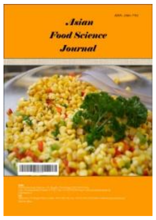

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Influence of Compounds Contents and Particle Size on Some Functional Properties of *Moringa oleifera* Leaves (Lam) Powders

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Authors' contributions

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

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ABSTRACT

Objective: This study aims to determine the influence of the contents of compounds and particle size on the functional properties of leaves powders of M. oleifera.
Methodology: The leaves were collected from three farms in the localities of Mbouda and Maroua and processed in powders. The proximate composition, some functional properties such as particle size, true Water Absorption Capacity (WACt), apparent Water Absorption Capacity (WACa), Water Solubility Index (WSI), Oil Holding Capacity (OHC), and Bulk density were determined.
Results: The mean contents of young and mature leaves powders are 24.96 ± 0.29 and 23.13 ± 0.50 g/100 DM in total proteins; 34.26 ± 0.52 and 29.11 ± 1.44 g/100g DM in available

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carbohydrate, 8.34 ± 0.64 and 8.34 ± 0.68 g/100g DM in total lipids, 8.75 ± 0.74 and 9.08 ± 0.48 g/100g DM in total ash, 21.13 ± 1.34 and 27.14 ± 1.04 g/100g DM in total fibers, respectively. The particle size of powders is majority large. The fiber's contents significantly affect the increase of rehydration properties and the OHC, while the large particle size, the density. Values of WACt and WACa are 27.02 ± 0.20 and 32.88 ± 1.24 % in young leaves and 28.98 ± 0.15 and 35.88 ± 1.02 % in mature leaves, respectively. The WSI and OHC are 3.02 ± 0.06 and 257 ± 1% in young leaves and 3.5 ± 0.04 and 261 ± 2 % in mature leaves, respectively. The Bulk density is 0.42 ± 0.01 g/ml in young leaves and 0.39 ± 0.01 in mature leaves.

Conclusion: Functional properties of M. oleifera leave powders do not always depend on the contents of compounds and particle size distribution.

Keywords: Moringa oleifera leaves powders; contents of the compounds; particle size; functional properties.

1. INTRODUCTION

The powders rich in starch have been since many decades studied about their functional properties following their different utilization methods [1,2,3]. Many authors have reported the influence of particle size, amino acid profile, protein, and fiber contents of those powders on their behavior in the formulations of several foods (sausage, cake, salads, biscuits, composite flours) [3,4]. However, other powders non-starch such as leafy vegetables contains also the high contents of those compounds whose functional properties are appreciated highly in the foods formulations. The Moringa oleifera is a tree native to Asia and widely cultivated in sub-Saharan Africa and all Cameroon regions [5]. The leaves of that shrub do not contain starch but are a good protein source and bioactive [5,6]. Their nutritional and medicinal potential have recently appeal to the attention of various researchers and industries worldwide [7,8]. Processed to the powders, that leafy vegetable is incorporated like the powders rich in starch, in the cakes, salads, biscuits, and composite flours for their high contents in proteins, fibers, and bioactive compounds to benefit their functional properties. Zhu et al. [9] report the total fiber role in the lower blood cholesterol and control blood glucose, and their ability like the proteins, to increase the rehydration properties of powders (Water Absorption Capacity, Water Solubility Index) and Oil Holding Capacity. Huang et al. [10] mention that the particle size of the powders significantly affects the hydrophilic and lipophilic properties of fibers and proteins, while Deli et al. [11] report that particle size affects the contents of compounds and rehydration properties of leafy vegetable powders. The particle size influences the packaging of powders and could affect their handling, transportation, and conservation. From the above, two main interrogations emerge: Does interest given to the functional properties of powders depend on the contents of these compounds only? What correlations exist between those compounds contents and the functional properties of powders before any interest? Few authors reported the answers to those questions before going deeply into their analysis. Particularly those working on M. oleifera leaves powders. Thus, to answers those questions, the present study aims to determine the influence of the contents of compounds and particle size on the functional properties of M. oleifera leaves powders.

2. MATERIALS AND METHODS

2.1 Sampling

Young (bright green colored leaves at the apex of the branch) and mature (dark green-colored leaves at the base of the branch) leaves of Moringa oleifera trees (3 to 4 years) were collected from three farms, well-kept (irrigate, weed) and without fertilizer application, in the localities of Mbouda (West Region, Cameroon) and Maroua (Far North Region, Cameroon) for the constant of farmers in the maintenance of farms.

