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Effects of dehulling, soaking, and cooking on the nutritional quality of *Moringa oleifera* seeds

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Abstract

The effect of dehulling, soaking and cooking methods on nutrients, antinutrients and *in vitro* protein digestibility (IVDP) of *Moringa oleifera* seeds was investigated. Dehulling significantly increased the levels of ash, protein, fat, carbohydrates, minerals, phytate, trypsin inhibitor activity (TIA) and lectin activity, but decreased fiber and tannins. Soaking had no effect on ash, protein, carbohydrates and lectin activity, but significantly decreased fat, minerals, phytate, TIA and tannins; on the other hand, soaking increased the fiber content. All cooking methods (either with or without soaking) significantly decreased the nutrient content (except for fiber and carbohydrates) as well as the antinutrients. Autoclaving and cooking were the most effective in reducing the antinutrients. Moreover, all cooking methods improved *in vitro* protein digestibility (IVPD) (autoclaving and cooking were the most effective) but dehulling decreased IVPD and soaking had no effect. Therefore, moringa seeds should be soaked and cooked before being consumed.

Keywords: *Moringa oleifera* seeds; nutrients; antinutrients; dehulling; soaking; cooking methods.

1. Introduction

In developing countries, food shortages continue to be of great concern. Many factors contribute to global food shortages including population growth and importation restrictions on certain foods. Recently, a growing interest is currently being focused on exploiting lesser known plants as alternative food sources. *Moringa oleifera*, which belongs to the genus *Moringaceae*, is a fast growing, aesthetically pleasing tree (commonly known as the horse-radish or drumstick tree). It is native to the Indian subcontinent and has become naturalized in the tropical and subtropical areas around the world [1]. Moringa is considered to be one of the world's most useful trees, because every part of the moringa tree can be used for industrial purposes, food or medication [2]. Its leaves, flowers, and fresh pods are used as vegetables for human consumption as well as livestock feed [3]. Also, moringa seeds are used as a tasty vegetable and in water purification because of their coagulant properties [4]. In Egypt, all parts of moringa are used; for example, leaves are used fresh for cooking and dried as a healing tea and for flavoring.

Several investigations were conducted to evaluate the chemical composition of moringa seeds. The seeds had high levels of fat, protein, fiber, vitamins (B and C), and minerals (such as calcium and phosphorus) [5-7]. Also, moringa seeds can be used to fortify staple foods, particularly for children, because of their high levels of macro and micronutrients [8]. However, moringa seeds also contain high levels of antinutritional/toxic factors such as tannins, phytate, alkaloids, saponin and oxalate, which interfere with digestion and absorption of various nutrients as well as interfering with general metabolism [7]. Oliveira et al. [6] reported that consumption of moringa seeds should be viewed with some caution until suitable

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processing methods are developed to remove the adverse factors. Several treatment methods have been applied to a variety of seed to abolish harmful antinutrients and toxic factors. These methods include soaking, dehulling, and cooking methods, which have been used on lupin seeds [9], roasting is effective for sesame and peanuts [10] and cooking for beans and chickpeas [11]. However, studies conducted on possible treatments to improve the suitability of moringa seeds for human and animal consumption are still scanty. Therefore, the present study was carried out to evaluate the effect of soaking, dehulling and cooking methods on the nutrients, some antinutritional factors (phytate, trypsin inhibitor, lectin and tannins) and *in vitro* protein digestibility (IVPD) of moringa seeds.

2. Materials and methods

2.1. Materials

Dry, mature seeds of *Moringa oleifera*were obtained from the Horticulture Department, Faculty of Agriculture, Suez Canal University. The seeds were manually cleaned to remove foreign material and then stored in polyethylene bags at room temperature (25^{o}C) until used. All chemicals and reagents used in this study were of analytical grade and purchased from Sigma-Aldrich Co. (St. Louis, Mo., U.S.A.).

2.2 Processing treatments

2.2.1. Soaking and dehulling: Raw moringa seeds were soaked in distilled water (seed: water, 1: 10) for 12 h. Another portion of soaked and raw moringa seeds was dehulled manually.

