



Effect of Processing on the Nutritional Composition of *Moringa oleifera* Leaves and Seeds

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Authors' contributions

This work was carried out in collaboration among all authors. Author NNU designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors JIO and AIA managed the analyses of the study. Author NNU managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Background/Objective: Processing improves the nutritional quality of food and may/not lead to nutrient losses. Processing is done to eliminate inactive microorganisms/ antinutrients and extend the shelf life of food. *Moringa oleifera* plant is an important tree in some part of Nigeria having been successfully used as food, medicinal and for industrial purpose. This study was designed to determine the effect of processing on the nutritional profile of *Moringa oleifera* leaves and seeds.
Materials and Methods: The leaves and seeds were harvested from the forest. The leaves were washed, drained and divided into three portions. The first portion was processed raw, the sun and shade dried samples were the second and third portion. The seeds were cracked and divided into six portions. The first portion was processed raw and the other five portions were fermented for 24, 48, 72, 96 and 120 h respectively. The samples were analyzed for proximate, vitamin, mineral, and anti-nutrients contents using the standard method.

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Results: The proximate composition of the seeds showed that the samples had a range of moisture, 16.63-17.75%, protein 13.92-38.45%, fat 14.93-19.00%, fibre 3.94-7.10%, ash 1.96-6.22% and carbohydrate 9.08-36.61%/100 g respectively. The ranges for the mineral contents of the seeds were iron 2.10-33.35 mg, zinc 1.19-1.35 mg/100 g, and iodine 12.33-126.61 mg. Also, the ascorbic acid content of the seeds ranged from 3.57- 24.55 mg. The anti-nutrient contents of the seeds were 0.03 – 1.35/100 g saponin, 0.21 – 6.25 mg/100 g of oxalate, 0.11 – 0.28 mg tannins and 5.69 – 16.81 mg/100 g of phytate. The proximate composition of the vegetables ranged from 8.99 – 75.33% moisture, 6.01 – 17.78% protein, 0.64 – 3.89% fat, 3.14 – 11.96% fibre, 2.46 – 15.22% ash and 12.01 – 48.52% carbohydrate. The ranges for mineral contents of the vegetables were iron 0.04 – 0.23 mg, zinc 0.03 – 0.10 mg and iodine 13.66 – 46.61 mg. The vitamin levels of the vegetables were ascorbic acid 56.43 – 167.66 mg/100 g. The level of the anti-nutrients in the vegetables ranged from 0.04 – 1.26 mg/100 g saponin, 0.31 – 8.44 mg/100 g oxalate, 0.05 – 0.20 mg/100 g tannins while phytate varied from 3.31 – 13.20 mg/100 g.

Conclusion: Processing of both leaves and seeds of *Moringa oleifera* increased their nutrient density and reduced the concentration of anti-nutrients. The consumption of *Moringa oleifera* should be popularized to diversify diet and extend their food use.

Keywords: Processing; *Moringa oleifera*; nutrients; seeds; vegetables.

1. INTRODUCTION

Moringa oleifera is known as the drumstick tree or horseradish tree. It is used as a vegetable [1]. It resembles a leguminous species at a distance especially when flowering. *Moringa oleifera* is known as *Zogallagandi* (Hausa), *Ewe-igbale* (Yoruba) and *Okwe Oyibo* (Igbo) [2]. *Moringa Oleifera* has traditional, medicinal and nutritional uses and also have biological and physiological activities. These biological and physiological activities are hypotensive properties [3], hypoglycemic and hypocholesterolemic effects [4,5,6], anti-inflammatory, antihepatotoxic activities [7], anti-helminthic, analgesic, dyspepsia and in the management of heart diseases and ulcers [3]. The leaves represent an important source of proteins. The nutritional quality of protein found in food depends on the absolute and relative contents of essential amino acids and its bioavailability after digestion and absorption [8].