2.2 Preparation of Powders

After harvesting, leaflets were detached from the leaf, washed with clean water and dried at 55°C in an electric dryer (Riviera & Bar QD105A, Paris, France) for 5 hours. The dried leaves were ground (Zaiba ZB-2225, China) and sieved through a 1mm mesh sieve to obtain a powder. The powders were then stored in airtight bottles at 4°C before analysis.

2.3 Proximate Composition Evaluation

The M. oleifera leaves powders were analyzed for moisture, protein, lipid, and ash contents using Helrich [12] methods. Available sugars were determined according to Fischer and Stein [13] following acid hydrolysis of samples. Total fibers were determined by the method described by Wolf [14] with little modifications. The method consists in treating 5 g of powder by boiling in sulphuric acid, and then in sodium hydroxide. The residue obtained is then dried, then burned and weighed.

2.4 Determination of Some Functional Properties

2.4.1 Particle size distribution evaluation

The particle size distribution of M. oleifera leaves powders was determined after sieving. A column of AFNOR brand sieve of decreasing size (40, 50, 100, 125, 200, 250, 400, 500, 710, 800, 1000 µm) up to the collector used to study the particle size distribution of the powders [15]. 44 g (M1) of sample is placed on top of the sieve stack and submitted to the vibration of 50 Hz for 15 min on a vibrator of the Merck type. The particles of dimensions smaller than the mesh of the sieve pass through (Mi) while those of larger dimensions are retained (Mj). Each of these fractions is weighed with a view to determining the particle size distribution (Rp). For each sample and depending on the sieve, it's expressed as follows:

$$R_p = (M_i/M_1) \times 100 \quad (1)$$

2.4.2 Water absorption capacity and water solubility index

The Water Absorption Capacity (WAC) and Water Solubility Index (WSI) were determined by the method described by Phillips [16] with some modifications. A mass of powder 1g (M0) mixed with 10 ml of distilled water. The whole is agitating for 30 min by a mechanical shaker (Prolabo n ° 54 433 France) at 220 rpm and centrifuged at 3500 rpm for 30 min in a centrifuge (DL 6000 brand, rotor 15 cm, Japan). The pellet collected, then weighed (M1), is heated in an oven at 105˚C for 24 hours, and the weight of the dry residue (M2) is determined. The true Water Absorption Capacity (WACt), apparent Water Absorption Capacity (WACa), and WSI were determined by the formulas:

$$\mathbf{WAC_t} = [(\mathbf{M_1} - \mathbf{M_2})/\mathbf{M_1}] \times 100 \quad (2)$$

$$\mathbf{WAC_a} = [(\mathbf{M_1} - \mathbf{M_0})/\mathbf{M_0}] \times 100 \quad (3)$$

$$\mathbf{WSI} = [(\mathbf{M_0} - \mathbf{M_1})/\mathbf{M_0}] \times 100 \quad (4)$$

2.4.3 Oil holding capacity

The Oil Holding Capacity (OHC) was determined by the method of Beuchat [17]. 0.5 g (M0) of powder is mixed with 3 ml of cotton seed oil. The whole is agitating for 30 min using a mechanical shaker (Prolabo n ° 54 433 France) at 220 rpm and centrifuged at 3500 rpm for 30 min in a centrifuge (DL 6000 brand, rotor 15 cm, Japan). The pellet collected, then weighed (M1) and the OHC is expressed as the mass of oil retained per 100g of powder by the formula.

$$OHC = [(M_1 - M_0)/M_0] \times 100 \quad (5)$$

2.4.4 Bulk density

The density was determined by the modified method of adbowale et al. [18]. A mass of powder 5 g is placed in a tarred capsule of known volume (V) to the level. During the measurement, the capsule is tamped several times to eliminate the empty space between particles. Once the capsule is full, the whole is weighed (M). The result was expressed in grams of sample per unit of volume (ml).

2.5 Statistical Analysis

Analyses were carried out in triplicates. Microsoft Excel 2013 software was used for calculation of means and standard deviations; Stat-graphic centurion 15.2 software (StatPoint Technologies, Inc, Warrenton, Virginia, USA) for the one way analysis of variance and means separated using the Duncan multiple range test at P = .05 and the correlation test. Sigma plot 11.0 software (Systat Software, Inc. 1735 Technology Drive, Suite 430 San Jose, CA 95110 USA) was used to plot the graphs.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition

3.1.1 Moisture contents

The moisture content of young and mature leaves powders obtained in that study ranged from 9.01 ± 0.20 to 13.5 ± 0.50 g/100g DM with the similar mean contents for the both maturities of 11.50 ± 0.50 g/100g DM (Table 1). These results are near those reported by

Abouel-Yazeed (8) (7.57 g/100g DM) and permit to keep the powder for many months well [19]. That last result can also explain by the absence of significant correlations between moisture content and rehydration properties of powder (Table 2).