*2.2.2. Cooking methods***:** Raw moringa seeds were cooked (ordinary cooking) at 100°C in distilled water (seed: water, 1: 10) for 40 min. Another portion of the seeds was autoclaved (15 psi and 121°C) in distilled water (seed: water, 1: 10) for 20 min. Additional seeds were microwave cooked in distilled water (seed: water, 1: 10) for 6 min using a Moulinex microwave (Microchef 2335, type 907; Modéle Depos, France**)**. To assess the effects of combining soaking and cooking, three units of presoaked moringa seeds were treated with one of the three cooking methods as described above. After each treatment, the seeds were dried at 50°C for 12 h then ground into flour and stored in plastic containers until analyzed.

2.3. Proximate composition

The moisture, crude protein (N × 6.25), fat, ash and fiber were determined by using the Standard Association of Official Analytical Chemists (AOAC) [12]. Soluble carbohydrates were calculated by difference.

2.4. Minerals analysis

Minerals were determined after wet ashing using concentrated nitric acid and perchloric acid (4:1, v/v). Potassium (K), sodium (Na) and calcium (Ca) were determined using Flame photometer (Jenway Clinical PFP7, Jenway LTD, Felsted, Dunmow, Essex, U.K.). Iron [Fe], manganese [Mn], and zinc [Zn] were estimated using Atomic Absorption spectrophotometer (Thermo Electron Corp., S series, AA spectrometer, Type S4 AA system, assembled in China). Phosphorus [P] was measured photometrically via the phosphomolybdovanate method (AOAC) [12].

2.5. Determination of phytic acid

The method described by Latta and Eskin [13], and later modified by Vaintraub and Lapteva [14] was used to determine phytic acid. The extraction was carried out with HCl (2.4%) and the clear supernatant was used for phytate estimation. After adding the wade reagent (0.03% solution of $FeC1_3.6H_2O$ containing 0.3% sulfosalicylic acid in water) to the sample solution, the absorbance was measured at 500 nm using a spectrophotometer (6505 UV/Vis; Jenway Ltd., Felsted, Dunmow, UK). The standard curve was prepared using sodium phytate, and the results were expressed as g phytic acid/100 g dry matter.

2.6. Determination of tannins

Folin-Denis reagent was used to determine the tannins content as described by the method of AOAC [15]. Aqueous acetone (70%, v/v) was used to extract the tannins and supernatant was analyzed. Tannic acid was used as a standard and the results were expressed as mg/g (dry matter).

2.7. Determination of trypsin inhibitor

One gram of defatted moringa seed flour was extracted with 100 ml of phosphate buffer (pH 7.0) in an ultra-turrax homogenizer (Model T50; IKA®-

Labortechnik, Germany) at 8000 rpm for 5 min at room temperature. The homogenate was centrifuged at 8000 ×*g* for 30 min and the clear supernatant was used to estimate the amount of trypsin inhibitor present. Trypsin inhibitor activity was determined spectrophotometrically according to the procedure of Kakade et al. [16] using α-N-benzoyl-DL-argininep-nitroanilidehydrochloride (BAPNA) as a substrate.

2.8. Determination of Haemagglutinin activity

One gram of defatted moringa seed flour was mixed with 25 ml of NaCl (0.15 M) in an ultra-turrax homogenizer at maximum speed for 5 min at room temperature. Then the mixture was centrifuged and the supernatant was used to estimate lectin activity. Haemagglutinating activity (HA) was measured according to Paredes-López et al. [17] by a serial dilution using a 2% suspension of human erythrocytes (A, B and O). One unit of HA was defined as the reciprocal of the highest dilution giving positive agglutination.

2.9. Determination of in vitro protein digestibility (IVPD)

The IVPD of moringa seed was measured according to the multienzyme technique [18] using a 3-enzyme solution (trypsin, chemotrypsin and peptidase).

2.10. Statistical analysis

All treatments and determinations were carried out in triplicate and the results are presented as means ±SD. The data were subjected to analysis of variance (ANOVA) accompanied with Duncan test using SPSS software (version 16.0 for Windows, SPSS Inc., Chicago). Significance was set at $p < 0.05$.