Teixeira et al. [9] observed that the dried leaf contained 28.7% crude protein, 7.1% fat, 10.9% ash, 44.4% carbohydrate and 3.0 mg 100 g⁻¹ calcium and 103.1 mg 100 g⁻¹ iron. *Moringa* is a good source of polyphenol and antioxidant [10]. Phytochemicals such as vanillin, omega fatty acids, carotenoids, ascorbates, tocopherols, beta-sitosterol, moringine, kaempferol, and quercetin have been reported in its flowers, roots, fruits, and seeds. The leaves, in particular, have been found to contain phenolic compounds and flavonoids [11,12].

Green Leafy Vegetables (GLVs) are the most nutritious agricultural products and are widely and preferably consumed in fresh form. They are

rich sources of calcium, iron, β -carotene, vitamin C, dietary fibre and many trace elements. Green leafy vegetables are generally consumed in the cooked form apart from the salads. Therefore, there is a need to assess the effect of processing on the nutritional quality of the dried leaf [13].

Processing improves and promotes digestibility, shelf life, palatability and lead to inactivation of anti-nutrients. Processing sterilizes food by killing harmful bacteria and other microorganisms, and lead to the bioavailability of nutrients. Vegetables and seeds undergo postharvest treatments of drying, roasting, fermentation and boiling to improve sensory properties, reduce anti-nutrient and extend the shelf life of foods. Some processing techniques alter (positive and negative) nutrient content of plants [14,15,16]. Processing makes food healthier, safer, tastier and more shelf-stable. The benefits of processing are numerous but can also be detrimental, affecting the nutritional quality of foods. Blanching, for instance, can lead to leaching of vitamins and minerals. Milling and extrusion during processing can cause the physical removal of minerals. The nutritional quality of minerals in food depends on their quantity as well as their bioavailability. Processing can lead to the removal of anti-nutrient and toxic content of foods thereby making the vitamin and minerals more bioavailable [17].

Fermentation is the oldest method of processing legumes [18]. It enhances the flavour of food [19,20,21]. The food flavouring condiments are prepared by traditional methods of uncontrolled solid substrate fermentation resulting in

extensive hydrolysis of the protein and carbohydrate components [22,23]. In addition to increasing the shelf-life, fermentation reduces anti-nutritional factors [19,24]. Fermentation markedly improves the digestibility, nutritive value, flavours, reduces bulk and level of antinutrients. Increased digestibility is due to extensive hydrolysis of proteins to amino acids and the hydrolysis of galactooligosaccharides to simple sugar [19].

United Nations Food and Agriculture Organization [25] has widely noted that most widespread and debilitating nutritional disorders, including birth defects, mental and physical retardation, weakened immune systems, blindness and even death has resulted from poor fruits and vegetables consumption habits [26]. Promotion of traditional food consumption can help reduce food insecurity and improve the nutritional status of the dwellers [16,27]. The ideal strategy for fighting micronutrient deficiency is to improve the diet by including a large variety of food rich in micronutrients and to increase dietary absorption of these nutrients. According to [28] while the crisis caused by the lack of animal foods may require broad and fundamental rethinking about policy and action, traditional food may be the short term remedy. There is the need, however, to identify those foods that would enhance household and national food security. Foods from animal sources such as liver and eggs are good sources of micronutrients and are in the form in which the body can readily utilize them. Too often people cannot afford these foods. Micronutrients are found in vegetables, seeds and fruits but in a formless easily absorbed unless taken at the same time with enhancer or processed in a way to enhance the absorption of these micronutrients [29]. Thus, this study was designed to determine the effect of processing on the nutritional profile of *Moringa oleifera* leaves and seeds.

2. MATERIALS AND METHODS

The fresh *Moringa oleifera* leaves and seeds were collected from a home garden in Nri community of Anambra State of Nigeria.

2.1 Sample Preparation

The edible leaves were divided into three portions. One portion was processed raw, the second portion was shade dried and the third portion sun-dried. The seeds were scraped from the pulp to obtain clean seeds. The seeds were

cracked, boiled, drained and fermented by inherent micro-flora of the seeds for 24, 48, 72, 96 and 120 h at room temperature ($28.0 \pm 2^\circ\text{C}$) using ash as the catalyst. The fermented seeds were dried until brittle in an air oven at 55°C and ground using hammer mill into a fine flour (70 mm-mesh screen). The flour from each sample was packaged, labelled and stored in an airtight container until needed for further use.