3.1.2 Total protein contents

The proteins play a major role in many food formulations and their contents vary according to the used foods. They provide thus the specific functional properties to those formulated foods. In that effect, the total protein contents of M. oleifera leaves powders from Maroua and Mbouda, regularly used in the formulation of the foods, are displayed in Table 1. These contents range from 22.72 ± 0.81 to 25.89 ± 0.90 g/100gDM with mean contents in young and mature leaves powders of 24.96 ± 0.29 and 23.13 ± 0.50 g/100gDM respectively. These high protein contents are similar to those reported by Abouel-Yazeed [8] (23.14 g/100g DM) and lower than the range (31.69-36.83 g/100gDM) obtained by Castillo-lopez et al. [20]. We observe that those proteins' contents directly affect the functional properties of powders. Indeed, the negative significant correlations (Table 2) between total proteins with apparent Water Absorption Capacity (WACa) (r= -0.635; P= 0.026), true Water Absorption Capacity (WACt) (r= - 0.752; P= 0.005), Water Solubility Index (WSI) (r=- 0.750; P= 0.005), and Oil Holding Capacity (OHC) (r= - 0.681; P = 0.015) show that the increasing of proteins contents contribute to reduce the WACa, WACt, WSI, and OHC of the powders. The proteins are molecules that possess hydrophilic and lipophilic properties and this result indicates that many factors limit the effect of these properties. Amongst those factors, the presence of high antinutrients contents that chelate the proteins [6] and limit their solubility. The pH of the protein, linked directly to a different type of amino acid that constitutes the protein, which significantly affects its functional properties [21,22]. The secondary structure composition of the protein [22] also affect the rehydration properties and fat fixation of powders. High contents of proteins in M. oleifera leaves does not implies automatically the high rehydration and oil holding properties of powders.

3.1.3 Available carbohydrate contents

The available carbohydrate contents of leaves powders of M. oleifera are range from 28.27 ± 1.33 to 34.26 ± 0.52 g/100g DM. The mean contents in young and mature leaves are 34.26 ± 0.52 and 29.11 ± 1.44 g/100g DM respectively (Table 1). Those contents are high and similar to those reported (28.32 g/100g DM) by Sahay et al. [23]. Indeed, the high contents of carbohydrates in a powder favor the increase in his hygroscopic (ref) with direct consequences on his Water Capacity Absorption and Water solubility Index. In fact, the negative significant correlations (Table 2) between WACa (r = - 0.669; P= 0.017), WACt (r= - 0.900; P= 0.001), WSI (r= - 0.893; P= 0.001) show that high carbohydrates contents in that study, as previously with the protein contents (r= 0.681; P= 0.015), lower the rehydration properties of powders. This result can explain by the presence in the powders of sugar’s microcrystals that limits their WAC and WSI and also the OHC (r= - 0.671; P = 0.017). However, these results on available carbohydrate contents are a real advantage in the manufacture of energetic drinks from the powdered leaves of M. oleifera.

3.1.4 Total lipid contents

Powdered leaves of M. oleifera have the mean contents in total lipid for both maturities of 8.34 ± 0.68 g/100g DM. They do not present significant correlations (Table 2) with the functional properties of powders. However, the total lipid contents obtained in that study are similar to those reported (8.38 ± 0.63 g/100g DM) by Olusanya et al. [24] in the leaves of M. oleifera from South African. Those low lipid contents are an advantage in the formulation of composite powders for the manufacture of some products as biscuit, bread [25]. That reduces the eventual oxidation reactions of fat responsible for the rancidity of product processed.

3.1.5 Total ash contents

The leaf powders of M. oleifera are a major source of minerals [5]. Those are used to alleviate many mineral deficiencies (calcium, magnesium, iron, zinc) [26]. It’s why several consumers add them in the crudities, salads, and sauces to increase their nutritional density. The total ash contents of powders leaves of M. oleifera obtained in that study vary from 7.70 ± 0.50 to 10.46 ± 0.45 g/100 g DM. Their mean contents are 8.75 ± 0.74 and 9.08 ± 0.48 g/100g DM in young and mature leaves respectively and are slightly high to those reported (7.27± 0.25 g/100g DM) by Oladeji et al. [27]. These results confirm the richness of the powdered leaves of

M. oleifera in minerals. The previous works in the leaves of M. oleifera of Cameroon reported the high contents in calcium, potassium, iron, zinc, and manganese [5]. We observe no significant correlation between total ash and functional properties (Table 2). That indicates probably no major interactions between ions and the functional properties studied.