3. Results and Discussion

3.1. Proximate composition

Proximate compositions of raw and treated *Moringa oleifera* seeds are presented in Table 1. No significant differences in ash content were observed among the following treatments: soaking, microwave only, soaking plus microwave, soaking plus cooking, and raw *Moringa oleifera* seeds. However, cooking and autoclaving significantly ($p < 0.05$) decreased the level of ash. The decreased ash content may be attributed to diffusion into cooking water [19]. On the other hand, dehulling and soaking plus dehulling caused a significant ($p < 0.05$) increase in ash content, indicating that ash is located primarily in the moringa seed kernel. These results are in agreement with those reported for whole and dehulled sunflower seeds [20]. There were no significant differences in protein content among soaking, microwave only, and soaking plus microwave when compared to the raw moringa seed. On the other hand, cooking, autoclaving, soaking plus cooking and soaking plus autoclaving caused a significant ($p < 0.05$) decrease in protein content. These results agree with those reported for some African yam bean seed varieties [21]. The decreased protein content could be attributed to protein leaching into the soaking and cooking water [22]. On the other hand, improved protein content after dehulling and soaking plus dehulling could be due to removal of the hull. These results agree with those obtained for some legume seeds by Ghavidel and Prakash [23].

Fat content significantly ($p < 0.05$) decreased after soaking, microwave only, cooking, autoclaving, soaking-microwave, soaking plus cooking and soaking plus autoclaving when compared to raw *Moringa oleifera* seeds. Similar results had been reported for mung bean seeds [24] and chickpeas [19]. The decrease in fat content might be attributed to their diffusion into the soaking and cooking water. On the other hand, dehulling and soaking plus dehulling significantly increased the fat content, which was due to removal of the hull. Similar observations were reported for some legume seeds [23]. The results in Table (1) also show that soaking, microwave, cooking, autoclaving, soaking plus microwave, soaking plus cooking, and soaking plus autoclaving caused significant ($p < 0.05$) increases in fiber content. These results agree well with those reported for chickpeas [19]. The increased fiber content may be due to protein-fiber complexes formed after possible chemical modification induced by soaking and cooking the seeds [25]. However, dehulling and soaking plus dehulling noticeably decreased the fiber content, which was attributed to the concentration of fiber in the moringa seed hull. Moreover, in moringa seeds the percent weight of hull in relation to entire seed is 26.33 [26]. Except for dehulling and soaking plus dehulling, no significant differences in total carbohydrate contents were

observed among the different treatments. These observations are in agreement with those reported by Barampama and Simard [27] for cooked common beans and by El-Adawy [28] for cooked chickpeas. Dehulling and soaking plus dehulling significantly ($p < 0.05$) increased the carbohydrate content and this could be due to removal of the hull and concentration of the endosperm.

Table 1. Effect of the treatments on proximate composition of *Moringa oleifera* seeds

Treatment	Component (g/100 g-dry weight basis)				
	Ash	Protein	Fat	Fiber	Carbohydrate
Raw	3.30±0.06^{b}	27.5±0.31^{b}	43.6±0.15^{b}	23.1±0.10^{e}	2.51±0.38^{c}
Soaking	3.25±0.24^{b}	27.4±0.31^{b}	42.6±0.17^{cd}	24.3±0.37^{d}	2.36±0.31^{c}
Dehulling	4.08±0.14^{a}	32.1±0.37^{a}	55.5±0.21^{a}	3.49±0.15^{f}	4.82±0.46^{a}
Soaking-Dehulling	3.84±0.16^{a}	31.8±0.38^{a}	54.3±0.31^{a}	3.30±0.15^{f}	6.74±0.24^{b}
Microwave	3.16±0.19^{bc}	27.5±0.24^{b}	43.1±0.13^{c}	23.9±0.42^{d}	2.32±0.47^{c}
Cooking	2.73±0.32^{d}	26.6±0.15^{c}	42.2±0.11^{d}	26.2±0.33^{a}	2.21±0.19^{c}
Autoclaving	2.60±0.22^{d}	26.8±0.42^{c}	43.1±0.27^{c}	25.5±0.51^{b}	2.04±0.05^{c}
Soaking-Microwave	3.12±0.07^{bc}	27.5±0.12^{b}	42.5±0.32^{d}	24.5±0.43^{cd}	2.38±0.33^{c}
Soaking-Cooking	3.16±0.06^{bc}	26.6±0.32^{c}	42.4±0.33^{d}	25.3±0.71b	2.42±0.23^{c}
Soaking-Autoclaving	2.86±0.08^{cd}	26.8±0.18^{c}	42.6±0.38^{d}	25.3±0.13^{bc}	2.53±0.27^{c}