2.2 Chemical Analysis

Chemical analysis was done on all the samples and was performed in triplicate.

2.3 Moisture Determination

The moisture content of the samples was determined using the air oven method of AOAC [30].

2.4 Protein Determination

The crude protein content of the samples was determined using the automated micro-Kjeldahl method as described by AOAC [30].

2.5 Fat Determination

The fat content was determined using the Soxhlet extraction method [30].

2.6 Crude Fibre Determination

The crude fibre content of the samples was determined according to the procedure of AOAC [30].

2.7 Ash Determination

The ash content was determined according to the procedure of AOAC [30].

2.8 Carbohydrate Determination

Carbohydrate content was calculated by the difference when the estimated percentages of crude protein, ash, fat, fibre and moisture were summed up and the value subtracted from 100%. $\text{CHO} = 100\% - (\text{protein} + \text{fat} + \text{ash} + \text{fibre} + \text{moisture})$.

2.9 Mineral Determination

The mineral contents, namely: Sodium, potassium (using flame photometry), calcium, magnesium, copper, manganese and lead contents were determined by the method

described by Pearson [31] using a Pye Unicam SP9 Atomic Absorption Spectrophotometer (AAS) connected to an SP9 computer (Pye Unicam Ltd, York Street, Britain). Total phosphorus was determined by the spectrophotometric molybdovanadate procedure [30].

2.10 Determination of β -Carotene

The extraction of carotenoids was carried out according to the method of Seo et al. [32] with slight modifications.

2.11 Determination of Vitamin E Profile

Vitamin E content was analysed by the method described by Burri [33] using High-performance liquid chromatography (HPLC).

2.12 Vitamin C Determination

Vitamin C determination by iodine titration as described by Anne Helmenstine was carried out [30].

2.13 Statistical Analysis

All the analyses were carried out in triplicate and expressed as mean and standard deviation (SD). The calculation of means, SD and analysis of variance (ANOVA) were carried out using SPSS version 22 and Duncan's New Multiple Range Tests (DMRT) were performed to study the differences at 5% level of significance.

3. RESULTS

The effect of processing on the proximate composition of *Moringa oleifera* leaves and seeds were shown in Table 1. The moisture content of the leaves ranged from 8.99 to 75.33% per 100 g edible portion, with fresh leaves having the highest moisture content and sun-dried leaves having the least value. The protein content varied from 6.01- 17.68% per 100 g sample with shade dried leaves having the highest protein content. The fat content of the samples ranged from 0.64 in fresh leaves to 3.89% in shade dried leaves per 100 g sample. The crude fibre contents of the samples ranged from 3.41-13.14%/100 g, with shade dried leaves having the highest crude fibre content. The ash content of the leaves varied between 0.26% in fresh leaves to 15.22% in shade-dried while the carbohydrate content of the samples ranged from 12.01-48.52%.

The moisture content of the seeds ranged from 12.63-17.75%, with 120 hours fermented *Moringa oleifera* seed (FMS₁₂₀) having the highest moisture value and fresh seeds (FS) having the least value. The protein content varied from 13.92-38.45% with 24 hours fermented *Moringa oleifera* seed (FMS₂₄) having the highest protein content. The fat content of the samples ranged from Traces-3.08%. The crude fibre contents of the samples ranged from 3.94-7.10%/100 g, with FS having the highest crude fibre value. The ash content of the fruits was between 1.96-6.22%/100 g sample while the carbohydrate contents of the samples were between 19.50-45.20%.