3.1.6 Total fibers contents

Dietary fiber is a term that describes the non-digestible carbohydrates from plants and is a key component of a healthy diet [28,29]. Their presence in the food does not only correlates to the health benefit but also affects significantly his behavior during the manufacture. In the M. oleifera leaves powders studied, the total fibers contents varied from 21.12 ± 0.98 to 27.58 ± 1.04 g/100g DM. Their mean contents are 21.13 ± 1.34 and 27.14 ± 1.04 g/100g DM respectively in young and mature leaves. The similar results (28.91 ± 0.13 g/100g DM) was obtained by Caicedo-Lopez et al. [30] in M. oleifera leaves powders of Mexico. We observe that (Table 2) the total fibers presents the positive significant correlations between OHC (r= 0.803; P=0.002); WACa (r= 0.764; P= 0.004); WACt (r= 0.942; P= 0.001); WSI (r=0.938; P= 0.001). About that result, the increase of the total fibers contents favor also the increase of functional properties. That can explain by the fact that the fibers possess hydrophilic and lipophilic properties which significantly improve the rehydration properties and OHC of the powders. Barchechath [31] reports the lipophilic and hydrophilic properties of fibers in his works and their importance in the food formulation and management of hyperglycemia. High contents of total fibers in M. oleifera leaves increase the functional properties (WAC, OHC, WSI) of powders and their utilization in several food domains (healthy diet, food powders, functional food, and supplement food).

3.2 Functional Properties

Previously was showed that only available carbohydrate, fibers, and total protein contents significantly affect the functional properties of leaves powders of M. oleifera. We observed that these compounds for each maturity were not presented a significant difference from one to another locality. For this purpose, the functional properties of powder leaves from one locality were studied. These properties do not depend on only compounds contents of powders, but also his particle size distributions.

3.2.1 Particles size distributions

The particle size of young and mature leaves powders of M. oleifera vary from 40 to 800 µm (Fig. 1). Three range 40-100; 100-400; 400-800 µm corresponding to the mono-modal particle size distributions each of whom the modes are 50, 250, 500 µm respectively, characterize these powders. However, only the particle size distribution of 100-400 µm characterized by the high percentages of particles with a maximum of 34.12 and 34.58% in young and mature leaves, respectively. That particle size distribution (100-400 µm) significantly affects the behavior of the powders. Indeed, these young and mature leaves of M. oleifera powders studied are the large particles (> 100 µm). They will tend to segregate and could to be a limiting factor of rehydration properties [11].

3.2.2 Water absorption capacity

Generally, the powders are added to the foods (sauces, porridges) to regulate their viscosity. However, their utilization for that purpose depends on their Water Absorption Capacity (WAC). Indeed, the WAC is the water quantity in gram absorbed by one hundred gram of powder after saturation and centrifugation. Fig. 2 displayed the WAC from young and mature leaves powders of M. oleifera studied. We observe that WACt (true Water Absorption Capacity) is significantly lower than WACa (apparent Water Absorption Capacity) for both maturities. Values are 27.02 ± 0.20 and 32.88 ± 1.24 % for the young leaves and 28.98 ± 0.15 and 35.88 ± 1.02 % for the mature leaves, respectively. These significant differences between WACa and WACt are due to the water losses during the dehydration at the drying time. However, we note that those significant losses are less in the mature leaves to young leaves contrary. That can explain by the higher contents compounds at hydrophilic properties total fibers precisely in the mature leaves (Table 1). Indeed, the leaves of M. oleifera are compound of cellulose, hemicellulose, and lignin [10] which are characterized by polysaccharide chains able to keep the water molecules through hydrogen bonds [9]. The significant positive correlations between fibers and WACt (r=0.942, P=0.001, Table 2) higher than WACa (r= 0.764, P=0.004, Table 2) show that hydrophilic properties of fibers keep some quantity of water after dehydration, which contributes significantly to improve their WAC. On the other hand, although the proteins are known to have hydrophilic properties, they do not participate, despite their high contents in leaves studied in the improvement of WAC. The negative significant correlations observed (Table 2) with WACa (r= -0.635, P= 0.026) and WACt (r= - 0.752, P= 0.005) confirm that result. The residues of amino acid which constitute the protein and the destruction of hydrogen bonds between them during the grinding can explain those protein's behavior.