Mean values of each column followed by different superscript letter are significantly different ($p < 0.05$).

Table 2. Effect of the treatments on mineral composition of *Moringa oleifera* seeds

Treatment	Mineral (mg/100g dry weight basis)						
	Fe	Zn	Mn	Na	K	Ca	P
Raw	12.2±0.95^{b}	1.38±0.04^{b}	0.687±0.00^{b}	76.0±0.50^{e}	700±5.00^{a}	130±5.00^{b}	481±16.0^{b}
Soaking	6.89±0.04^{e}	1.17±0.02^{ef}	0.526±0.00^{f}	58.0±2.00^{d}	522±7.00^{e}	85.0±5.00^{def}	331±11.0^{f}
Dehulling	14.3±0.56^{a}	1.50±0.05^{a}	0.737±0.03^{a}	78.0±2.00^{f}	712±12.0^{a}	170±10.0^{a}	618±2.00^{a}
Soaking-Dehulling	7.11±0.17^{e}	1.22±0.01^{d}	0.561±0.01^{e}	58.0±2.00^{f}	637±7.00^{b}	90.0±0.00^{de}	472±12.0^{b}
Microwave	9.44±0.49^{c}	1.35±0.05^{b}	0.647±0.01^{c}	73.0±2.00^{d}	633±11.0^{b}	117±7.00^{g}	439±1.00^{c}
Cooking	6.61±0.24^{e}	1.16±0.01^{f}	0.379±0.01^{h}	53.0±2.00^{a}	370±8.00^{h}	57.0±2.00^{c}	245±5.00^{h}
Autoclaving	8.29±0.01^{d}	1.27±0.03^{c}	0.613±0.01^{d}	68.0±2.01^{b}	608±6.00^{c}	92.0±2.00^{d}	423±3.00^{d}
Soaking-Microwave	7.33±0.18^{e}	1.22±0.02^{de}	0.526±0.00^{f}	74.0±3.00^{cd}	542±7.00^{d}	87.0±2.00^{de}	415±3.00^{de}
Soaking-Cooking	5.28±0.57^{f}	1.17±0.01^{f}	0.431±0.00^{g}	63.0±2.00^{b}	415±5.00^{g}	77.0±2.00^{f}	267±7.00^{g}
Soaking-Autoclaving	7.37±0.09^{e}	1.19±0.02^{def}	0.555±0.02^{e}	68.0±2.00^{bc}	485±5.00^{f}	82.0±2.00^{ef}	402±4.00^{e}

Means values of each column followed by different superscript letter are significantly different ($p < 0.05$).

Table 3. Effect of the treatments on phytic acid, tannins and trypsin inhibitor in *Moringa oleifera* seeds

