%, 7.81-9.13%, 32.0-39.97 and 346.51-359.47 kcal/100g. Soy flour from processing method one (PM1), a traditional soymilk production method modified to produce soy flour significantly affected some of the proximate parameters such as fat, carbohydrate and energy value. Interestingly, processing (modified) method three (PM3) significantly affected protein, fibre, ash, some antioxidant properties such as ferrous reducing antioxidant power (FRAP) and 1, 1, diphenyl-2-pycryl- hydrazyl (DPPH) % inhibition and all functional properties except for oil absorption capacity.

**Keywords**: Antioxidant properties, foam capacity, functional properties, processing methods, proximate properties, swelling power,

**1. Introduction**

During the last decade, health improving nutrition has acquired worldwide prominence. In this context, soybean and products developed from it have become of great interest in human and animal nutrition (Liu 2000). Soybean is regarded as one of the most nutritive food sources known to man. It is unique in its nutritional value because of its high content of protein (40%) and oil (20%) (Enwere1998; Fabiyi 2006). Soya bean is a widely used inexpensive, and nutritional source of dietary protein (McArthur *et al*.,1988). Its protein content (40%) is higher and more economical than that of beef (18%), chicken (20%), fish (18%) and groundnut (23%) (IITA, 1990).

Soybean, a native of China is one of the oldest crops of the Far East. For centuries, the Chinese and other oriental people, including Japanese, Korea and Southeast Asians have used the bean in various forms as one of the most important sources of dietary protein and oil (Liu 2012). The cultivated form, called Glycine max (L.) Merrill, grows annually. The seeds are nearly spherical in shape with an average seed weight of 120-180mg. Soybean can be growing in a wide variety of soils and climatic conditions than any other major world crop. It is well known for its variation in physical properties as well as in its chemical composition (Osthoff *et al.,* 2010). Soy is highly desired for its high content of nutritious protein as well as niacin and phytochemicals (especially isoflavones). It is used in a wide range of foods such as meat products, baked goods and infant foods (Liu, 2012). Not being of animal origin, it lacks lactose and cholesterol, and therefore is less of a problem with dietary disorders or intolerances (Liu, 2012).

The only drawback of soybean is the high content of anti-nutritional factors in the form of trypsin inhibitors (Brinda et al., 2017; Ibanez et al., 2020) which is almost completely removed during processing of soymilk using various heat treatments.

In Asian countries, soybean is processed into various products such as soymilk powder, soymilk, tofu, soy sauce, soy flour, soybean oil, tempeh etc. (Tyug *et al., 2*010). Different processing methods including soaking and grinding, fermentation, pasteurization, thermal treatment, high pressure processing, traditional methods etc are used for the production of these products either to inactive spoilage microorganisms and extend the shelf-life of soymilk or decrease anti-nutritional factors that are found in soy.

According to Tyug *et al.* (2010) the processing of soybean into soy powder involves three major steps. First, soybeans are soaked in water to remove the inedible soy husk. However, this might represent a major disposal problem for the soybean processing industry, as soy husk represents about 8% of the entire soybean. After the removal of the soy husk, the beans are dried, ground, sieved and cooked into slurry. Finally, the cooked slurry is subjected for vacuum drying to obtain grade A soymilk powder (GASP). Under normal circumstances, wastes produced during the production of grade A soymilk powder will be discarded or used as animal feed. However, in Malaysia, the wastes are processed to a lower-quality powder, called grade B soymilk powder (GBSP) Tyug *et al.,* 2010).

Several efforts have been made in the production or processing of soymilk with little or no success in the keeping quality of the product. Soy flour/powder is now the alternative to the aqueous extract of soymilk which closely resembles cow milk in appearance and composition but with short shelf life. Soy flours are prepared using different processing methods to ensure availability of soy protein (soymilk). However, the effect of these methods on the nutrient and mineral/vitamin compositions, quality and sensory acceptability of the soy flours/powder is not well understood and therefore, should be evaluated. It is against this background that this study was conducted to evaluate the quality of soy flours as influenced by processing methods.

