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Effects of Different Processing Methods on the Quality of *Moringa oleifera* Seed Flours

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Abstract

The effects of different processing methods on the quality of *Moringa oleifera* seed flours was studied. The seeds were processed into flours by toasting, oven drying and, boiling and sun drying processing methods. Unprocessed *Moringa* seed flour was used as the reference sample. The functional properties, proximate, qualitative phytochemical and antinutrient composition as well as the sensory characteristics were evaluated. The functional analysis showed that, bulk density and emulsification capacity ranged from 0.50 to 0.59 g/ml and 75.96 to 94.62 % respectively with oven dried sample (OMF) having the highest value. The viscosity (21.53-15.39) and gelatinization temperature (107.15-91.95°C) decreased with processing. The pH (4.55-5.64), water absorption (1.70-2.00 g/ml) and oil absorption (0.50-1.25 g/ml) capacity increased with processing. Proximate analysis showed that, processing resulted to decreased moisture (12.70-9.80%), crude protein (22.97-18.06%), and fat (13.90-13.30%) content, while increase in carbohydrate (45.48-53.42%) and ash (4.45-4.88%) was recorded. The qualitative phytochemical test showed that all seed flours could possibly contain alkaloids, flavonoids and terpenoids. Steroids were absent in all samples. The antinutrient analysis revealed that, processing led to decreased oxalate (11.66-9.39 mg/100g) and phytate content (69.60-46.45 mg/100g). The alkaloid content ranged from 1.53 to 1.88 mg/100g, with the oven dried sample having the highest alkaloid content. Sensory analysis revealed that unprocessed *Moringa* seed flour possessed better organoleptic characteristics. The different processing methods affected the functional properties, proximate and antinutrient compositions of the flours. However, processed *M. oleifera* seed flours, had good nutrient composition which can be exploited in functional foods.

Key Words: *Moringa oleifera*, Flour, Phytochemical, Antinutrient, Sensory

Introduction

Moringa oleifera belongs to the family *Moringaceae.* It is commonly called bean oil tree and locally known as "Zogeli" among the Hausa speaking people of Nigeria. It is grown and widely cultivated in the northern part of Nigeria and many countries in tropical Africa (Cushnie *et al.,* 2014). The plant seeds contain hypotensive activity, strong antioxidant activity and chelating property against arsenic toxicity (Kittakoop *et al.,* 2014). It is considered as one of the most useful trees in the world because almost all parts of this plant can be used as food, in medicines and for industrial purposes (Farzana *et al.,* 2017). *M. oleifera* has been used in several developing countries to prevent protein-energy malnutrition especially among children at an early age and pregnant women (Gopalakrishnan *et al.,* 2016).

M. oleifera seeds have been reported to contain appreciable amount of lipid and proteins comparable to most legumes (Abioye, 2015), than some important leguminous seeds with respect to human nutrition, whose dry seeds usually contain 18 to 25% of protein. Mature seeds yield 38–40% edible oil, called bean oil from its high concentration of behenic acid. The refined oil is clear, odorless and resists rancidity. The seeds oil can also be used as a natural source of behenic acid, which has been used as an oil structuring and solidifying agent in margarine, shortening, and foods containing semisolid and solid fats, eliminating the need to hydrogenate the oil (Bennett *et al.,* 2003). Oleic acid is the major unsaturated fatty acid (67.90-70.00%) whose high concentration is desirable in terms of nutrition and stability during cooking and frying. The seed cake remaining after oil extraction may be used as a fertilizer (Bennett *et al.,* 2003). In developing countries, *Moringa* has potential to improve nutrition, boost food security, foster rural development, and support sustainable land care (Qiu *et al.,* 2014).

Moringa seeds had been known to combat malnutrition in infant and nursing mothers. *Moringa* seeds are rich in vitamins A and C and iron. Vitamin A is important for eye health and night vision, healthy skin, hair and nails and cell growth (Basuny and Al-Marzouq, 2016). Vitamin C is an important antioxidant that protects you from the damaging effects of free radicals. It is also important in wound healing, immune function and collagen synthesis (Ijarotimi *et al.,* 2013).