3.2.3 Water solubility index

The Water Solubility Index (WSI) reflects the ability of a powder to dissolve in water. It’s an indispensable functional property in the study of the properties of powders on rehydration. Fig. 3 displayed the WSI from young and mature leaves powders of M. oleifera with values of 3.02 ± 0.06 and 3.5 ± 0.04 %, respectively. We note that the WSI increases significantly from young to mature leaves. That increase is probably due to the high contents of fibers in the mature leaves. Indeed, the high positive significant correlation (Table 2) between WSI and WACt (r=0.999, P=0.001), fiber (r=0.938, P= 0.001), and WACa (r= 0.874, P= 0.002) show that in the powders, fibers are one of the main compounds which facilitate the absorption of water and dissolution of powders. On the other hand, the significant negative correlation between WSI and protein (r= -0.750, P= 0.005) and available carbohydrate (r= -0.893, P= 0.001) show that both compounds contribute to limit the solubility of powders. This result shows that the contents of compounds of M. oleifera should be always considered before any utilization. Barchechath [31] reports that beyond the contents of the compounds some factor as pH, type of ions in solution, temperature and internal parameters such as particle distribution, influences significantly the rehydration properties of powders.

3.2.4 Oil holding capacity

Fig. 4 present the Oil Holding Capacity (OHC) from young and mature leaves powders of M. oleifera. The values vary from 257 ± 1 and 261 ± 2 %, respectively. We note a significant difference in OHC from young to mature leaves powders. The OHC is the oil quantity in gram retained by one hundred gram of food matrix. Barchechath [31] defines the OHC as the potential quantity of oil retained within a fiber matrix. Indeed, the fiber contents play a significant role, not only in the powders rehydration but also in the increase of OHC of powders studied. The high positive significant correlations between OHC and fibers (r= 0.803, P= 0.002), WACa (r= 0.900, P= 0.001), WACt (r= 0.811, P= 0.001), WSI (r= 0.818, P= 0.001) are in agreement with that result. As previously shown, the fibers constituted by the polysaccharide chains characterized by the lipophilic sites keeping the fat and increase the OHC of powders. Large particle size distribution is another factor that characterizes the powders studied. And can also contribute to increasing the OHC. Total protein (r= -0.681, P= 0.015) and available carbohydrate (r= - 0.671, P= 0.017) contribute rather to limit the OHC in that studied. The compounds of leaves powder of M. oleifera plays a key role in their functional properties. Increase the OHC favorise utilization of powders in the food formulations such as salad dressings, cake batters, sausages [32].

3.2.5 Bulk density

Bulk density is the mass of powder that can occupy a given volume. That physical functional property is important in the packaging, handling and transportation of powders. The density of young and mature leaves powders are presented in the Fig. 5. We observe that the density of young is higher than mature leaves with values of 0.42 ± 0.01 and 0.39 ± 0.01 g/ml. Those values are lower than this (0.66 ± 0.01 g/ml) reported by Deli et al. [11] on Hibiscus sabdariffa for the range of particles 180 to 315 µm. That difference is probably due to the determination method used. In the other hand, we note that only available carbohydrate present the positive significant correlation (Table 2) with bulk density (r= 0.764, P= 0.004) while fibers (r= - 0.743, P= 0.006) the negative significant correlation. This result show that contrary to the fibers, available carbohydrate more abundant in young leaves, could significantly contribute to increase the bulk density of powders studied. On the other hand, the negative significant correlations (Table 2) with WACa (r = - 0.749, P= 0.005), WACt (r= - 0.878, P= 0.002), WSI (r= -0.881, P= 0.002) show that only the physical properties of powders affects the density. Indeed, the particle size distribution seem to be one of main factor which influence the density of powders. The large particle size limit the cohesion and rehydration powders but exhibited the higher bulk density [9,11].

