Quality Assurance and Safety of Crops & Foods, December 2013; 5 (4): 303-309

Wageningen Academic Publishers

Physicochemical properties of *Moringa peregrina* seed and its oil

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Received: 11 May 2012 / Accepted: 12 December 2012

RESEARCH PAPER

Abstract

Physico-chemical properties of Iranian *Moringa peregrina* seeds were studied at moisture content of 4.40% wet basis. Some oil quality properties of the seeds were also examined. Physical properties of the seeds and kernels in terms of linear dimensions, mass, volume, sphericity, surface area, true and bulk densities, porosity, repose angle, shell ratio, terminal velocity and static coefficient of friction on various surfaces were determined. The proximate analysis of seeds showed the following composition: 4.4% moisture, 2.7% ash, 55.7% fat, 23.4% protein and 14.8% carbohydrate. The results of mineral analysis demonstrated that *M. peregrina* seeds contained considerable amounts of macro and micro elements. Gas chromatography analysis indicated that oleic acid (77.9%) is the dominant fatty acid in seed oil followed by palmitic acid (9.3%), stearic acid (3.5%) and behenic acid (2.6%). Also, the seed oil had low levels of acids (0.06%), iodine (91.70 mg/g), peroxide (0.66 meq O_2/kg), conjugated dienes (K_{232}=1.77) and conjugated trienes (K_{270}=0.72). The stability, unsaponifiable matter and saponification value of oil were 10.1 h at 120 °C, 0.32 g/kg oil and 179.3 mg KOH/g, respectively. Moreover, the oil refractive index, viscosity and density were 1.4621, 52.05 mPa·s and 0.9092 g/cm^3, respectively.

Keywords: chemical composition, fatty acids, *Moringa peregrina*, physical properties

1. Introduction

Moringa peregrina is a small and fast-growing tree with greyish-green bark, long leaves, and bisexual yellowish white to pink, showy, fragrant flowers (Olson, 2002). Young seeds of *M. peregrina* are eaten in the way peas are eaten while mature seeds are fried or roasted like groundnuts. The kernel of *M. peregrina* seed is rich in oil (42-54%) with up to 23% protein. The bright yellow oil, with a pleasant taste, has been compared in quality with olive oil due to the high amounts of oleic acid (Afsharypuor *et al.*, 2010). High-oleic oils are gaining importance, especially for replacing polyunsaturated vegetable oils because of the good oxidative stability during frying (Anwar *et al.*, 2007).

M. peregrina seeds and their oil show pharmacological properties, recognised by popular use and corroborated by the scientific community. The seeds show antimicrobial activity against fungi and bacteria, antitumor, anti-inflammatory, antispasmodic, diuretic and larvicidal activity against the mosquito that transmits dengue and yellow fever (Donli and Dauda, 2003). This oil resembles olive oil in its fatty acid composition and is oleic acid-rich, which makes it suitable for edible purposes. The edible oil obtained from this seed kernel is used medicinally as diuretic, rubefacient and astringent. Moreover, other applications have been pointed out as preparation of cosmetics, mechanical lubricant, and lately for potential biodiesel fuel elaboration. The powdered seeds are also used as a primary coagulant in drinking water clarification and wastewater treatment due to the presence of a water-soluble cationic coagulant protein able to reduce turbidity of the water treated (Ghebremichael *et al.,* 2005).

The knowledge of the morphology and size distribution of *M. peregrina* seeds is essential for the accurate design of the equipment for cleaning, grading, separation and components extraction. Gravimetric properties are important in design of equipment related to aeration, drying, storage, transport and oil extraction. Bulk density determines the capacity of storage and transport systems, while true density is useful for separation equipment. Porosity of the mass of seeds determines the resistance to air flow during aeration and drying of seeds (Ahmadi *et al.,* 2012). The frictional properties such as the angle of repose and the coefficient of external friction are recognised by engineers as important properties concerned with rational design of seed bins and other storage structures including the compressibility and flow behaviour of materials (Jaliliantabar *et al.*, 2012; Shahbazi *et al.*, 2011). Aerodynamic properties such as terminal velocity are useful for air conveying or pneumatic separation of materials in such a way that when the air velocity is greater than the terminal velocity, it lifts the particles. The air velocity at which the seed remains in suspension is considered as terminal velocity (Gharibzahedi *et al.,* 2011b).

To our knowledge, detailed measurements of Iranian *M. peregrina* seeds' physical properties, chemical composition and the oil extracted have not been reported. Therefore, the objective of this study was to evaluate physical properties of seeds and kernels of *M. peregrina* and some physicochemical attributes of its oil.