Processing and utilization of *Moringa* seeds is currently low, especially in African countries such as Nigeria. The *Moringa* seeds are edible though they are not widely consumed. It is utilized in its primary form by roasting, made into flour before being used in snacks and soups or even consumed fresh (Kane *et al.*, 2017). Seed flour from *M. oleifera* is widely used as a natural coagulant for water treatment in developing countries (Omobolanle *et al.,* 2016). It has an impressive range of medicinal uses with high nutritional value. Despite the usefulness and nutritional value, the seeds are still among the lesser known crop and are under-utilized. This could be related to the limited information on the chemical, phytochemical, antinutrient as well as functional properties of the flour. This work therefore aimed at investigating the quality of *M. oleifera* seed flour produced using different processing methods.

Materials and methods

Source of raw materials

Matured seeds of *M. Oleifera* (Plate 1) used for this research work was obtained from Kurmi market in Kano state, Nigeria. The *Moringa* seeds were removed manually from the pod (shelled), sorted and divided into four portions for subsequent processing.

Plate 1: *M. oleifera* Seeds.

Sample preparation

Four portions of *M. oleifera* seeds were processed into flours by toasting (Plate 2), oven drying (Plate 3) and sun drying (Plate 4) processes respectively while the fourth portion was not given any preliminary processing prior to flour production. The unprocessed sample was simply sundried prior to milling into flour (unprocessed sample; Plate 5). Roasting was done at 110°C and the seeds were allowed to cool to room temperature. Oven drying was done at 50°C for 20 hours and allowed to cool in a desiccator. Prior to sun drying the seeds were first subjected to boiling for 10 minutes, followed by draining using a metal sieve to separate the seeds from water then allowed to cool. The seeds were spread on an aluminum trays and sun dried for 7 days. The methods for processing each sample into flour is presented in Figure 1. Codes for each sample are presented in Table 1.

Table 1: Sample codes representing each flour sample.

Sample	Sample Codes
Unprocessed *M. oleifera* seed flour	UMF
Toasted *M. oleifera* seed flour	TMF
Oven dried *M. oleifera* seed flour	OMF
Boiled and Sun dried *M. oleifera* seed flour	BSMF

Plate 2: Toasted *M. oleifera* seed flour.

Plate 3: Oven dried *M. oleifera* seed flour.

Plate 4: Boiled and sundried *M. oleifera* seed flour. Plate 5: Unprocessed *M. oleifera* seed flour.