Treatment	Phytic acid		Tannins		Trypsin inhibitor	
	g/100 sample	Change	mg/g sample	Change	Ti, mg/g sample	Change
Raw	2.56±0.04^{c}	0.00	1.54±01^{a}	0.00	0.155±0.02^{a}	0.00
Soaking	2.44±0.02^{f}	4.7	1.13±0.15^{b}	26.6	0.13±0.00^{b}	15.5
Dehulling	2.85±0.01^{a}	11.3	0.65±0.02^{e}	57.8	0.16±0.01^{a}	7.1
Soaking + Dehulling	2.75±0.01^{b}	7.4	0.81±0.05^{d}	47.4	0.12±0.00^{b}	22.6
Microwave	2.49±0.01^{de}	2.7	0.98±0.09^{c}	36.4	0.04±0.01^{d}	71.6
Cooking	2.33±0.01^{g}	9.0	0.67±0.01^{e}	56.5	0.00±0.00^{e}	100
Autoclaving	2.31±0.01^{g}	9.8	1.00±0.03^{c}	35.1	0.00±0.00^{e}	100
Soaking + Microwave	2.54±0.05^{cd}	0.8	1.03±0.10^{bc}	33.1	0.06±0.01^{c}	58.7
Soaking + Cooking	2.48±0.03^{e}	3.1	0.67±0.01^{c}	56.5	0.00±0.00^{e}	100
Soaking + Autoclaving	2.51±0.02^{de}	1.9	0.92±0.08^{cd}	40.3	0.00±0.00^{e}	100

Mean values of each column followed by different superscript letter are significantly different ($p < 0.05$).

Table 4. Effect of the treatments on Haemagglutinin activity in *Moringa oleifera* seeds

Treatment	Heamagglutinin (lectin)					
	A		B		O	
	Level	Change	Level	Change	Level	Change
Raw	64	0.0	64	0.0	64	0.0
Soaking	64	0.0	64	0.0	64	0.0
Dehulling	512	700.0	512	700.0	512	700.0
Soaking-Dehulling	512	700.0	128	100.0	128	100.0
Microwave	64	0.0	32	50.0	64	0.0
Cooking	32	50.0	32	50.0	64	0.0
Autoclaving	0	100.0	0	100.0	0	100.0
Soaking-Microwave	8	87.5	8	87.5	32	50.0
Soaking-Cooking	4	93.8	0	100.0	4	93.8
Soaking-Autoclaving	0	100.0	0	100.0	0	100.0

Table 5. Effect of the treatments on *in vitro* protein digestibility (IVPD) in *Moringa oleifera* seeds

Treatment	*In vitro* protein digestibility	
	%	Change
Raw	80.66±0.36^{d}	0.00
Soaking	81.03±0.33^{d}	0.5
Dehulling	77.64±0.65^{f}	3.7
Soaking + Dehulling	78.92±0.85^{e}	2.2
Microwave	82.15±0.76^{c}	1.8
Cooking	86.40±0.27^{a}	7.1
Autoclaving	86.70±0.27^{a}	7.5
Soaking + Microwave	83.92±1.01^{b}	4.0
Soaking + Cooking	86.22±0.21^{a}	6.9
Soaking + Autoclaving	86.64±0.18^{a}	7.4

Mean values of each column followed by different superscript letter are significantly different ($p < 0.05$).

3.2. Minerals composition

Mineral content of raw and processed *Moringa oleifera* seeds is presented in Table 2. Significant differences ($p < 0.05$) in mineral content (Fe, Zn, Mn, Na, K, Ca and P) were observed among all the processing treatments. Like ash, protein, fat and carbohydrates; the minerals increased after dehulling indicating that minerals in moringa seeds are mainly located in the kernel. On the other hand, all other processing methods significantly decreased the mineral content. However, microwave only, autoclaving and the combination of these two methods with soaking resulted in the greatest retention of all minerals. These results are in agreement with those reported for chickpeas [19] and mung bean seeds [24]. Also, Salama and Ragab [29] reported that kidney beans, cooked by conventional and microwave methods, had different retention rates for minerals.

3.3 Phytic acid

Moringa seeds had higher levels of phytic acid (2.56%) (Table 3) when compared to other common seeds such as lentils, chickpeas, beans and lupin [9, 11, 30]. Dehulling either with or without soaking caused a significant ($p < 0.05$) increase in phytic acid (by 7.4 and 11.3%, respectively) indicating that phytic acid is concentrated in moringa seed kernels. Similar results had been reported for lentils [30] and bitter and sweet lupin seeds [9]. However, Mubarak [24] reported a significant decrease in phytate in dehulled mung beans. Soaking slightly decreased phytic acid (by 4.7%) in moringa seeds and this may be attributed to leaching during soaking. Also, soaking activated endogenous phytase and the extent of reduction depended on the type of legume seed [31]. While the present results agree with those reported by Mubarak [24] for soaked mung beans they are not as robust. In contrast, a significant increase of phytic acid was found in soaked lupin seeds [9] and soaked castellano chickpea [32].