Table 1. Proximate composition of young and mature leaves of M. oleifera (g/100gDM)

Powders	Moisture content	Total proteins	Available carbohydrates	Total lipids	Total ash	Total fibers
YLM	9.01 ± 0.20^{a}	24.03 ± 0.48^{bc}	34.55 ± 0.82^{b}	8.16 ± 0.62^{a}	9.49 ± 0.55^{b}	21.12 ± 0.98^{a}
YLMb	13.5 ± 0.50^{d}	25.89 ± 0.90^{c}	33.97 ± 0.22^{b}	8.53 ± 0.65^{a}	8.02 ± 0.93^{a}	21.14 ± 1.71^{a}
Mean	11.25 ± 0.35	24.96 ± 0.29	34.26 ± 0.52	8.34 ± 0.64	8.75 ± 0.74	21.13 ± 1.34
MLM	10.50 ± 0.50^{b}	22.72 ± 0.81^{a}	29.95 ± 1.55^{a}	8.67 ± 0.96^{a}	7.70 ± 0.50^{a}	27.58 ± 1.04^{b}
MLMb	12.5 ± 0.50^{c}	23.55 ± 0.18^{ab}	28.27 ± 1.33^{a}	8.02 ± 0.40^{a}	10.46 ± 0.45^{b}	26.70 ± 1.04^{b}
Mean	11.50 ± 0.50	23.13 ± 0.50	29.11 ± 1.44	8.34 ± 0.68	9.08 ± 0.48	27.14 ± 1.04

Values are means ± standard deviation (n = 3). Means in the same column with different superscripts are significantly different from each other (P = .05). YLM/MLM = Young/Mature Leaves of Maroua; YLMb/MLMb = Young/Mature Leaves of Mbouda

Table 2. Pearson correlation between compounds of M. oleifera leaves powders and their functional properties

	Available carbohydrate	Density	Moisture content	OHC	Total ash	Total fibers	Total lipid	Total protein	WAC_a	WAC_t	WSI
Available carbohydrate	1										
Density	0.764 (0.004)	1									
Moisture content	-0.210 (0.510)	-0.044 (0.892)	1								
OHC	-0.671 (0.017)	-0.504 (0.094)	0.178 (0.578)	1							
Total ash	-0.392 (0.207)	-0.156 (0.627)	-0.033 (0.914)	0.204 (0.524)	1						
Total fibers	-0.842 (0.001)	-0.743 (0.006)	0.040 (0.901)	0.803 (0.002)	0.016 (0.958)	1					
Total lipid	0.215 (0.502)	-0.413 (0.181)	0.006 (0.985)	-0.278 (0.380)	-0.439 (0.152)	-0.124 (0.700)	1				
Total protein	0.681 (0.015)	0.574 (0.050)	0.339 (0.280)	-0.681 (0.015)	-0.340 (0.280)	-0.664 (0.018)	0.180 (0.575)	1			
WAC_a	-0.669 (0.017)	-0.749 (0.005)	0.167 (0.603)	0.900 (0.001)	0.213 (0.505)	0.764 (0.004)	0.100 (0.757)	-0.635 (0.026)	1		
WAC_t	-0.900 (0.001)	-0.878 (0.002)	0.095 (0.768)	0.811 (0.001)	0.192 (0.549)	0.942 (0.001)	0.013 (0.966)	-0.752 (0.005)	0.861 (0.003)	1	
WSI	-0.893 (0.001)	-0.881 (0.002)	0.099 (0.758)	0.818 (0.001)	0.195 (0.544)	0.938 (0.001)	0.024 (0.941)	-0.750 (0.005)	0.874 (0.002)	0.999(0.001)	1

Correlation coefficient (p-value) in bold are significant at P = .05; OHC = Oil Absorption Capacity; WAC_a = apparent Water Absorption Capacity; WAC_t = true Water Absorption Capacity; WSI = Water Solubility Index