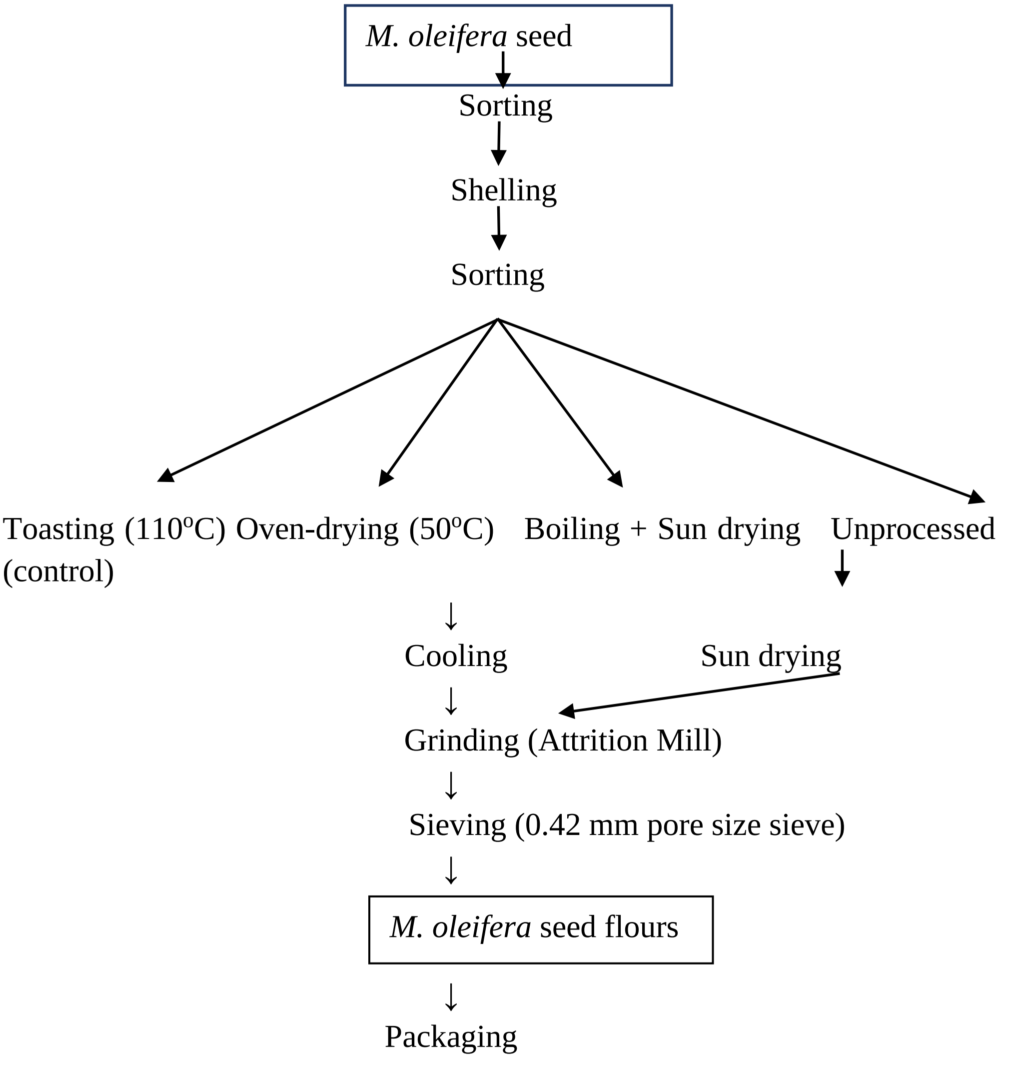

Figure 1: Flowchart for the production of *M. oleifera* seed flour samples.

Analysis of functional properties

The functional properties, bulk density, water and oil absorption capacity, gelation temperature, foam capacity and stability, emulsion capacity and stability of the flour samples were determined using methods described by Onwuka (2018).

Proximate analysis

The determination of the proximate composition of the samples for dry matter content, moisture, ash, protein, fat, fiber contents were determined by methods described by AOAC (2005). The carbohydrate content was calculated by difference.

Qualitative test for phytochemicals

Qualitative tests for the presence of alkaloids, flavonoids, steroids and terpenoids were performed according to the method described by Ndife (2015).

Anti-nutrients analysis

The levels of oxalate, phytate and total alkaloid contents were determined gravimetrically using uv-spectrophotometer method as described by (Manjunath *et al*., 2012). The phytate was determined by the Biphyrimidine colorimeter method as described by Onwuka, (2018) while the oxalate content was determined by titration method as described by (Onwuka, 2018).

Sensory analysis

The protocol described by Iwe (2010) was used. The organoleptic properties of the *M. oleifera* seed flour samples were evaluated by 25-member semi-trained panelists, randomly selected from the staff and students of Michael Okpara University of Agriculture, Umudike. Sensory attributes including appearance, aroma, texture, taste, and general acceptability of the seed flours were scored in a 9-point hedonic scale. The degree of likeness was expressed as: Like extremely 9, like very much 8, like moderately 7, like slightly 6, neither like nor dislike 5, dislike slightly 4, dislike moderately 3, dislike very much 2, dislike extremely 1.

Experimental design and statistical analysis

The experimental set-up was a completely randomized design. All determinations were done in triplicates and the results are presented as mean ± standard deviations. The data obtained from the various analyses were subjected to analysis of variance (ANOVA) for comparison of the means. Differences between means were considered to be significant at $p<0.05$. The statistical package for social sciences version 16.0 was used (SPSS, 2011).

Results and discussion

Functional properties

The functional properties of the *M. oleifera* seed flour samples are presented in Table 2.

The values for bulk density (BD) ranged from 0.50-0.59 g/mL. Oven dried samples (OMF) had the highest value (0.59 gm/L) while boiled and sundried flour samples (BSMF) had the lowest value (0.50 g/mL). There was no significant difference ($p<0.05$)

between the toasted samples (TMF (0.57 g/mL) and the unprocessed samples (UMF) (0.57 g/mL). BD is defined as the mass/volume of a substance. It reveals how porous a product is which is an important determinant in the design and requirement of packaging materials, since it reveals the load carrying capacity of a food material when allowed to rest on its weight (Onimawo and Akurbor, 2005). It could be used in determining the packaging requirement of flour as it relates to the load the sample could carry if allowed to rest directly on one another (Ezeocha and Onwuka, 2010). The results showed that oven drying process improved the BD of *M. oleifera* seed flour while boiling and sun drying processes reduced it. Toasting did not influence the BD. Generally, the BD values of the processed and control flours were regarded as low. Although, the obtained BD results were higher than the value reported for soybean flour (0.38 g/mL) (Edema *et al*., 2005) but lower than the value (0.63 g/mL) reported by Oluwole *et al.* (2013). The low BD exhibited by the flour samples would be advantageous when used in food formulation-mix (Omobolanle *et al.*, 2016) and may possibly encourage bulk packing of the flour samples using compact packaging material (Ezeocha and Onwuka, 2010).