All cooking methods significantly ($p < 0.05$) decreased phytic acid content, with autoclaving (by 9.8%) being more pronounced than cooking (by 9.0%). Moreover, the combined effect of soaking with all cooking methods was less pronounced than cooking alone for lowering phytate and this may be attributed to differences in the rate of leaching

between phytate and other components in moringa seeds during soaking. The reduction in phytic acid during heating may be attributed either to formation of insoluble complexes between phytate and other components or to hydrolysis of phytate to penta- and tetra-phosphate. In general, the data indicate that phytic acid in moringa seeds was heat-stable because of the low removal of phytate during cooking. Similarly, a significant decrease of phytate was reported in cooked cowpeas [33], cooked mung beans [24], cooked lentil [30] and cooked peanuts [10] but with reduction considerably greater than that observed with moringa seeds. Contrary to our results, other workers reported a significant increase of phytic acid in some cooked seeds [9, 32]. On the other hand, Wang et al. [11] reported that cooking had no effect on phytic acid in beans and chickpeas.

3.4. Tannins

We observed that moringa seeds had lower levels of tannins (1.54 mg/g) (Table 3) when compared to other common seeds such as chickpea seeds [28] and bitter and sweet lupin seeds [9]. All treatments significantly ($p < 0.05$) decreased the level of tannins and dehulling was the most effective (by 57.8%) indicating that tannins in moringa seeds occurred mainly in the hull. Similarly, Mubarak [24] reported a significant decrease in tannins in dehulled mung bean seeds. In contrast, Embaby [9] found a significant increase in tannins in dehulled bitter and sweet lupin seeds. Soaking significantly decreased the level of tannins (by 26.6%), which may be due to leaching of tannins during soaking. Similar results were reported for soaked mung beans [24]. Contrary to our results, Embaby [9] found a significant increase in tannins in soaked bitter and sweet lupin seeds. The combination of soaking and dehulling caused a higher reduction in tannins (47.4%) but still lower than dehulling alone (57.8%). All cooking methods (microwave, cooking and autoclaving) significantly ($p < 0.05$) decreased the levels of tannins. Also, no additional reduction in tannins content was observed with the combination of soaking and cooking methods. Cooking (either with or without soaking) was the most effective (by 56.5%) when compared with other cooking methods (but lower than dehulling). The decreased tannins in cooked moringa seeds may be due to degradation of the tannins or formation of complexes with other seed components at high temperatures. The present results agree with those reported by El-Adawy [28] for cooked chickpeas, by Embaby [9] for soaked and cooked lupin seeds and by Mubarak [24] for cooked mung beans.

3.5. Trypsin inhibitor activity (TIA)

Moringa seeds had a lower level of TIA (0.155 mg/g) (Table 3) when compared with other common seeds such as chickpeas, beans, lupin seeds and peanuts [9-11]. All treatments significantly ($p < 0.05$) decreased TIA except dehulling, which did not increase TIA significantly; indicating that trypsin inhibitor in moringa seeds is mainly located in the kernel. Embaby [9] reported similar results for dehulled bitter and sweet lupin seeds. However a significant decrease of TIA was found in dehulled mung beans [24] and dehulled lentils [30]. Significant decreases in TIA were noticed in soaked and soaked plus dehulled moringa seeds (15.5% and 22.6%, respectively) and this may be due to leaching during soaking. Similar results had been reported in soaked cowpeas and mung beans [24, 33]. On the other hand Embaby [9] reported a significant increase in TIA in soaked lupin seeds. Fortunately, considerable reduction in TIA was observed after all cooking methods; and cooking and autoclaving, either with or without soaking, completely removed TIA. Similarly, partial and complete removal of TIA was reported in cooked, autoclaved and microwave cooked seeds [9-11]. Thermal inactivation of trypsin inhibitor may be due to the hydrolysis of peptide bonds and destruction of disulfide bonds. These results indicate that trypsin inhibitor in moringa seeds is heat-labile and dehulling improved TIA.