**2. Materials and methods**

***2.1 Materials***

Soybean seeds (Var: 1904 - 6F) for this study was procured from National Cereal Research Institute (NCRI), Yandev Sub-Station, Box 454, Gboko, Benue state, Nigeria. All the chemicals and reagents (NaHCO3, CCL4, Olive oil etc) needed for use were made available at the University of Mkar, Mkar, Benue state for the preparation of soy flour samples.

***2.2 Methods***

## *2.2.1 Sample Preparation of Soy flours*

**2.2.2 Processing method one - (PM1)**

This is a traditional soymilk processing method described by Iwe, (1991) but slightly modified to produce soy flour. Cleaned sorted and washed whole soybean seeds was soaked in water overnight at room temperature, dehulled manually, sundried for two-three days and milled into soya flour (Figure 1) using attrition Mill, model No. R175A at rated speed of 2600 rpm. The soy flour obtained was packed into an air-tight container.

**2.2.3 Processing method two - (PM2)**

This is a soymilk processing method involving use of sodium bicarbonate described by Afroz *et al*. (2016) but slightly modified to produce soy flour. In this method, dry whole soybean seeds were cleaned, washed and soaked in a solution of water + 0.5% sodium bicarbonate (NaHCO3) overnight in 4 times weight per volume (w/v). After decanting the soak water, the bean was dehulled manually. The dehulled bean was sundried to its original moisture content and milled into soy flour using an attrition mill model N0 R175 at rated speed of 2600 rpm and packed into air-tight container for further use (Figure 1).

**2.2.4 Processing method three – (PM3)**

This is a soymilk powder processing method described by Cheryl (2021) but with some modifications to produce soy flour. In this method, washed soybean seeds were soaked overnight in a stainless steel container. The following morning the bean was blanched at 1000 C for 5min (modifications) and then removed and placed in a bowel ¾ filled with cold water. The skins or husks were removed manually. The dehulled beans were sundried for 2-3 days and milled in an Attrition mill model No R175 at rated speed of 2600 rpm. The soy flour obtained was sieved and packed in an air-tight container ready for use (Figure 1).

**2.3 Functional properties of the flours**

**2.3.1 Swelling capacity (mL)**

The swelling index (SI) was determined by the method described by Ukpabi and Ndimele (1990). 2.5 g of each sample was put in 210 mL measuring cylinder. Distilled water (150Ml) was added and allowed to stand for 4h before observing the level of swelling

SI = (1)

Swelling capacity was calculated from the result of swelling index as follows:

Swelling capacity = x 100 (2)

**2.3.2 Water absorption capacity (WAC, %)**

Water absorption capacity of the flour samples was determined using a method described by Onwuka (2005). 1.0g of the sample was weighed into a 15mL centrifuge tube and suspended in 10mL distilled water. It was shaken on a platform tube rocker for 1 minute at room temperature.

The sample was allowed to stand for 30 minutes and centrifuged at 1200 x g for 30 minutes. The volume of the free water was read directly from the centrifuge tube

WAC% = x 100 (3)

**2.3.3 Oil absorption capacity**

Oil absorption capacity was determined by the method of Onwuka (2005). AboutOne gram of the flour was mixed with 10mL of refined corn oil in a centrifuge tube and allowed to stand at room temperarure 30±2oC for 1hr. It was centrifuged at 1600 x g for 20min. the volume of the free oil was recorded and decanted. Fat absorption capacity was expressed as mL of oil bond by 100g dried flour;

OAC% = x 100 (4)

**2.3.4 Emulsion activity/stability**

The emulsion activity was determined using a method described by Neto *et al*. (2001) 2.0g of soy flour sample dispersed in distilled water (10 mL) and height of solution in the cylinder measured. The solution homogenized with refined canola oil (5.0 mL) and the resulting emulsion was centrifuged at 1100 x g for 5 minutes. The height of the emulsified layer observed, and the emulsifying activity calculated as the percent increase in the height of the solution by the following equation:

Emulsion activity (%) = X 100 (5 )

where, H1= Initial height of solution before emulsification

H2=height of the emulsified layer

* + 1. **Emulsion stability**

Emulsion stability was estimated after heating the emulsion contained in calibrated centrifuged tube at 80°C for 30 min in a water-bath, cooling for 15 min under running tap water and centrifuging at 2000 × g for 15 min. The emulsion stability expressed as percentage was calculated as the ratio of the height of emulsified layer to the total height of the mixture.