The results for viscosity ranged from 19.99 cP to 21.53 cP. The viscosity of the flour samples decreased with processing. Oven drying (OMF) had the highest effect on the viscosity of the flour samples having a value of 15.39 cP. Toasting process (TMF) (19.79 cP) as well as boiling and sun drying processes (BSMF) (19.99 cP) recorded similar effect. The reduced viscosity in the processed samples compared to the unprocessed samples could be attributed to the effect of heat which may have led to the loss of their starch crystalline structure.

Table 2: Functional properties of *M. oleifera* seed flour samples.

Samples	Bulk Density (g/mL)	Viscosity (cP)	Emulsion Capacity (%)	Gelatinization Temp (°C)	Ph	WAC (g/mL)	OAC (g/mL)
TMF	$0.57^{b}\pm0.01$	$19.79^{b}\pm0.36$	$75.96^{d}\pm0.21$	$99.10^{b}\pm0.14$	$5.64^{a}\pm0.10$	$1.70^{b}\pm0.40$	$0.70^{b}\pm0.14$
OMF	$0.59^{a}\pm0.01$	$15.39^{c}\pm2.69$	$94.62^{a}\pm0.76$	$91.95^{d}\pm0.21$	$5.18^{b}\pm0.10$	$2.00^{a}\pm0.01$	$1.25^{a}\pm0.50$
BSMF	$0.50^{c}\pm0.01$	$19.99^{b}\pm1.21$	$77.92^{c}\pm0.03$	$96.30^{c}\pm0.00$	$5.09^{c}\pm0.10$	$2.00^{a}\pm0.01$	$1.25^{a}\pm0.50$
UMF	$0.57^{b}\pm0.01$	$21.53^{a}\pm0.72$	$88.05^{b}\pm0.01$	$107.15^{a}\pm0.07$	$4.55^{d}\pm0.40$	$1.70^{b}\pm0.40$	$0.50^{bc}\pm0.40$

The results represent mean values ± standard deviation. Data with different superscript letters in the same column are significantly different ($p<0.05$). Keys: WAC- Water Absorption Capacity; OAC-

Oil Absorption Capacity. cP-Centipoise. UMF- Unprocessed *M. oleifera* seed flour. TMF- Toasted *M. oleifera* seed flour. OMF- Oven dried *M. oleifera* seed flour. BSMF- Boiled and sun dried *M. oleifera* seed flour.

This could simply indicate that, the unprocessed sample (UMF) (21.53 cP) might resist shear stress or tensile stress while processing could reduce the rate at which this resistance exist since viscosity of seed flour is the ability of the seed flour to resist shear stress or tensile strain (Yusuff *et al.*, 2008). More so, viscosity is inversely related to water absorption capacity of flour samples. The higher the viscosity of flour samples, the lower their ability to absorb water (Yusuff *et al.*, 2008). Thus, the processed samples may absorb more water than the unprocessed sample.

Emulsion capacity of the samples ranged between 75.96 to 94.62 %. Protein being the surface active agents can form and stabilize the emulsion by creating electrostatic repulsion on oil droplet surface (Kaushal *et al.*, 2012). Emulsion stability can be greatly increased when highly cohesive films are formed by the absorption of rigid globular protein molecules that are more resistant to mechanical deformation. Increasing emulsion activity (EA), emulsion stability (ES) and fat binding during processing are primary functional properties of protein in such foods as comminuted meat products, salad dressing, frozen desserts and mayonnaise. From the results obtained, it was observed that processing influenced the emulsion capacity of the seed flours. Oven drying process increased the emulsion capacity of *M. oleifera* seed flours with OMF having the highest value (94.62%), while toasting process (TMF; 75.96%) and boiling and sun drying processes (BSMF; 77.92%) resulted to a decreased emulsion capacity of the seed flours, with values lower than the value obtained for the unprocessed sample (UMF; 88.05%). Thus, oven drying process might possibly possess better processing influence on *M. oleifera* seed flours in food formulations.