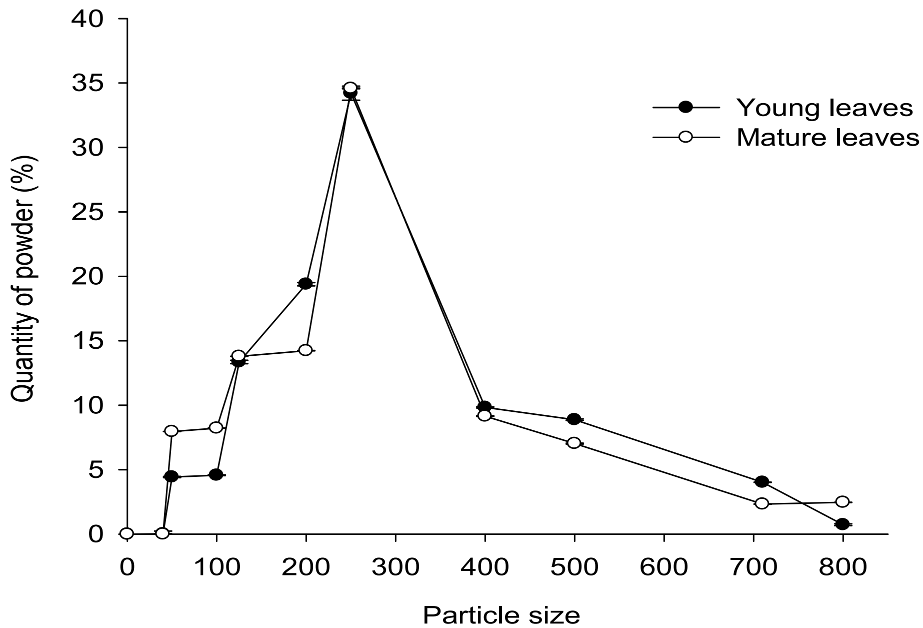

Fig. 1. Particle size distribution from young and mature leaves powders of *M. oleifera*

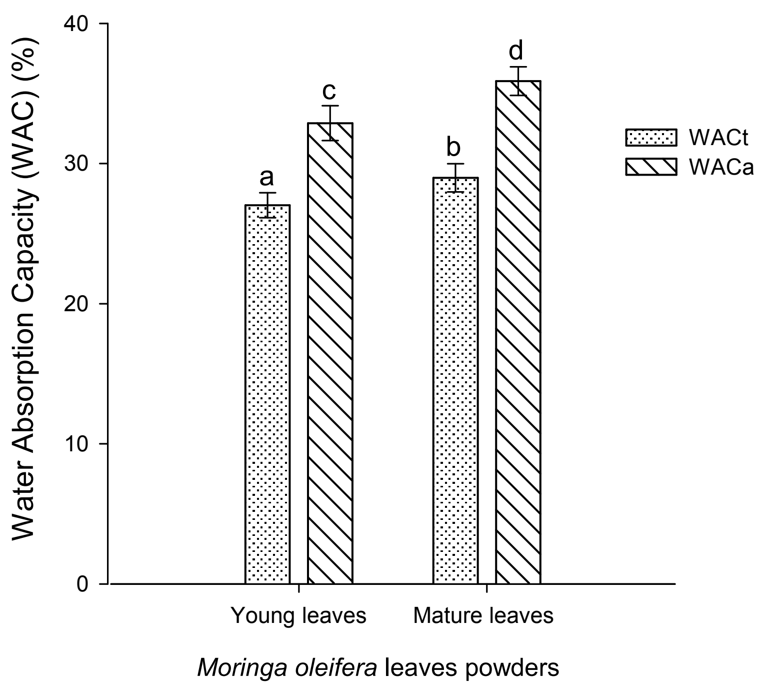

Fig. 2. Water absorption capacity (WAC) from young and mature leaves powders of *M. oleifera* (WACt = true Water Absorption Capacity, WACa = apparent Water Absorption Capacity)

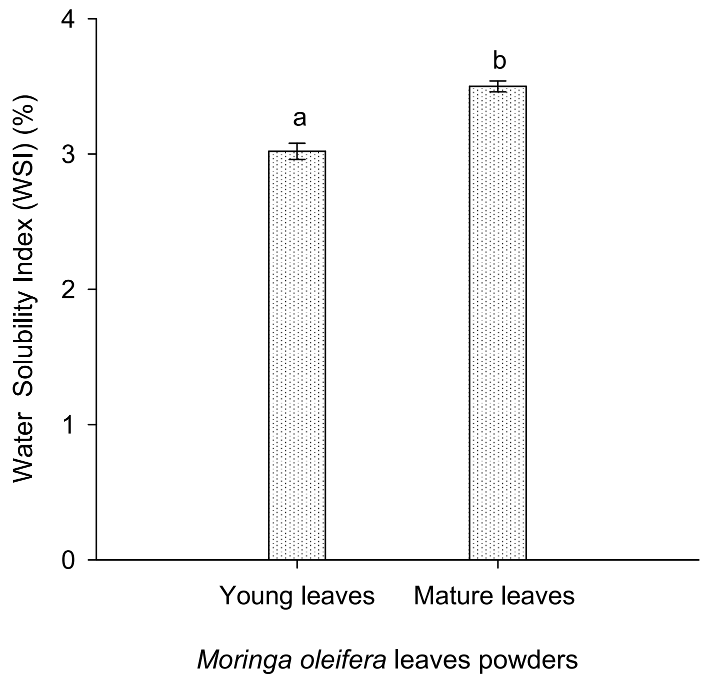

Fig. 3. Water solubility index from young and mature leaves powders of *M. oleifera*