Cleaned and sorted soybean seeds Cleaned soybean seeds Soybean seeds

Soaked + 0.5% NaHCO3 (modified)

Soak overnight

Soaked overnight (at room temperature)

**Figure 1**. Flow chart showing the three processing methods used in the preparation of soy flour

*Processing method 3 (PM3)*

*Processing method 2 (PM2)*

*Processing method 1 (PM1)*

Sundrying for 2-3days (modification)

Placed beans in a bowl ¾ filled with cold water

Packaged (Air-tight container)

Soy flour

Milling

Sundrying 2-3 days to original moisture content

Cleaning with water to remove husk

Dehulling (using pressure from 2 hands)

Washing

Decant soaked water

Storage in an air-tight container

Soy flour

Sieving

Milling

Strained and pat beans dry with paper towel

Dehulling

Draining

Blanching at 100**ᵒ**C for 5min (modified)

Packaged (Air tight container)

Soy flour

Milling

Sundrying for 2-3 days (Modify)

Dehulling

**2.3.6 Foam Capacity**

The foam capacity (FC) and foam stability (FS) were determined using method ofAOAC, (2006). 2.0g flour sample was weighed and blended with 100mL of distilled water using warring blender and the suspension was whipped at 1600 rpm for 5 minutes. The mixture was then poured into 100mL of measuring cylinder and calculated thus:

Foam capacity (%) = X 100 (6)

Where, VO = volume before whipping andV1 = Volume after whipping

The volume of foam was recorded 1 hour after whipping to determine foam stability as per percent of initial foam volume

Foam stability = x 100 (7)

**2.3.7**  **Bulk density (g/ml)**

The method described by Onwuka (2005) was used to determine the bulk density of the soy flours. About 10g of the sample was weighed into (50mL) graduated measuring cylinder. The cylinder was packed by gently tapping the cylinder on the bench top 10 times from a height of 5cm. The volume of the sample was recorded and the bulk density (g/mL) was calculated as:

Bulk density (g/ml) = x 100 (8)

**2.4.1 Proximate compositions.**

**2.4.2 Determination of moisture content**

The moisture content was determined by air oven drying method described in AOAC (2005). 1 gram of soy powder sample was weighed in duplicate into already weighed and cooled mixture dishes and transferred into a hot oven at 105±20C for 2 to 3 hours. The samples were removed from the oven, transferred into desiccators and allowed to cool for 15 minutes before reweighing. The dishes were returned to the oven to reweigh until constant weights were obtained. The loss in weight was calculated as moisture.

**2.4.3 Determination of crude protein**

This was done by micro Kjedahl method as described in AOAC (2005). A catalyst mixture (0.8g) was placed in conical flask with few boiling chips. The sample (0.2g) was weighed using a balance and transferred into the flask. Concentrated sulphuric acid (10ml) was added, the mixture heated on a heating mantle, initially gently until foaming has ceased and the content became completely liquefied. It was then heated vigorously until the liquid was clear and free from black colour. The flask was then cooled and the content with 25ml distilled water. Distillation apparatus was connected, 5ml of 2% boric acid solution was measured into a 100mL conical flask and 2 to 3 drops of mix indicator was added, the flask was placed on the receiver so that the end of the delivery tube tips just below the level of the boric acid. 5mL of digested sample was pipette into distillation unit and 7mL to 10mL of 50% or 40% NaOH solution was added. The unit was close and the liberated ammonia was steam, distilled into boric acid. 20mL to 50mL of distillate was collected and the tip of the delivery tube was rinsed with distilled water. The distillate was titrated with 0.1mL HCL acid until the green colour change to purple. The percentage of nitrogen in the sample was calculated from the formula:

%Nitrogen = x 100 (10)

Where, S-B means sample titre value minus blank,

D Means dilution factor =25/5

Crude protein = %Nitrogen x 6.25 (11)