The result of the gelatinization temperature (GT) of the processed samples ranged from 91.95 to 99.10°C which is lower than the value recorded for the unprocessed sample (UMF) (107.15°C). OMF was observed to gelatinize at a lower temperature (91.95°C) compared to TMF (99.10°C) and BSMF (96.30°C). This phenomenon could be linked to the impact of the respective heat treatments on the rigidity of the intermolecular bonds (glycosidic bond), holding the starch molecules together. Also, the heat processing treatments that has impacted on the starch bonding might have possibly resulted into the starches being partially solubilized, thus making them to require lower temperature to form gel since GT is the temperature at which food material form gel or become gelatinous. The primary function of gel in foods is to bind or solidify the free water (Onimawo and Egbekun, 1998). The GT results obtained in this study are generally high and could be suitable for the stabilization of emulsion in soups and cakes and other food formulation.

The pH of the flour samples ranged from 4.55 to 5.64. Processing was found to increase the pH content of the flours. TMF had the highest value (5.64) followed by OMF (5.18) and BSMF (5.09) while UMF (4.55) had the lowest value (Table 2). However, the pH of the samples is moderately acidic, which may be an advantage in probably discouraging the growth of pathogens known to be associated with gastrointestinal problems.

Water absorption capacity (WAC) is the ability of flour to absorb water. The water absorption capacity of the samples ranged from 1.70 to 2.00 g/mL. The toasting process did not significantly affect the WAC of the flour samples; reason could be that the WAC of TMF (1.70 g/ml) was not significantly different ($p>0.05$) from that of the unprocessed sample (UMF) (1.70 g/ml). However, oven drying process and boiling and sun drying process resulted in improved WAC with values of 2.00 g/mL being recorded for each of OMF and BSMF samples. The increase in WAC of OMF and BSMF compared with TMF and UMF may be due to increase in the amylose leaching and solubility and loss of starch crystalline structure as well as more availability of polar amino acids in the flours. This suggested that OMF and BSMF may have more hydrophilic constituents such as polysaccharides. The high WAC of OMF and BSMF implied that the flours might be used in formulation of some foods such as sausage, dough processed cheese and bakery products (Niba *et al.,* 2001). More so, protein has both hydrophilic and hydrophobic nature and therefore they can interact with water in foods. The observed variation in different flours may be due to different protein concentration, their degree of interaction with water and conformational characteristics (Butt and Batool, 2010).

The results of oil absorption capacity (OAC) ranged from 0.50 g/mL to 1.25 g/mL. The unprocessed sample had the lowest value. OMF and BSMF had the highest value with no significant difference ($p>0.05$) between them. Although, the OAC of the processed samples are higher than the unprocessed sample, however, the OAC of the flour samples are considerably low. Low OAC exhibited by all the samples will result in reduced retention of flavor, reduced mouth feel of products and would make the *M. oleifera* seed flours less valuable in ground meat formulations, meat replacers and in soups (Onimawo and Egbekun, 1998).

Proximate composition

The results of proximate composition of the flour samples are presented in Table 3.

The moisture content of the samples ranged from 9.80 to 12.70 %. The unprocessed sample (UMF) had higher moisture content (12.70 %) than the processed samples which could be attributed to the different heat processing the samples were subjected to. Among the processed samples, oven drying process (OMF) had a more pronounced moisture reduction on the flour samples with a value of 9.80% but no significant difference ($p>0.05$) was observed in the moisture content of TMF (11.00 %) and BSMF (11.20 %). The reduced moisture content recorded for the processed samples could be linked to the effect of heat treatment. Since moisture content can be used as an index of stability of foods (Offor, 2015), it could be presumed that the processed samples would have better shelf stability.

The protein content of the processed samples ranged from 18.06 to 21.25 %. These values are lower than the value obtained for the unprocessed sample (UMF) (22.97 %). Among the processed samples, TMF had the highest protein content (21.25 %) followed by BSMF (19.69 %) while OMF had the lowest value (18.06 %).

Table 3: Proximate composition of *M. oleifera* seed flour samples.