3.6. Haemagglutinin activity

Lectin content was assayed by haemagglutination of red blood cells (a semi quantitative method), which is a safe method for determination the efficiency of treatments with respect to seed toxicity. A 2% suspension of human erythrocytes (A, B and O) was used to determine lectin activity in moringa seeds. Lectin activity of raw and processed moringa seeds are presented in Table 4. The results show that moringa seeds had high levels of lectin activity for all types of human erythrocytes (64 units for A, B and O types). Dehulling either with or without soaking caused significant increases for all types of

erythrocytes indicating that lectin in moringa seeds is mainly concentrated in the kernel. Also, soaking had no effect on lectin activity in moringa seeds. In contrast, Mubarak [24] reported a significant decrease in lectin activity in dehulled and soaked mung beans. On the other hand no detectable changes in lectin activity were found in dehulled and soaked lupin seeds [9]. All cooking methods considerably decreased lectin activity with autoclaving completely eliminating lectin activity. Moreover, the combined effect of soaking with the different cooking methods caused further decreases in lectin activity. Clearly, lectin activity in moringa seeds is sensitive to thermal processing. Again, many investigators reported partial and complete inactivation of lectin activity after cooking, microwave and autoclaving in some common seeds [9, 10, 19, 24]. The decrease of lectin during heat treatment could be attributed to protein denaturation, either breakdown of lectin into component subunits or changes in native structure.

3.7. Protein digestibility (IVPD)

Moringa seeds exhibited 80.66% IVPD (Table 5), which is close to that reported for some other common seeds [9, 19, 24]. Dehulling either with or without soaking caused a significant ($p < 0.05$) reduction of IVPD (by 2.2 and 3.7%, respectively). This reduction could be due to the effect of dehulling on the studied antinutritional compounds because dehulling improved trypsin inhibitor activity and increased the phytic acid contents (according to the present results), which impair the protease action on peptide bonds. Soaking had no effect on IVPD in moringa seeds. Contrary to our findings, dehulling and soaking improved IVPD in mung beans [24] and bitter lupin seeds [9]. On the other hand, soaking had no effect on IVPD in sweet lupin seeds [9]. Fortunately, all cooking methods improved IVPD in moringa seeds and autoclaving and cooking (with or without soaking) were the most effective. The improvement of IVPD in moringa seeds after cooking could be due to removal of antinutritional compounds, which can interact with proteins to form complexes. Also, heat treatment changes the structure of proteins, causing increases in chain flexibility and accessibility to proteases. Similarly, improvements in IVPD were reported in cooked, microwave cooked and autoclaved seeds such as chick peas [19], lupin [9] and peanuts [10].

4. Conclusion

Moringa seeds had high levels of protein, fiber, fat and minerals as well as certain antinutrients (phytic acid, tannins, trypsin inhibitor and lectin activity). Dehulling either with or without soaking increased the studied nutrients and antinutrients, except fiber and tannins. Thus fiber and tannins are mainly located in the hull of moringa seeds but other components are primarily located in the kernel. Soaking had different effects on nutrients; soaking slightly decreased antinutrients with the exception of lectin activity. Cooking methods either with or without soaking significantly decreased the nutrients except for fiber and carbohydrates. Considerable reductions in antinutrients were observed after all cooking methods, with autoclaving and cooking being the most effective. Also, TIA and lectin activity were completely abolished by autoclaving and cooking, indicating that they are heat-labile. Improvements of IVPD were observed after the different cooking methods, again, with autoclaving and cooking being most effective. However, dehulling decreased IVPD and soaking had no effect on IVPD. In summary, moringa seeds should be soaked and cooked before consumption to eliminate adverse factors (antinutrients) and improve the IVPD.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human / or animal subjects (if exist) respect the specific regulation and standards.

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