**2.4.4 Determination of crude ash**

The percent ash content of the samples was determined employing the method described in AOAC (2005). The weight of the crucible dish was taken and 2.0g of the dried soy powder sample was measured and added to each of the crucibles. The dish and the content were placed on the furnace rack and the furnace with the temperature set at 5000C to 5500C for 2-4 hours until the sample was completely ashed. The ash in the crucibles dishes was weighed and perceive ash was calculated as:

% Ash = x 100 (12)

**2.4.5 Determination of crude fat**

The soxhlet solvent extraction method as described in AOAC (2005) was used to determine the crude fat in the samples. 5.0g of the sample was weighed and the weight of the fat bottom flask was taken. The thimble was held half way into the extractor and the weighed sample was carefully transferred into the thimble. Extraction was carried out using petroleum ether (boiling point 40-600C) the thimble was plugged with cotton wool. extraction was continuous for 2-3 hours. At completion of extraction, the solvent was removed by evaporation on a water bath and the remaining part in the flask dried to 800C for 30minutes in the hot air oven to dry the flask then cooled in a desiccator. It was reweighed and percentage fat calculated as follows:

Crude fat% = x100 (13)

**2.4.6 Determination of crude fibre**

The procedure outlined in AOAC, (2005) was used in determining the crude fibre content of the soy powder samples. 2.0g of the sample were weighed into a 500ml beaker and boiled in 200ml H2SO4 (%) for 30 minutes. The suspension was filtered and the residue washed vigorously with botching water until it was no longer acidic the sample residue was boiled in 200ml NaOH solution for 30 minutes, rinsed with hot water and dried in an oven. The dried residue was cooled in a desiccator and reweighed. The weighed sample residue was washed in a muffle furnace when the temperature was 2000C. It was cooled in a desiccator and weighed. The loss in weight of the incinerated residue before and after incineration was taken as crude fibre content. Percentage crude fibre was calculated as:

% Crude fiber = x 100 (14)

**2.4.7 Determination of carbohydrate content**

Determination of carbohydrate content was done by differential method i.e. summing up the % (moisture, protein, fat, ash and crude fibre) contents and subtracting their sum from 100% and expressed in percentage. This gave the amount of nitrogen free extract otherwise known as carbohydrate by Serah *et al*. (2015).

% carbohydrate = 100- sum of % (moisture + fat +protein +fibre +ash) (15)

**2.4.8 Determination of energy value Kcal/100g**

Food energy containing samples were determined by calculation based on the contents of carbohydrate; protein and lipid multiplied by a factor of 4, 4 and 9 respectively, and their product summed. The result expressed in kcal/100g (Aunyachulee and Chutinan,2019; Alimi et al., 2024b).

Energy value = [(% carbohydrate x 4) + (% protein x 4) + (% fat x 9)] kcal/100g (16)

**2.5 Anti-oxidants properties**

**2.5.1**  **Estimation by ferrous reducing antioxidant power (FRAP)**

This assay was as described by the method of Benzie and Strain (1996). The method is based on the reduction of Fe3+ TPTZ complex (colourless) to Fe2+- tripyridyl triazine (blue coloured complex) formed by the reaction of the electron donating antioxidants at low PH. This reaction was monitored by measuring the change in absorbance at 593nm. The ferric reducing antioxidant power (FARP) reagent was prepared by mixing 300Mm acetate buffer, 10mL TPTZ in 40mM HCL and 20Mm FeCl3.H2O in the proportion of 10:1:1 at 370C. Freshly prepared working FRAP reagent was pipetted using 1-5µL variable micropipette (3.995mL) and mixed with 5µLof appropriately diluted soy powder sample and mixed thoroughly. An intense blue colour complex was formed when ferric tripyridyltriazine (Fe3+ TPTZ) complex was reduced to Ferrous (Fe2+) form and the absorbance at 593nm was recorded against a reagent blank (3.993mL). FRAP reagent + 5µL distilled water after 30min. incubation at 37 0C. All the determinations were performed in duplicates. The calibration curve was prepared by plotting the absorbance at 593nm versus different concentrations of Feso4. The concentrations of Feso4 were in turn plotted againstconcentration of standard antioxidant Trolox. The FRAP were obtained by comparing the absorbance change in the test mixture with those obtained from increasing concentrations of Fe3+ values be monitored by measuring the formation of Perl’s Prussian blue at 700 nm. 0.25 mL samples/standard solution at different concentrations and expressed as mg of Trolox equivalent per gram of sample.