Samples	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Fibre (%)	Carbohydrate (%)
TMF	$11.00^{b}\pm0.57$	$21.25^{b}\pm0.76$	$13.50^{ab}\pm0.14$	$4.80^{a}\pm0.02$	$0.80^{a}\pm0.80$	$48.56^{c}\pm0.90$
OMF	$9.80^{c}\pm0.85$	$18.06^{d}\pm0.79$	$13.30^{ab}\pm0.14$	$4.83^{a}\pm0.01$	$0.60^{b}\pm0.01$	$53.42^{a}\pm0.05$
BSMF	$11.20^{b}\pm0.28$	$19.69^{c}\pm0.00$	$13.70^{a}\pm0.14$	$4.88^{a}\pm0.01$	0.30d±0.40	$50.24^{b}\pm0.25$
UMF	$12.70^{a}\pm1.41$	$22.97^{a}\pm1.54$	$13.90^{a}\pm0.14$	$4.45^{b}\pm0.01$	$0.50^{c}\pm0.40$	$45.48^{d}\pm1.61$

The results represent mean values ± standard deviation. Data with different superscript letters in the same column were significantly different ($p<0.05$). UMF- Unprocessed *M. oleifera* seed flour. TMF- Toasted *M. oleifera* seed flour. OMF- Oven dried *M. oleifera* seed flour. BSMF- Boiled and sun dried *M. oleifera* seed flour.

The results indicated that heat processing reduced the protein content of *M. oleifera* seed flours, which could be attributed to the impact of denaturation from heating.

There was no significant difference ($p>0.05$) in the fat content of the samples with values ranging from 13.30 to 13.90 %. However, a slight reduction was observed in the values of the processed samples. Generally, the lipid content of the samples is quite high which might result to decreased keeping quality as a result of increased susceptibility to rancidity (Ikujenlola *et al*., 2013). Also, the samples may have the capability of serving as a viable vehicle for fat soluble transport as well as improving mouth-feel and palatability that fat provides (Coppin and Pike, 2011).

The ash content of the samples ranged from 4.45 to 4.88 %. The processed samples had higher ash content (4.83-4.88 %) than the unprocessed sample (UMF) (4.45 %). This observation could be attributed to the effect of heat application on the sample. Boiling and sun drying process (BSMF) resulted in flour with better mineral content (4.88 %) compared to oven drying process and toasting process. Ash content represents total minerals content in foods and thus, serves as a viable tool for nutritional evaluation of mineral (Mamiro *et al.*, 2011). The increased ash content of the processed samples could indicate improved mineral content in processed samples than in the unprocessed sample (UMF).

The fibre content of the samples ranged from 0.30 to 0.80 %. UMF had higher fibre content (0.50 %) than BSMF (0.30 %) while oven drying process (OMF; 0.60 %) and toasting (TMF; 0.80%) process resulted in samples with higher fibre contents than the unprocessed sample. These results implied that the fibre content of *M. oleifera* seed flour might be increased by subjecting the native sample to toasting and oven drying prior to processing. Crude fibre offers a variety of health benefits and is essential in reducing the risk of chronic disease such as diabetes, obesity, cardiovascular disease and diverticulitis. It acts to lower the concentration of low-density lipoprotein cholesterol in the blood, possibly by binding with bile's acids (Ishiwu and Tope, 2015). The values obtained in the present study are considerably low, which suggest that *M. oleifera* seed flours could be complemented with fibre-rich flour in food formulation for improved fibre benefits.

The carbohydrate content of the samples ranged from 45.48 to 53.42 %. The processed samples had higher carbohydrate content (48.56-53.42%) than the unprocessed samples (UMF) (45.48%). Among the processed samples, OMF had the highest carbohydrate content (53.42 %) followed by BSMF then TMF. The results showed that *M. oleifera* seed flours contain an appreciable amount of carbohydrate, thus, *M. oleifera* seed flours could contribute to the energy value of foods.

Qualitative phytochemical composition

The results of qualitative phytochemical tests are presented in Table 4**.**

The results revealed that, there is presence of alkaloids, oxalates and terpenoids in the unprocessed and processed samples, while steroids were absent in all the studied samples.

Table 4: Qualitative phytochemical tests of *M. Oleifera* seed flour samples.

