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Influence of Soaking and Cooking Techniques on Physical and Hydration Properties of *Moringa oleifera* Kernels

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Abstract Prior to consumption, most human foods are subjected to certain processing techniques such as soaking, roasting, parboiling and cooking, which causes important changes in their physical and hydration properties. Several physical and hydration properties were evaluated as function of soaking time as well as cooking methods. Standard methods were followed to investigate changes in the axial dimensions, shape indices, hydration and swelling capacity of *Moringa oleifera* kernels that were soaked in distilled water for 2, 4 and 6 h and subjected to cooking by conventional and microwave methods. For conventional and microwave cooking, minimum cooking time reduced from 46 to 44.3 min and from 25 to 23 min, respectively. The hydration capacity of the cooked kernels (g/kernel) decreased from 0.16 to 0.15 (conventional cooking); whereas it increased from 0.10 to 0.14 (microwave cooking). The axial dimension of kernels that were soaked for 2, 4 and 6 h and cooked were found to be 7.9 and 7.48 mm, 7.94 and 7.18 mm, 8.12 and 7.13 mm for length; 8.48 and 7.61 mm, 8.11 and 7.26 mm, 8.14 and 7.26 mm for width and 8.09 and 7.12 mm, 7.64 and 7.14 mm, 7.77 and 7.06 mm for thickness, respectively. Understanding the properties of specific food products with respect to different methods of processing is vital to their overall utilization.

Keywords: *Moringa, physical properties, hydration properties, soaking, cooking*

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1. Introduction

Moringa is the sole genus in the flowering plant family *Moringaceae*. It contains thirteen species of shrubs and trees originating in Asia and Africa. The most widely cultivated species is *Moringa oleifera*, a multipurpose tree native to the foothills of the Himalayas in northwestern India and cultivated in the semi-arid, sub-tropical and tropical regions [1,2]. *Moringa oleifera* (herein after, simply referred to as moringa) is a very important tropical tree as some of its parts including the leaves, flowers, fruits and immature pods have been traditionally used as highly nutritive vegetables in India and some other parts of Asia. They contain sizeable amounts of iron, β-carotene, ascorbic acid per 100 g of sample and essential amino acids which are seldom found in daily diets [3]. With about 40 g of protein/100g of kernel, moringa seeds have been recently explored as an alternative source of vegetable proteins [4,5]. The seeds contain 35-45% (wt) oil which is sometimes referred to as Ben oil. This oil has been used extensively in effleurage process, as lubricant in fine machineries (such as wrist watches and miniature precision equipment), coagulant for water purification and as a booster of cardiac function [6,7].

Prior to consumption, most human foods from plant sources (especially legume seeds) are subjected to processing techniques such as soaking, roasting, parboiling and cooking which causes important changes to the physical, hydration, nutritional, biochemical and sensory characteristics of the food. Cooking causes some physico-chemical changes such as food texture improvement and palatability, starch gelatinization, protein denaturation, inactivation or reduction of heat labile toxic compounds such as trypsin inhibitors and flatulence-causing oligosaccharides, resulting in improved nutritional quality [8,9,10]. Many food properties show a unique dependence on the state of the water in a food material. Soaking has been shown to cause a change in the physical and hydration properties, cooking time and anti-nutritional content of food. De Leone *et al.*, [11] stated that soaking aids in shortening of cooking time, results in more evenly textured products and increases the nutrition profile of legume seeds when combined with cooking. This helps to prevent indigestion, which is due to non-nutritional factors such as phytic acid and tannins. Soaking involves hydration of the seeds in water, usually until they reach maximum weight, with or without discarding of the soaking medium [12,13]. One of the most important uses of soaking is to hydrate beans evenly and completely in shorter times, which is necessary to provide the water needed for starch gelatinization and protein denaturation of legumes during cooking [14]. Ibarz *et al.* [15] studied the hydration and cooking of common chickpea, investigating soaking as a pre-cooking condition for chickpea and observed that lower cooking time corresponded to the soaked samples and that the cooking time decreased as soaking time increased.