**2.5.2 Determination by 1, 1-Diphenyl -2- picryl hydrazyl (DPPH**)

Total free radical scavenging capacity of the extracts from different soy powder processing methods were estimated as reported by Brand-william *et al*. (1995) with slight modifications using stable DPPH radical which has an absorption maximum 515nm. A solution of the radical is prepared by dissolving 2.4mg DPPH in 100mLmethanol. A test solution 5µL was added to 3.995Ml of methanol DPPH. The mixture was shaken vigorously and kept at room temperature for 30min. in the dark. Absorbance of the reaction mixture was measured at 515nm spectrophotometrically. Absorbance of the DPPH radical without antioxidant i.e. blank was also measured. All the determinations were performed in duplicates. The capability to scavenge the DPPH radical was calculated using the following equation (Yen and Duh, 1994).

Where,

AB = Absorbance of blank at t = 0

AA= absorbance of the antioxidant at t = 30min.

**2.5.3 Determination by 3 2, 2- Azinobis (3 ethyl)–benzothiozoline-6-suphonic acid) ABTS assay (AA)**

Free radical scavenging of the soy powder samples was determined by ABTS radical cation decolorization assay (Re *et al.,*1999). ABTS cation radical was produced by the reaction between 7mM ABTS in water and 2.45mM potassium persulfate (1: 1), stored in the dark at room temperature for 12- 16h before use. ABTS+ solution was diluted with methanol to obtain an absorbance of 0.700 at 734nm. After the addition of 5µL of the extracts to 3.995mL of diluted ABTS solution, the absorbance was measured at 30min. after the initial mixing. An appropriate solvent blank was run in each assay. All the measurements were made at least two times. Percent inhibition of the absorbance at 734nm was calculated using the formula;

ABTS scavenging effect % = x 100 (14)

**2.5.4 Determination by Oxygen radical absorbance scavenging capacity (ORAC)**

The procedure for ORAC method was performed according to Ronald *et al.* (2003). Briefly, 20 μl of blank, Trolox standard, or food extracts in 75 mM [potassium phosphate](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/potassium-phosphate) buffer, pH 7.4, was added to triplicate wells in a black, clear-bottom, and 96-well [microplate](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/microplate). The duplicate samples were distributed throughout the microplate and were not placed side by side, to avoid any effects on readings due to location. A volume of 200 μl of 0.96 μM fluorescent in working buffer was added to each well and incubated at 37 °C for 20 min, with intermittent shaking, before the addition of 20 μL of freshly prepared 119 mM ABAP. The microplate was immediately inserted into a plate reader at 37 °C. The decay of fluorescence at 538 nm was measured with excitation at 485 nm every 5 min for 2.5 h. The areas under the fluorescence versus time curve for the samples minus the area under the curve for the blank were calculated and compared to a standard curve of the areas under the curve for 6.25, 12.5, 25, and 50 μM Trolox standards minus the area under the curve for blank.

## 2.6 Statistical Analyses

Data generated from the experiment was subjected to one-way statistical analysis of variance (ANOVA) test, SPSS (version 21). Sample means were separated using Duncan’s multiple range comparison test (DMRCT) to determine which sample differed significantly from each of the three (3) soy powder samples. The least significant difference (LSD) was also used to evaluate significant difference between pairs of treatments at 5% level of significance.

**3. Results and Discussion**

**3.1 Functional composition of the soybean flours**

The functional properties of the soybean flours produced using three different methods are presented in Table 1. Significantly (P<0.05) different functional properties were obtained under processing methods (PM1, PM2 and PM3). Quality parameters of prime importance that depicts the end of flour is known as the functional properties (Alimi and Alimi, 2019). The swelling power of the soybean flour ranged from 12.50 to 14.25%, with PM3 having the highest while PM1 had the lowest. The processing method three (PM3) was significantly (p<0.05) higher compared to PM2 in terms of the swelling power.