The effect of processing on the mineral and ascorbate composition of *Moringa oleifera* leaves and seeds are shown in Table 2. The iron content of the vegetables varied between 0.04-0.16 mg/100 g with shade dried leaves having the highest iron content while fresh leaves had the least value. The zinc content were between 0.03- 0.10 mg/100 g and iodine 13.66- 40.03 mg/100 g. The ascorbate content ranged from 56.43-167.66 mg/100 g. The iron contents of these processed seeds were between 2.10- 3.35 mg/100 g with fresh seed having the highest iron content and 96 hours fermented *Moringa oleifera* seed (FMS₇₂) having the least value. The zinc content was highest in 120 hours fermented *Moringa oleifera* seed (FMS₉₆) 2.06 mg/100 g and lowest in 120 hours fermented *Moringa oleifera* seed (FMS₁₂₀) 1.19 mg/100 g. Iodine content ranges from 12.33 to 126.61. The levels of ascorbic acid in the seeds range from 3.57 to 24.55 with 48 hours fermented *Moringa oleifera* seed (FMS₄₈) having the highest value and fresh seed (FS) having the least value.

The effect of processing on the anti-nutrient content of *Moringa oleifera* leaves and seeds are shown in Table 3. The phytate content of the vegetables ranged between 3.31-13.20 mg/100 g. The saponin contents varied between 0.04-1.26 mg/100 g, oxalate content ranges from 0.31 to 8.44 mg/100 g while the tannin contents ranged from 0.05 to 0.20 mg/100 g sample. The phytate content of *Moringa oleifera* seeds ranged from 5.26 to 16.81 mg /100 g with FS having the highest value. The saponin contents varied between 0.03 in FMS₁₂₀ to 1.35 mg/100 g in FS edible samples. The oxalate contents ranged from 0.21 in FMS₉₆ to 6.25mg/100g in FS samples and the tannin level was between 0.11 to 0.28 in the seeds.

Table 1. Effect of processing on the proximate composition (%) of *Moringa oleifera* leaves and seeds

Samples	Moisture	Protein	Ash	Fibre	Fat	CHO
FL	75.33 ^a ±0.77	6.01 ^c ±0.02	2.46 ^b ±0.26	3.41 ^b ±0.36	0.78 ^b ±0.64	12.28 ^c ±0.48
SDL	8.99 ^c ±0.23	14.26 ^b ±0.13	13.21 ^a ±0.01	11.96 ^a ±0.71	3.06 ^a ±0.14	48.58 ^a ±0.12
SHL	11.04 ^b ±0.55	17.68 ^a ±0.43	15.22 ^a ±0.15	13.14 ^a ±0.12	3.81 ^a ±0.86	39.11 ^b ±0.18
FS	12.63 ^b ±0.35	13.92 ^c ±0.38	6.22 ^a ±0.11	7.10 ^a ±0.51	14.93 ^b ±0.06	45.20 ^a ±0.00
FMS ₂₄	16.63 ^a ±0.06	31.26 ^b ±0.44	3.00 ^b ±0.00	4.66 ^b ±0.03	16.94 ^b ±0.45	27.51 ^b ±1.02
FMS ₄₈	16.66 ^a ±0.23	32.60 ^b ±0.11	2.68 ^b ±0.22	4.60 ^b ±0.22	17.75 ^{ab} ±0.81	25.71 ^b ±0.37
FMS ₇₂	16.68 ^a ±0.04	38.98 ^a ±0.00	2.36 ^b ±0.14	4.00 ^b ±0.16	18.23 ^a ±0.30	19.75 ^c ±0.55
FMS ₉₆	17.64 ^a ±0.42	36.14 ^a ±0.01	2.06 ^b ±0.16	3.94 ^b ±0.28	18.50 ^a ±0.74	21.72 ^c ±0.68
FMS ₁₂₀	17.75 ^a ±0.18	32.45 ^b ±0.71	1.96 ^b ±0.21	3.26 ^b ±0.00	19.00 ^a ±0.55	25.58 ^b ±0.72

Values are means and standard deviation of 3 replication. Means with different superscripts along the same column for leaves and seeds are significantly different at $p < 0.05$.