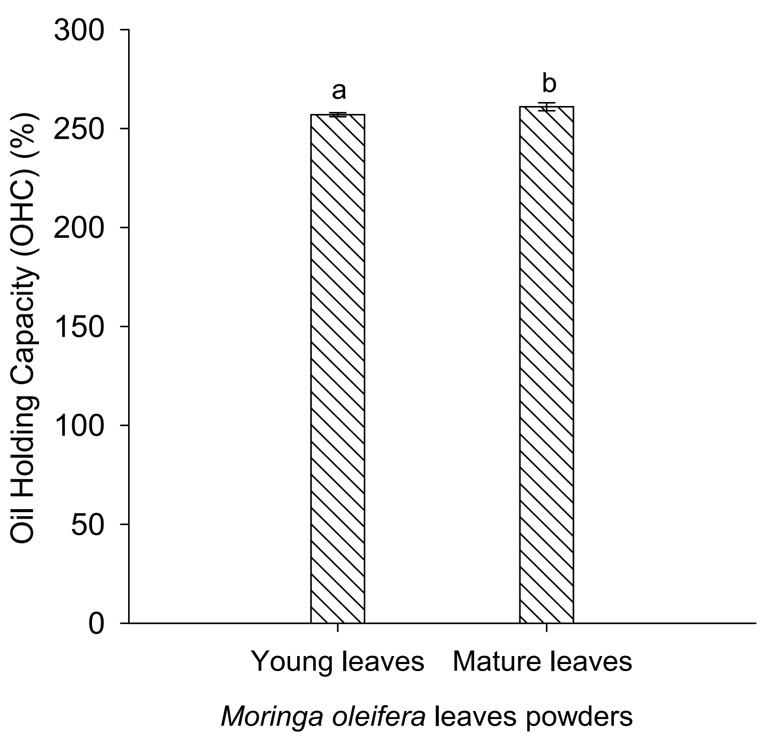

Fig. 4. Oil holding capacity from young and mature leaves powders of *M. oleifera*

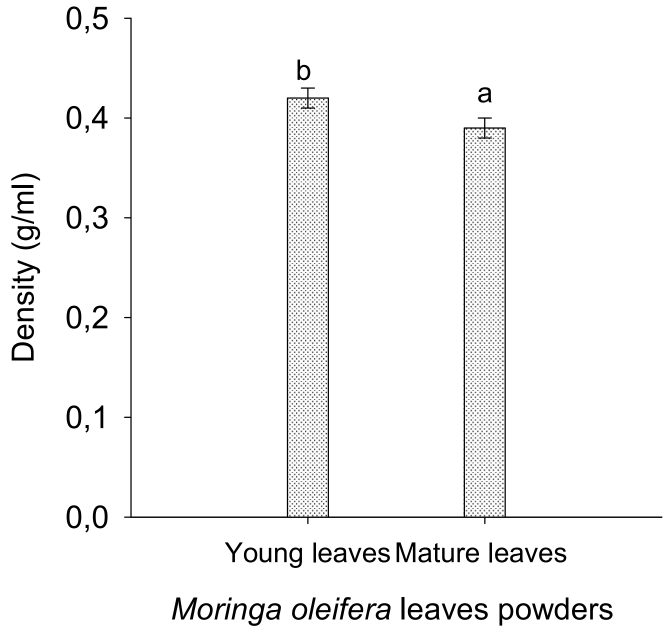

Fig. 5. Density from young and mature leaves powders of *M. oleifera*

4. CONCLUSION

The *Moringa oleifera* leaves powders studied have higher contents in total protein, available carbohydrate, and total fibers for both maturities. The particle size of those powders is large in the majority. Their rehydration properties and Oil holding capacity depend mainly on totals fiber contents, while the bulk density depends on particle size distribution. Protein contents limit the Water Capacity Absorption, Oil Holding Capacity of powders studied, while available carbohydrate contents positively affect the bulk density. The protein contents do not sufficient to conclude on their functional properties. Their amino acid profiles should be known. Functional properties of *M. oleifera* leave powders do not always depend on the contents of the compounds and particle size distribution. Used them to the benefit of those properties, it should be mainly consider their fiber contents and the more abundant particle size.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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