Processing of moringa kernels into edible commercial food products requires that appropriate equipment and facilities be designed and selected to process, handle and store moringa kernels, hence the need to quantify its physical and hydration properties. Sphericity is the ratio of volume of solid to the volume of a sphere that has a diameter equal to the major diameter of the object so that it can circumscribe the solid sample while aspect ratio relates the width to the length of the seed and is indicative of a tendency towards an oblong shape [16,17]. Sphericity and aspect ratio are common shape indices for most bio-materials. Surface area indicates how the material will behave in a moving fluid (such as air) and when separating extraneous materials from the product during pneumatic cleaning. It is also important in heat and mass transfer processes such as drying and other thermal treatments [17]. Knowledge of axial dimensions and bulk density of food materials are essential in the design of storage and handling equipment [18].

Hydration capacity denotes the maximum amount of water that a protein material can take up and retain under food formulation conditions. The hydration capacity is crucial in the food industry, because it affects its functional properties and the quality of cooking products. For example, the hydration capacity of flour often defines its quality and its aptitude to form viscoelastic dough [19,20]. Generally, understanding the properties of specific food products with respect to different processing technique is vital to their overall utilization [21].

However, there is general scarcity in the published data that have been carried out on the influence of processing technique on the physical and hydration properties of moringa kernels. Therefore, the objective of this study was to quantify the effect of processing techniques (soaking duration and cooking methods) on the physical (axial dimensions, shape indices and bulk density) and hydration properties of moringa kernels.

2. Materials and Methods

2.1. Sample Preparation and Processing

Dried moringa seeds (Figure 1a) were obtained from the Teaching and Research Farm of Obafemi Awolowo University, Ile Ife, Nigeria and dehulled. The kernels (Figure 1b) were cleaned manually to remove lighter foreign matter such as dust, dirt, chaff, immature, damaged and shrink seeds. The cleaned kernels were thereafter sealed in a polythene bag and stored in a refrigerator until processing and analysis. The initial moisture content of the raw kernels was determined by AOAC method [22] was 7.9% (wet basis, wb).

Figure 1. a: Moringa Seeds, b: Moringa Kernels

About 50 g of kernels were soaked in distilled water for 2, 4 and 6 h, respectively. The soaked samples were then subjected to conventional cooking and microwave cooking methods with the use of an electric hot plate and microwave oven (Model: MDS-2000 CEM Corp. Matthews, NC). The conventional cooking method was designed to simulate method used in home meal preparation while the microwave cooking method was designed to simulate the processing method used in food processing industries.

2.2. Physical Properties

The three significant axial dimensions (length, L; width, W; and thickness, T) of 100 randomly selected uncooked and cooked kernels were measured using an electronic Vernier caliper (having least count 0.02 mm).

Geometric Mean Diameter (D_e), sphericity, aspect ratio and surface area are properties calculated as function of the axial dimensions. The geometric mean diameter of the kernels was calculated using the following relation [23].

$$D_e = (LWT)^{1/3} \tag{1}$$

The shape indices of the kernels were determined in terms of sphericity, aspect ratio and surface area [16]. Sphericity (S_p), a ratio of volume of ellipsoid with equivalent diameters to volume of circumscribed sphere, was calculated using the relationship below;

$$S_p = D_e / L. \tag{2}$$

The aspect ratio was calculated as;

$$\text{Aspect ratio} = W / L. \tag{3}$$

Surface area (S) of the kernel was calculated using the relationship [24] below;

$$S = \left[\pi L^2 (WT)^{0.5}\right] / \left[2L - (WT)^{0.5}\right] \tag{4}$$

Where L is length, W is width and T is thickness.

Bulk density was determined using the mass/volume relationship. An empty conical flask of predetermined volume and tare weight was filled with the kernels and weighed on the electronic balance [17].