FL---Fresh leaves of *Moringa oleifera*; SDL---Sun-dried leaves of *Moringa oleifera*; SHL----Shade dried leaves of *Moringa oleifera*; FS-----Fresh seed of *Moringa oleifera*; FMS₂₄----24 hours fermented *Moringa oleifera* seed; FMS₄₈----48 hours fermented *Moringa oleifera* seed; FMS₇₂----72 hours fermented *Moringa oleifera* seed; FMS₉₆----96 hours fermented *Moringa oleifera* seed; FMS₁₂₀----120 hours fermented *Moringa oleifera* seed

Table 2. Effect of processing on the ascorbate and mineral composition (mg/100g) of *Moringa oleifera* leaves and seeds

Samples	Ascorbate	Iron	Zinc	Iodine
FL	167.66 ^a ±0.03	0.04 ^c ±0.11	0.04 ^b ±0.00	13.66 ^c ±0.43
SDL	57.47 ^b ±0.28	0.23 ^a ±0.07	0.03 ^b ±0.01	46.61 ^a ±0.38
SHL	56.43 ^b ±0.33	0.16 ^b ±0.31	0.10 ^a ±0.08	40.03 ^b ±0.51
FS	3.57 ^c ±0.17	10.35 ^b ±0.62	1.24 ^a ±0.17	12.33 ^d ±0.18
FMS ₂₄	20.52 ^b ±0.18	2.10 ^c ±0.47	1.19 ^a ±0.11	107.44 ^c ±0.82
FMS ₄₈	21.18 ^{ab} ±0.46	2.12 ^c ±0.26	1.20 ^a ±0.66	110.25 ^c ±0.06
FMS ₇₂	22.28 ^{ab} ±0.96	2.23 ^c ±0.17	1.24 ^a ±0.18	111.36 ^c ±0.65
FMS ₉₆	23.77 ^a ±0.5	32.24 ^a ±0.41	1.34 ^a ±0.30	119.33 ^b ±0.16
FMS ₁₂₀	24.55 ^a ±0.28	2.43 ^c ±0.81	1.35 ^a ±0.14	126.61 ^a ±0.48

Values are means and standard deviation of 3 replication. Means with different superscript along the same column for leaves and seeds are significantly different at $p < 0.05$.

FL---Fresh leaves of *Moringa oleifera*; SDL---Sun-dried leaves of *Moringa oleifera*; SHL---Shade dried leaves of *Moringa oleifera*; FS-----Fresh seed of *Moringa oleifera*; FMS₂₄....24 hours fermented *Moringa oleifera* seed; FMS₄₈....48 hours fermented *Moringa oleifera* seed; FMS₇₂....72 hours fermented *Moringa oleifera* seed; FMS₉₆....96 hours fermented *Moringa oleifera* seed; FMS₁₂₀....120 hours fermented *Moringa oleifera* seed

4. DISCUSSION

4.1 Proximate Composition

4.1.1 Moisture

In this study, the moisture content of the *Moringa oleifera* fresh leaves was 75.33%/100g. The result of the present study is in line with the value reported by Sheela et al. [34] who observed that the moisture content of thirty-eight underutilized green leafy vegetables in Southern Karnataka was between the range of 68.00-93.00%. The high moisture content in these fresh vegetables was not a surprise as Ene-Obong [35] noted that the most single constituent of vegetable is water, which accounts for more than 80% of the nutrients. This will result in a lower contribution of other proximate components. The high moisture content of these vegetables indicates that they will not have prolonged keeping quality. Drying led to reduced leaf moisture content. The loss was similar for both the shade and sun-dried leaves. The result of this study is in line with the report of Traore et al. [36], who observed that the moisture content of dried vegetables ranged between 7.22 - 11.82 in three leafy vegetables studied. The moisture content of the seeds increased with an increase in fermentation time. The increase could be as a result of water absorption during fermentation.