Samples	Alkaloids	Flavonoids	Steroids	Terpenoids
TMF	+	+	-	+
OMF	+	+	-	+
UMF	+	+	-	+
BSMF	+	+	-	+

Key: (+) Present (-) Not detected. UMF- Unprocessed *M. oleifera* seed flour. TMF- Toasted *M. oleifera* seed flour. OMF- Oven dried *M. oleifera* seed flour. BSMF- Boiled and sun dried *M. oleifera* seed flour.

Anti-nutrient composition

The antinutrient composition of the flour samples is presented in Table 5.

The oxalate content of the seed flours ranged from 9.39 to 11.66 mg/100g. Processing reduced the oxalate content of *M. oleifera* seed flours. Boiling and sun drying processes (BSMF) had the highest reducing effect with a value of 9.39 mg/100g, followed by toasting process (TMF) (10.17 mg/100g) while oven drying process (OMF) (10.40 mg/100g) had the lowest effect. The reduction in the oxalate content of the samples could be attributed to the different processing method used. High concentrations of oxalate can bind with calcium, magnesium, iron and zinc making them unavailable, by forming calcium oxalate complexes with them (Onwuka, 2018). From the results it could be inferred that, the oxalate content of the processed *M. oleifera* seed flours were lower than the lethal dose (50 mg/100g) that can pose health risk (Ijarotimi *et al*., 2013), and thus could be consumed moderately on a regular basis.

The phytate content of the samples ranged from 46.45 to 69.60 mg/100g. The unprocessed sample (UMF) had a significantly ($p<0.05$) higher phytate content (69.60 mg/100g) than the processed samples (46.45-46.71 mg/100g), thus, revealing the influence of processing on the phytate content of *M. oleifera* seed flour. The results also showed that, there was no significant difference ($p<0.05$) among TMF (46.45 mg/100g), OMF (46.46 mg/100g) and BSMF (46.71 mg/100g). Phytate is often considered as an antinutrient because it may bind with minerals in the digestive tract, making minerals such as Zn^{2+}, $Fe^{2+/3+}$, Ca^{2+}, Mg^{2+}, Mn^{2+}, and Cu^{2+} unavailable as well as their absorption (Dick *et al.*, 2018). Also, high phytate value can reduce digestibility of starch in both humans due to inhibition of pancreatic and salivary amylase activity (Olitino *et al.,* 2007). Although, the phytate content of the processed samples reduced significantly after processing, but the values are still considerably high, and could therefore affect the bioavailability of important minerals needed by the body.

Table 5: Anti-nutrient compounds of *M. oleifera* seed flour samples.

Samples	Oxalate (mg/100g)	Phytate (mg/100g)	Alkaloid (mg/100g)
TMF	10.17[ab] ± 0.06	46.45[b]±0.06	1.53[b]±0.070
OMF	10.40[b]±0.07	46.46[b]±0.02	1.88[a]±0.04
BSMF	9.39[b]±0.72	46.71[b]±0.42	1.56[b]±0.05
UMF	11.66[a]±0.00	69.60[a]±0.04	1.85[a]±0.04

The results represent mean values ± standard deviation. Data with different superscript letters in the same column were significantly different ($p<0.05$). UMF- Unprocessed *M. oleifera* seed flour. TMF- Toasted *M. oleifera* seed flour. OMF- Oven dried *M. oleifera* seed flour. BSMF- Boiled and sun dried *M. oleifera* seed flour.

The alkaloid content in the processed samples ranged from 1.53 to 1.88 mg/100g while that of the unprocessed sample (UMF) was 1.85 mg/100g. The alkaloid content of TMF (1.53 mg/100g) and BSMF (1.56 mg/100g) were lower than that of the unprocessed sample which suggested that, toasting process and boiling and sun drying processes might have a reducing effect on the alkaloid content of *M. oleifera* seed flours. Oven drying process (OMF) increased the alkaloid content from 1.85 mg/100g in the unprocessed sample to 1/88 mg/100g. However, the alkaloid content of *M. oleifera* seed flour samples were lower than the upper limit (60 mg/100g) recommended for a safe food (Ijarotimi *et al*., 2013).

Sensory characteristics

The results of sensory analysis of *M. oleifera* seed flours are presented in Table 6.

The taste of the *M. oleifera* seed flours ranged from 5.20 to 6.45. The results showed that, among the processed samples, the taste of the oven dried sample (OMF) with a rating of 6.45 was best preferred by the panelists. Toasted (TMF) and boiled and sundried (BSMF) samples with a rating of 5.20 and 5.40 respectively was less preferred to the unprocessed sample (UMF) (5.80). Thus, the results of the taste scores for the unprocessed sample, toasted sample and sundried samples suggested that the samples may neither be liked nor disliked as rated by the panelists while the oven dried samples might be liked slightly when consumed by consumers.