2.3. Hydration and Swelling Properties

Hydration and swelling properties of the kernels were determined using the procedure described by Williams et al. [25]. A weighed amount of the kernel sample was poured into a measuring jar containing 100 mL distilled water and left to soak for 24 h at room temperature (23°C). The water was drained afterwards and the soaked kernels were blotted on soft tissue to remove adhered water and the kernels were weighed again. Hydration capacity and index were calculated according to the expressions below:

$$\text{Hydration capacity } (\text{g / kernel}) = \frac{\begin{pmatrix}\text{Weight of soaked kernels} \\ -\text{Weight of kernels before soaking}\end{pmatrix}}{\text{Number of kernels}} \quad (5)$$

$$\text{Hydration index} = \frac{\text{Hydration capacity per kernel}}{\text{Weight of one kernel}}. \quad (6)$$

One hundred kernels were randomly selected and the initial volume of kernels was determined. The selected kernels were soaked overnight in distilled water and the volume of the soaked kernels was noted in a graduated cylinder. The swelling capacity and swelling index were calculated as follows:

$$\text{Swelling capacity} = \frac{\text{Volume after soaking} - \text{volume before soaking}}{\text{Number of seeds}} \quad (7)$$

$$\text{Swelling Index} = \frac{\text{Swelling capacity per kernels}}{\text{Volume of kernels}}. \quad (8)$$

2.4. Water Uptake Ratio

A weighed amount of moringa samples were cooked in 20 ml of distilled water for a minimum cooking time in a boiling water bath. After this, the contents were drained and the adhering superficial water present on cooked moringa kernels was removed by pressing the samples between filter papers. Cooked moringa samples were weighed and the water uptake ratio was calculated as increase in weight of moringa samples after cooking [26].

2.5. Minimum Cooking Time

Few kernels were removed at different time intervals while the cooking lasts and pressed in-between two glass slides. The minimum cooking time was considered to be the time at which the boiled kernel shows no uncooked core.

2.6. Statistical Analysis

Data collection for all the properties was carried out in triplicate. A significant test (α <0.05) using the ANOVA procedure in the statistical software SAS 9.3 [27] was conducted to show the effect of soaking duration and cooking methods on the physical and hydration properties. The results were presented in mean ± standard deviation.

3. Results and Discussion

3.1. Physical Properties

The effect of soaking duration and cooking techniques on the physical properties of conventionally and microwave cooked moringa kernels are presented in Table 1a and 1b, respectively. The mean length, width and thickness of the kernels varied between 7.10 - 8.16 mm, 7.26 – 8.48 mm and 6.90 – 8.09 mm, respectively. Cooking method had a significant effect ($p<0.05$) on the axial dimensions and geometric mean diameter of the kernels while soaking duration had no significant effect ($p<0.05$). The axial dimensions and geometric mean diameter of conventionally cooked kernels were higher in comparison to the microwave cooked kernels. Although prior to cooking, soaking duration (which causes increase in moisture content) can lead to increased axial dimensions of food materials [28,29,30], its effect was subdued by the cooking methods. Changes in the axial dimension of cooked kernels shows the extent of moisture absorption and gelatinization of starch during the cooking duration [31].

The shape indices of the moringa kernels represented by sphericity and aspect ratio ranged from 0.36 to 0.40 and 1.02 to 1.08, respectively. There was no significant difference ($p<0.05$) in the sphericity and aspect ratio of the kernels which indicates that neither the soaking duration nor the cooking methods affected the shape indices of the moringa kernels. The surface area of the kernels varied between 166.8 and 222.5 mm^2 with the conventionally cooked kernels significantly higher ($p<0.05$) than the microwave cooked kernels. The maximum surface area of 222.5 mm^2 was recorded for the kernels soaked for 2 h and conventionally cooked, which indicated that the 2 h soaking would be the appropriate soaking duration for moringa kernels in obtaining maximum surface area during its processing.

Table 1a. Effect of soaking duration and cooking method on the physical properties of conventionally cooked moringa kernels