4.1.2 Protein

The protein content of the leaves varies between 6.01- 17.68%. Although vegetables are not good sources of protein. Fresh leaves (FL) had a

protein level of 6.01%. Eyo et al. [37] observed that the protein levels of fresh vegetables are comparable to those of cereals (7.90%). The protein contents of both the fresh and dried vegetables were lower than the values reported by Traore et al. [36]; Anin, et al. [38], and Grubben et al. [39]. The differences in protein content could be due to differences in vegetable composition. Drying increases the protein contents of vegetables. The higher protein content of sun and shade dried vegetables could be useful in fighting kwashiorkor in communities where protein-energy malnutrition is prevalence provided it is consumed in significant quantity. Fermentation increased the protein content of *Moringa oleifera* seeds. This result is in line with the findings of Buta and Emire, [40] who observed an increase in protein content of weaning food with an increase in fermentation time. Fermentation hydrolyzes protein into its amino acid components. The increase in protein was due to the increased activity of proteolytic enzymes that removed non-protein nitrogen to improve the protein quality.

4.1.3 Fat

Generally, vegetables are not good sources of fat. It was observed that drying led to an increase in the fat content of vegetables. This result disagrees with the report of Traore et al. (36) who observed a decrease in the fat content of vegetables studied concerning drying. Consumption of these vegetables may help reduce the high incidence of obesity, diabetes, cardiovascular diseases and high blood pressure, which are associated with a high intake of fatty foods. The fat contents of fresh

vegetables are in line with the values (0.20-2.60%) reported by Sheela et al. [34] on fresh vegetable studied. The fat content increased from 14.93% in raw seed to 19.99% in fermented seed as fermentation time increases. Buta and Emire [40] observed that as fermentation time increases the fat content of fermented blends increased from 8.42% to 10.9% concerning the fermentation time of 0, 24 and 48 h. The increase in the fat content of fermented samples could be due to increased activity of lipolytic enzymes which increased the released of more fatty acids.

4.1.4 Crude fibre

The crude fibre content of the vegetables (0.36-13.14%/100 g) and seeds (3.94-7.10%) was of interest. The high fibre contents of sun-dried leaves (SDL) and shade dried leaves (SHL) (11.96 and 13.14%) could provide bulk in the diet, enhance gastrointestinal function, prevent constipation and may reduce the incidence of metabolic diseases like maturity-onset diabetes mellitus and hypercholesterolemia [41]. The values of the crude fibre after fermentation (4.66 for FMS₂₄, 4.60 for FMS₄₈, 4.26 for FMS₇₂, 4.00 for FMS₉₆ and 3.96 FMS₁₂₀) are within the WHO recommended 5% specification of the maximum requirement of crude fibre in complementary food [40]. This result showed that the crude fibre decreased with an increase in fermentation time. Buta and Emire [40] had a similar observation that fermentation time significantly ($p < 0.05$) reduced the crude fibre contents of the samples studied. Amankwah [42] observed that high fibre contents of weaning foods may inhibit mineral absorption and reduce the digestibility of proteins in foods. Fetugal et al. [22] observed that high fibre could trap and protect a large proportion of nutrients such as protein and carbohydrate from hydrolytic breakdown, thus reducing digestibility.

4.1.5 Ash

SDL (sun-dried leaves) and SHL (shade dried leaves) (13.21 and 15.22%) with high ash contents suggest that the mineral contents of the dried vegetables may be high. The ash levels of foods are an indication of the mineral content of the food. The values (0.60-3.40%) reported by Ajayi et al [43]. as the ash contents of some leafy vegetables studied were within the range of the values observed for fresh vegetables in this study (2.46%). Drying increased the ash content of vegetables from 2.46 to 15.22%. The ash content decreased with increased in fermentation time from 6.22 in raw to 1.96% in FMS₁₂₀.

4.1.6 Carbohydrate

Vegetables and seeds are not major sources of carbohydrates compared to starchy foods, which form the bulk of food eaten. The very low carbohydrate content of the fresh vegetable (12.01%) is of interest. Drying increased the carbohydrate content of the vegetable. This may be as a result of the reduction in the moisture content of the food. There is a decrease in carbohydrate content with an increase in fermentation time. This result is in line with the findings of Buta and Emire [40] who observed a decrease in carbohydrate with an increase in fermentation time. The decrease in carbohydrate content of fermented foods is important for people with the challenges of obesity, high blood pressure and diabetes mellitus. The decrease in carbohydrate content of the fermented samples could be as a result of a decrease in amyolytic enzyme activity which hydrolyses starch into simpler sugar for quick energy supply.