The appearance scores of the samples ranged from 4.95 to 5.75. The appearance of the seed flours decreased after processing since the results of the processed samples (4.95-5.25) were lowered than the unprocessed sample (5.75). Toasting (TMF; 4.95) and oven drying (OMF; 4.95) processes did not produce any significant difference (p<0.05) in the appearance of their respective seed flours. These results suggested that the appearance of toasted and oven dried samples might be disliked slightly by consumers while the boiled and sundried samples may neither be liked nor dis liked. The unprocessed sample was best preferred.

The scores for texture ranged from 4.80 to 5.70. The unprocessed sample (UMF) was rated higher (5.70) in terms of texture than the processed samples (4.80-5.60). Among the processed samples, the texture of BSMF (5.60) was rated higher than TMF (5.25) while OMF (4.80) had the least preferred texture. Consequently, the results suggested that, toasting and sun drying may result to seed flours that were neither liked nor disliked by consumers, while oven drying may result to sample that

is slightly disliked by consumers. Based on the scores, the reference sample was best preferred.

Table 6: Sensory evaluation of *M. oleifera* seed flour samples.

Sample	Taste	Appearance	Texture	Aroma	General acceptability
TMF	$5.20^{d}\pm1.67$	$4.95^{c}\pm0.94$	$5.25^{b}\pm1.21$	$5.75^{b}\pm0.97$	$6.00^{ab}\pm0.76$
OMF	$6.45^{a}\pm0.69$	$4.95^{c}\pm0.94$	$4.80^{c}\pm1.58$	$5.65^{c}\pm1.09$	$5.75^{b}\pm1.16$
BSMF	$5.40c\pm1.10^{a}$	$5.25^{b}\pm1.02$	$5.60^{ab}\pm1.10$	$5.65^{c}\pm0.88$	$5.40^{bc}\pm0.88$
UMF	$5.80^{b}\pm1.15$	$5.75^{a}\pm0.91$	$5.70^{a}\pm0.92$	$6.00^{a}\pm1.21$	$6.05^{a}\pm1.08$

The results represent mean values ±standard deviation. Data with different superscript letters in the same column were significantly different (p<0.05). UMF- Unprocessed *M. oleifera* seed flour. TMF- Toasted *M. oleifera* seed flour. OMF- Oven dried *M. oleifera* seed flour. BSMF- Boiled and sun dried *M. oleifera* seed flour.

The aroma scores were found to be highest for the unprocessed sample (UMF) (6.00) as rated by the panellist. The aroma of OMF and BSMF did not significantly different from each other with both processing methods resulting to seed flours with an aroma rating of (5.65), which is the lowest aroma rating. However, all the processed samples were neither liked nor disliked by the panelists while the reference sample was liked slightly.

The scores for general acceptability showed that the unprocessed sample (UMF) was most preferred with a mean score of 6.05, followed by the toasted sample (TMF) (6.00). Generally, it could be inferred that, consumers would prefer the organoleptic properties of unprocessed *Moringa* seed flour with respect to appearance, texture, aroma and general acceptability compared to the processed sample.

Conclusion

The findings of this research revealed that, different methods used in processing *M. oleifera* seeds affected the functional properties, proximate and phytochemical compositions of the flours. Generally, oven dried flour samples possessed better functional properties. Processed and unprocessed *M. oleifera* seed flours, had comparable good nutritional composition. Proximate analysis showed that processing resulted in decreased moisture, protein and fat contents, while the ash and carbohydrate content, was found to increase. Furthermore, processing resulted in decreased anti-nutrient content. Boiling and sun drying processes resulted in samples with the lowest oxalate content, while toasting had the best reducing effect on phytate and alkaloid. The sensory analysis revealed that processing had some adverse effects on sensory perception. The unprocessed *Moringa* seed flour sample possessed better organoleptic properties.

In view of these, processed *M. oleifera* seed flours could be used as food ingredient to improve nutrient quality of diets and to enhance exploitation of the full potentials of *Moringa* plant. However, other processing methods such as cooking, fermentation, soaking and germination (sprouting) should be used in further researches.

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