Physical Properties	Treatments				
	Raw	1	2	3	4
Number of trials	100	100	100	100	100
Length (mm)	$7.55 \pm 1.11^{b,c}$	8.16 ± 0.91^{a}	$7.90 \pm 0.78^{a,b}$	$7.94 \pm 1.31^{a,b}$	8.12 ± 1.17^{a}
Width (mm)	$7.86 \pm 0.72^{b,c}$	8.32 ± 0.58^{a}	8.48 ± 0.87^{a}	$8.11 \pm 0.99^{a,b}$	$8.14 \pm 1.05^{a,b}$
Thickness (mm)	$7.34 \pm 0.77^{c,d}$	$7.99 \pm 0.51^{a,b}$	8.09 ± 0.88^{a}	$7.64 \pm 0.88^{b,c}$	$7.77 \pm 0.98^{a,b}$
Geometric Mean Diameter (mm)	7.55 ± 0.60^{b}	8.15 ± 0.57^{a}	8.14 ± 0.68^{a}	7.87 ± 0.87^{a}	7.99 ± 0.90^{a}
Sphericity	1.01 ± 0.11^{a}	1.00 ± 0.06^{a}	1.04 ± 0.08^{a}	1.01 ± 0.12^{a}	0.99 ± 0.10^{a}
Aspect Ratio	1.06 ± 0.17^{a}	1.03 ± 0.11^{a}	1.08 ± 0.12^{a}	1.05 ± 0.19^{a}	1.02 ± 0.15^{a}
Surface Area (mm^2)	$188.0 \pm 35.88^{c,d}$	$211.4 \pm 25.51^{a,b}$	222.5 ± 51.06^{a}	204.3 ± 49.79^{c}	205.5 ± 47.64^{c}
Mass (g)	0.20 ± 0.05^{e}	0.37 ± 0.07^{a}	$0.36 \pm 0.08^{a,b}$	0.37 ± 0.07^{a}	$0.35 \pm 0.08^{a,b}$
Bulk Density (g/cm^3)	0.49 ± 0.12^{d}	$0.68 \pm 0.06^{b,c}$	$0.69 \pm 0.21^{b,c}$	0.80 ± 0.31^{b}	$0.74 \pm 0.34^{b,c}$

^{a,b,c,d} Means with different letters on same row are significantly different ($P \leq 0.05$). All values are means of triplicate ± SD
1: unsoaked/conventionally cooked
2, 3, 4: soaked for 2, 4, 6 h/conventionally cooked.

Table 1b. Effect of soaking duration and cooking method on the physical properties of microwave cooked moringa kernels

Physical Properties	Treatments			
	5	6	7	8
Number of trials	100	100	100	100
Length (mm)	7.10 ± 0.97^{d}	$7.48 \pm 0.98^{c,d}$	7.18 ± 1.07^{d}	7.13 ± 0.94^{d}
Width (mm)	7.34 ± 0.80^{d}	$7.61 \pm 0.81^{c,d}$	7.26 ± 1.30^{d}	$7.50 \pm 0.70^{c,d}$
Thickness (mm)	6.90 ± 0.73^{e}	$7.12 \pm 0.83^{d,e}$	$7.14 \pm 0.80^{d,e}$	$7.06 \pm 0.73^{d,e}$
Geometric Mean Diameter (mm)	7.08 ± 0.54^{c}	$7.38 \pm 0.64^{b,c}$	$7.11 \pm 0.74^{b,c}$	7.20 ± 0.49^{c}
Sphericity	1.01 ± 0.13^{a}	1.00 ± 0.11^{a}	1.01 ± 0.15^{a}	1.02 ± 0.12^{a}
Aspect Ratio	1.06 ± 0.20^{a}	1.04 ± 0.18^{a}	1.04 ± 0.25^{a}	1.07 ± 0.18^{a}
Surface Area (mm^2)	166.8 ± 34.32^{e}	$176.5 \pm 36.69^{d,e}$	169.7 ± 39.32^{e}	$174.5 \pm 36.27^{d,e}$
Mass (g)	$0.35 \pm 0.07^{a,b}$	0.30 ± 0.08^{c}	0.34 ± 0.06^{b}	0.24 ± 0.07^{d}
Bulk Density (g/cm^3)	1.03 ± 0.36^{a}	$0.79 \pm 0.32^{b,c}$	1.03 ± 0.54^{a}	0.66 ± 0.20^{c}

^{a,b,c,d} Means with different letters on same row are significantly different ($P \leq 0.05$). All values are means of triplicates ± SD
5: unsoaked/microwave cooked
6, 7, 8: soaked for 2, 4, 6 h/microwave cooked.

There was significant difference ($p<0.05$) in the average mass and bulk density of the moringa kernels. The mass and bulk density of the processed kernels were significantly higher than the raw kernels. This increase is indicative of volumetric change as a result of moisture absorption by the kernels. Mass and bulk density have practical application in bulk solid handling of food products, hence change in these properties for cooked moringa kernels indicates that there is a need to provide a larger storage vessels to store the processed kernels [16,32].