4.2 Ascorbate and Mineral Content

4.2.1 Ascorbate

The ascorbic acid value 167.66 mg/100 g for the fresh vegetable studied was higher than the range of values (3.00-75.00 mg) observed by Sheela et al. [34] on 28 underutilized vegetables studied in Tanzania. There is a reduction in the ascorbate content of the dried vegetables. This could be as a result of the heat used in drying it. Sun-drying proved to be the most destructive of the drying methods tested in this study. The result conforms with results reported by earlier investigators [44]. The high ascorbate value for this fresh vegetable is of interest. The ascorbate content of the seed before fermentation was (3.57 mg/100 g). The ascorbate level increased (20.52-24.55 mg) with an increase in fermentation time. Consumption of adequate quantities of vegetables with iron-rich foods will enhance the absorption of iron. Ascorbic acid is important in the formation of connective tissue and for proper absorption of iron and calcium. Adequate intake of the vegetables may assist in the prevention of early death from heart diseases and cancer and may also play a primary role in collagen formation which is essential for the growth and repairs of tissue cells, gums, blood vessels, bones and teeth. Vitamin C is an important antioxidant. The high Vitamin C level in the vegetables may also help to battle against cancer and many degenerative diseases (i.e. Alzheimer's, Cardiovascular Disease, Diabetes, etc) [20].

Table 3. Effect of processing on the anti nutrient composition (mg/100 g) of *Moringa oleifera* leaves and seeds

Samples	Phytate	Saponin	Oxalate	Tannins
FL	13.20 ^A ±0.18	1.26 ^A ±0.72	8.44 ^A ±0.85	0.22 ^A ±1.54
SDL	2.31 ^C ±0.65	0.10 ^B ±0.00	0.70 ^B ±0.50	0.10 ^B ±0.01
SHL	5.26 ^B ±0.23	0.04 ^C ±0.00	0.31 ^C ±0.80	0.05 ^C ±0.02
FS	16.81 ^A ±0.15	1.35 ^A ±0.17	6.25 ^A ±0.62	0.28 ^A ±0.06
FMS ₂₄	10.74 ^B ±0.62	1.26 ^A ±0.84	1.22 ^B ±0.47	0.22 ^B ±0.01
FMS ₄₈	9.24 ^B ±0.85	0.10 ^B ±0.00	0.68 ^C ±0.30	0.17 ^C ±0.01
FMS ₇₂	8.00 ^{BC} ±0.04	0.07 ^{BC} ±0.01	0.21 ^D ±0.00	0.14 ^{CD} ±0.02
FMS ₉₆	7.58 ^C ±0.36	0.12 ^B ±0.11	1.48 ^B ±0.76	0.15 ^C ±0.05
FMS ₁₂₀	5.69 ^C ±0.26	0.03 ^C ±0.01	1.16 ^{BC} ±0.89	0.11 ^D ±0.00

Values are means and standard deviation of 3 replication. Means with different superscripts along the same column for leaves and seeds are significantly different at $p < 0.05$. FL---Fresh leaves of *Moringa oleifera*; SDL---Sun-dried leaves of *Moringa oleifera*; SHL----Shade dried leaves of *Moringa oleifera*; FS-----Fresh seed of *Moringa oleifera*; FMS₂₄....24 hours fermented *Moringa oleifera* seed; FMS₄₈....48 hours fermented *Moringa oleifera* seed; FMS₇₂....72 hours fermented *Moringa oleifera* seed; FMS₉₆....96 hours fermented *Moringa oleifera* seed; FMS₁₂₀....120 hours fermented *Moringa oleifera* seed

4.2.2 Iron (Fe)

There were low levels (0.04-0.23 mg/100 g) of iron in both fresh and dried vegetables. There was a decrease in iron level (10.33 to 2.10 mg/100 g) with increased in fermentation time. The unprocessed seed had 10.33 mg/100 g of iron. The slight increase in iron contents of the sun and shade dried (0.23 and 0.16 mg/100 g) leaves showed that drying can improve the iron content of the food. The fresh seeds with high iron levels could be useful in the fight against iron deficiency anaemia.