Swelling capacity is used as an index to assess the extent of interaction between the swollen starch granules and water (Alimi *et al*., 2024a). The water absorption capacity of the soybean flours ranged from 86.54 to 87.95%, with PM3 having the while the lowest value was recorded in PM1. There was significant (p<0.05) increase in water absorption capacity with mean scores range from 86.54±0.02 to 88.14 ±0.01. This result is in agreement with the findings of Akubor and Onimawo (2003) who reported that increase in water absorption capacity is due to high protein content of soy flour because proteins are capable of binding large quantity of water due to their ability to form hydrogen bonds between molecules and polar groups on the polypeptide chain. This explains why the water absorption capacities of all the soy flours from the processing methods in this study were proportional to their protein contents.

The soybean flours were significantly (p<0.05) different in terms of oil absorption capacity (Table 1). The oils absorption capacity of the soybean flours ranged from 70.26 to 80.63%, with PM1 having the highest while PM3 had the lowest. The ability of flour to retain oil is known as oil absorption capacity, this enhances the flavour and improves the textural properties of food (Alimi *et al*., 2024a).

There was no significant (p>0.05) difference in bulk density between PM2 and PM3 compared to PM1. The bulk density ranged from 0.70 to 0.85 g/cm3, with PM1 having the least while PM2 and PM3 had the highest. Bulk density is said to be important to dietary bulk and packaging requirements and depends on particle size and initial moisture content of flour (David *et al.,* 2015; Chandra *et al.*, 2015).

The foam capacity of soy flours prepared using the three different standard processing methods were significantly (p<0.05) different, which ranged from 24.50 to 36.12%, with PM1 having the least while PM3 had the highest. The foaming capacity measures the amount of interfacial area created by protein during foaming (Zhu *et al*., 2017).

The emulsion capacity of soy flours prepared using the three different standard processing methods were significantly (p<0.05) different, which ranged from 19.55 to 24.56%, with PM3 having the highest while the lowest was recorded in PM1.

Table 1. Functional properties of soy flours

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Properties (%) /Method | PM1 | PM2 | PM3 | SE |
| Swelling capacity | 12.50 ±0.04c | 12.94 ±0.02b | 14.25 ±0.00a | 0 .33 |
| Water absorption capacity | 86.54 ±0.02c | 87.95 ±0.02b | 88.14 ±001a | 0 .32 |
| Oil absorption capacity | 80.63 ±0.01a | 72.96 ±0.01b | 70.26 ±0.01c | 1.96 |
| Bulk density (g/cm3) | 0.70 ±0.00b | 0.85 ±0.01a | 0.85 ±0.01a | 0.03 |
| Foam Capacity | 24.50 ±0.00c | 34.15 ±0.00b | 36.12 ±0.01a | 2.27 |
| Emulsion capacity | 19.55 ±0.00c | 23.71 ±0.01b | 24.56 ±0.01a | 0.98 |

Means with the same superscripts in the same row are not significantly (p>0.05) different (n=2.000); Means are values of two replicates

**3.2 Proximate composition of the soybean flours**

The proximate composition of the soy flour prepared using three different standard processing methods are presented in Table 2. The soy flours were not different (p>0.05) in terms of moisture content but were significantly (p<0.05) different in terms of protein contents. The highest protein content was recorded in soy flour processed with PM3 while the lowest was recorded in soy flour processed with PM1. The soy flours from processing methods (PM1 – PM3) yielded significantly (p<0.05) different protein contents due to different processing treatments. According to Ogbemudia *et al*. (2018) the protein values obtained could be used in the management of protein deficiency cases such as kwashiorkor. The values of protein obtained were within the range reported by Serah *et al.* (2015) which according to them contain sufficient amount of protein required by rats thus, are good source of protein. Due to high protein content, soy flour could be used as an economical protein supplement in biscuit, bread, pasta and other cereal products (Mohajan *et al.,* 2018; Javed *et al*., 2024).