3.2. Hydration Properties, Water Uptake Ratio and Minimum Cooking Time

Table 2 shows that the hydration and swelling properties, water uptake ratio and minimum cooking time of the cooked moringa kernels. Hydration capacities of the processed kernels ranged between 0.10 and 0.16 g/kernel while the hydration indices ranged between 0.52 and 0.70. Black *et al.* [33] reported a similar result for the hydration capacities of four varieties of field peas, which ranged between 0.06 and 0.17 g/seed. The lower hydration capacity values showed the inability of the kernels to swell when soaked. Sefa-Dedeh and Stanley [34] stated that characteristics of seed coat and cotyledon structures for pulses are important factors affecting water absorption rate at initial stages of soaking. Swelling capacity was observed to range between 0.14 and 0.20 cm^3/kernel.

While hydration capacity shows change in the mass of the moringa kernels due to moisture absorption, swelling capacity measures the amount of water that can be absorbed by a material and represents the corresponding volumetric change. The swelling capacity of the unsoaked kernels cooked using the conventional method was significantly higher than the unsoaked kernels cooking using microwave method. This is attributable to the cooking time for each method. The longer the cooking time, the higher the swelling capacity as the kernel have more time to absorb more moisture. Kaur *et al.* [35] reported similar result for the swelling capacity of rice bean grown in Indian Himalaya regions. The bean with highest hydration and swelling capacities were found to have a longer cooking time.

Table 2. Hydration and swelling properties of moringa kernels

Parameters	*Treatments							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Hydration capacity (g/kernel)	0.15	0.16	0.16	0.15	0.10	0.11	0.1 3	0.14
Hydration index	0.64	0.67	0.70	0.67	0.52	0.54	0.6 1	0.68
Swelling capacity (cm^3/kernel)	0.19	0.14	0.14	0.22	0.15	0.16	0.1 9	0.20
Water uptake ratio	1.59	1.66	1.70	1.66	1.61	1.54	1.6 0	1.66
Minimum cooking time (min)	46.0	44. 3	44.5	44. 8	25.0	23.0	23. 0	23.0

*****1: unsoaked/conventionally cooked
2, 3, 4: soaked for 2, 4, 6 h/conventionally cooked
5: unsoaked/microwave cooked
6, 7, 8: soaked for 2, 4, 6 h/microwave cooked

Water uptake ratio generally ranged between 1.59-1.70. An increase in water uptake ratio may be directly related to increase in bulk density. Higher water uptake ratio contributes to longer cooking time [36]. Kernels cooked using the microwave method were found to have lower water uptake ratio as compared to the moringa kernels cooked using conventional method. The low water uptake ratio also correlates to the shorter cooking time of microwave cooking method.

The minimum cooking time for kernels cooked using the conventional method ranged between 44.3 to 46.0 min. The minimum cooking time measures the time at which there is no uncooked core. It was observed that microwave method used approximately half the cooking time of the conventional cooking method. Reduced cooking time can be a beneficial factor to consider when fuel consumption is a concern [36]. For kernels cooked by microwave method, a reduction in the minimum cooking time from 25 min to 23 min was observed. However, the soaking duration had no significant effect ($p<0.05$) on the cooking time. This was contrary to the findings of Ibarz *et al.* [15] for chickpeas, which when soaked showed marked decrease in cooking time. For chickpeas soaked for 3 h, cooking time reduced by half. As soaking time increased to 12 h, cooking time decreased to 14.3 min representing a cooking time reduction of 82%. This implies that although moringa is a legume, soaking prior cooking will not cause a significant reduction in its cooking time as compared to the cooking method used.

4. Conclusion

In this study, the influence of soaking duration and cooking methods on the physical and hydration properties of moringa kernels were investigated. The soaking duration did not have a significant effect on most of the properties measured. However, the cooking methods greatly influenced the physical properties of the processed moringa kernels. Reduction of cooking time which is an important parameter in terms of energy consumption was enhanced by the microwave cooking method. Although, soaking has been reported in several literatures to influence the physical and hydration properties of legumes, moringa kernels were found to be more affected by the cooking method as compared to the soaking duration.

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