4.2.3 Zinc (Zn)

The zinc contents of the vegetables studied were between 0.04 - 0.06 mg/100 g. The zinc levels in the seeds (1.24 – 1.35 mg/100 g) for both fermented and unfermented sample were quite low. The low level of zinc in this study may be due to low level of zinc in the soil where the plant was cultivated and this is a common phenomenon. The increase in zinc contents of the dried and fermented samples could be as a result of the increase in the activities of microflora enzymes that hydrolysed the zinc-protein-enzyme bond to release zinc for utilization.

4.2.4 Antinutrient

Antinutrients are the major limiting factors to the wider food use of many tropical plants. The effect ranged from a severe reduction in food intake and utilization to profound neurological effects and even death [45].

Phytate: Anti-nutrients such as phytate, oxalate, saponin and tannin are compounds which affect the nutritive value of food products. Phytate is naturally present in many foods especially cereals and legumes. When above a certain level, phytates reduce the availability of minerals and solubility, functionality and digestibility of proteins [46]. There is a decrease in phytate level after fermentation which may be due to the activity of the endogenous phytase enzyme within the sample and inherent microorganisms which are capable of hydrolyzing the phytic acid in the fermented food samples into inositol and orthophosphate [47]. Before fermentation, the phytate content was high in the raw sample but after fermentation, the phytate content was greatly reduced. The decrease in phytate content of cocoyam tubers after processing has also been reported by Marfo and Oke [48].

Tannin: The reduction in tannin contents observed in this study might be attributable to the activities of microorganisms involved in fermentation. The results of this study corroborated with the findings of Murwan et al. [49] who reported a decrease in tannin content in two sorghum cultivars (Dabar and Tabar) after fermentation. Processing reduces the levels of tannins in both leaves and seeds. Tannin is an anti-nutrient at high doses but acts as phytochemical at lethal dose. Tannins are known to inhibit the activities of some digestive enzymes such as trypsin, chymotrypsin, amylase and lipase. They are also known to precipitate proteins in the gut, thereby making them

biounavailable. Hydrolyzable tannins have 15-30 times more potent antioxidant effect than simple phenolics [50]. As phytochemicals, tannins increase high-density lipoprotein cholesterol and decreases low-density lipoprotein cholesterol concentration in rat models [50].

Oxalate: The study revealed a decrease in oxalate level after fermentation and drying which will lead to an improvement in nutrient availability. The oxalate levels for both fermented seeds and dried leaves were below the lethal dose in man 2-5 g [51,52]. It is known that oxalate forms an insoluble complex with some essential minerals thus, preventing their bioavailability. Also, it is often anticipated that oxalate containing foods when consumed may interfere with calcium metabolism. The similar result which revealed a decrease in oxalate content of fermented Bambara nut was reported in the findings of [53].

Saponin: The saponin content of both fermented seeds (0.21-1.48 mg/100 g) and dried leaves (0.04-0.10 mg/100 g) were quite low. Saponin has been shown to have both beneficial and detrimental effects and to exhibit structure-dependent biological activities [54].

5. CONCLUSION

The result of the study showed that *Moringa oleifera* leaves and seeds are good sources of protein, iron, ascorbate and iodine. Processing improved the nutrient content of the leaves and the seeds. Fermentation improved the protein, ascorbate, iron and iodine contents of *Moringa oleifera*. Drying improved the protein content of the sample. Both fermentation and drying reduced phytate, saponin, oxalate and tannin contents of *Moringa oleifera* seeds and leaves. *Moringa oleifera* leaves and seeds could serve as good sources of nutrients in food. Fermentation and drying are beneficial and are of nutritional importance to populations that prefer natural enhancement of nutrients to enrichment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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