The fat contents ranged from 7.93-9.11%, carbohydrate (32.0-39.97%) and energy value (346.51-359.47 Kcal/100g) with flour samples from PM1 recording significantly (p<0.05) highest fat, carbohydrate and energy value. Carbohydrate is an important source of energy in human diets comprising some 40 -80% of total energy in-take as reported by Zelalem *et al.* (2019). According to Zelalem *et al.* (2019) the brain is the only true carbohydrate-dependent organ in that it oxidizes glucose completely to carbon dioxide and water.

Table 2. Proximate composition of soy flours

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Composition (%) | PM1 | PM2 | PM3 | SE |
| Moisture | 7.20±0.00a | 7.20 ±0.00a | 7.15 ±0.07a | .00 |
| Protein | 29.40±0.00c | 33.96±0.00b | 36.80±0.01a | .00 |
| Fat | 9.11±0.01a | 8.0± 0.00b | 7.93±0.01c | .01 |
| Fibre | 6.51±0.01c | 6.95±0.00b | 7.00±0.00a | .01 |
| Ash | 7.81±0.06c | 8.16±0.01b | 9.13±0.00a | .01 |
| CHO | 39.97±0.04a | 35.74±0.02b | 32.0 ±0.06c | .03 |
| Energy value (kcal/100g) | 359.47±0.04a | 350.78±0.03b | 346.51±0.32c | .03 |

Means with the same superscripts in the same row are not significantly (p>0.05) different (n=2.000) Values are mean ± SD

**3.3** **Antioxidant properties of the flour**

The antioxidant properties of the soy flour prepared using three different standard processing methods are presented in Table 3. There were significantly (p<0.05) different antioxidant properties. PM3 had the highest (DPPH) % inhibition level of antioxidant properties and free radicals with mean score of 41.02 followed by PM2 with score of 39.13. The ferric reducing antioxidant power of the soy samples ranged from 0.25 to 0.45 with PM3 recording significantly (p<0.05) highest in FRAP. The results of ABTS indicated that soy flour processing method two (PM2) had significantly (p<0.05) highest scavenging capacity of 28.95 followed closely by PM1 28.26. The oxygen radical absorbance capacity (ORAC) was found to be significantly (p<0.05) high in PM1 with (TE)/g of 28.64. It has been reported in literature that in biological system, reactive oxygen species (ROS) and reactive nitrogen species (RNS), such as superoxide, hydroxyl, and nitric oxide radicals, can damage the DNA and lead to the oxidation of lipid and proteins in cells (Dong ping *et al.,* 2017).

Table 3. Antioxidant properties of soy flours

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Method | Ferric reducing  Antioxidant Power  (FRAP) | DPPH Radical scavenging  Activity RSA (% inhibition) | Trolox Equivalent  Antioxidant Capacity TEAC (µM/gDW)  ABTS | ORAC (µM  Trolox Equivalent (TE)/g) |
| PM1 | 0.25 ±0.00c | 31.71 ±0.62c | 28.26 ±0.01b | 28.95 ±0.01a |
| PM2 | 0.38 ±0.01b | 39.13 ±0.04b | 28.95 ±0.01a | 24.20 ±0.01b |
| PM3 | 0.45 ±0.01a | 41.02 ±0.00a | 26.34 ±0.01c | 22.45 ±0.00c |
| SE | 0.04 | 1.80 | 0.01 | 1.16 |
| LSD | - | 1.14 | - | - |

Means with the same superscripts in the same column are not significantly (p>0.05) different. (n=2.000); Means are values of two replicates

**Conclusion**

Soy flour from processing method one (PM1), a traditional soymilk production method modified to produce soy flour significantly affected some of the proximate parameters such as fat, carbohydrate and energy value. Interestingly, processing (modified) method three (PM3) significantly affected protein, fibre, ash, some antioxidant properties such as ferrous reducing antioxidant power (FRAP) and 1, 1, diphenyl-2-pycryl- hydrazyl (DPPH) % inhibition and all functional properties except for oil absorption capacity.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declared that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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