2. Materials and methods

Material and sample preparation

The *M. peregrina* seeds were harvested from Sistan and Balouchestan province located in the south-east of Iran, during the summer of 2010. They were stored in the shell, closed in plastic bags and frozen to 20 °C until the time of physical and analytical tests. For each chemical analysis, the seeds were manually cracked, shelled and then chopped in a 643MX mill (Moulinex, Barcelona, Spain). Figure 1 shows the type of *M. peregrina* seeds and kernels used for all the experiments in this study.

Physical properties measurement

The moisture content of the seeds was determined by drying samples in a hot air oven set at 105±1 °C for 24 h and was found to be 4.4% wet basis (w.b.). The drying condition was set based on preliminary studies and in reference to ASAE standards S352.3 (ASAE, 1994). The samples were placed into polyethylene bags and sealed. The sealed samples were kept in a curing room for two days to enable the moisture to distribute uniformly throughout the grains. After the grains reached moisture equilibrium, each sample was placed in a desiccator. Before each test, the required quantity of samples was taken out of the desiccator and allowed to warm up to room temperature.

The dimensions of 200 randomly selected *M. peregrina* seeds and their kernels were determined with a digital vernier caliper (SV-03 model; TMD Tools, Kaohsiung City, Taiwan) with an accuracy of 0.01 mm. Simultaneously, the unit mass and thousand-seeds mass was measured

Figure 1. Iranian *Moringa peregrina* (A) seed and (B) its kernel.

using an electronic balance with an accuracy of 0.001 g. The arithmetic mean diameter (AMD), and geometric mean diameter (GMD), aspect ratio, shell ratio, sphericity, surface area, volume, bulk and true densities, and porosity of the samples were calculated using standard formulas (Gharibzahedi *et al.*, 2011b, 2012). Emptying angle of repose and terminal velocity was determined by the methods applied by Taheri-Garavand *et al.* (2012) and Ahmadi *et al.* (2012), respectively. The coefficient of static friction was determined on four structural materials, namely mild steel sheet, stainless steel sheet, glass and plywood, using an inclined plane apparatus.

Measurement of biochemical properties

The nitrogen content, fat and ash of the kernel were measured by usual standard methods recommended by AOAC (1990). The percentage of protein was calculated by multiplying total nitrogen by a factor of 6.25. Carbohydrate content was estimated by difference of the other components, using the following formula:

carbohydrate content = 100% – (%moisture + protein + %fat + %ash).

M. peregrina kernels were wet-digested in a mixture of nitric perchloride acids (HNO_3:$HClO_4$; 4:1). Potassium, calcium, magnesium, iron, manganese, zinc, copper and sodium concentrations in the digest were determined using an atomic absorption spectrophotometer (Model 2380; Perkin-Elmer®, Norwich, UK). The amounts of minerals were calculated with a standard curve. Phosphorus was determined by a spectrophotometer (Spectronic Genesys™ 10; GENEQ Inc., Montreal, Canada) at 430 nm. The results were compared to the standard curve.

Moringa peregrina seed oil extraction

The oil of *M. peregrina* seeds was extracted using a Soxhlet extractor (Munich, Germany) with n-hexane and analysed immediately. Before the start of the measurements the oil was refined, i.e. degummed. The degumming process of extracted oil was applied according to the method described by Tsaknis (1998) with minor modifications. Briefly, the oil was heated at 75 °C and 20% boiling water was added. The obtained emulsion was mixed for 10 min with the aid of a glass rod. After cooling, the oil was centrifuged for 12 min in 3,600 rpm in tubes of 200 cm in a Beckman Refrigerated Centrifuge J20 (Beckman Instruments, Fullerton, CA, USA).

Fatty acid analysis

In order to evaluate fatty acid composition of *M. peregrina* seed oil, a DB-23 fused-silica capillary column (30 m × 0.22 mm, 0.25 μm film thickness; Düren, Germany) was connected to a Varian 3400 gas chromatograph (GC) (Palo Alto, CA, USA) equipped with a flame ionisation detector and split/splitless injector. Helium was used as the carrier gas at a velocity of 23 cm/s, and as the make-up gas at a rate of 30 ml/min. A temperature programme of 158 °C for 5 min rising to 220 °C at a rate of 5 °C/min was used. The fatty acid methyl ester (FAME) dissolved in hexane was injected (1 μl) in a split mode of injection at a split ratio of 40:1. The injector and detector temperatures were 230 and 250 °C, respectively (Gharibzahedi *et al.*, 2011a,b). A Varian 4270 integrator was used for recording the peak areas. No response factors were applied in calculating fatty acid composition, since the GC temperature programme showed almost equal responses for different FAME standard mixtures.

Physicochemical analysis of the seed oil

Acid, saponification, iodine, K_{270} and K_{232} values and unsaponifiable matter of the *M. peregrina* oils were measured according to the standard AOCS methods (AOCS, 1998). Peroxide values were determined using the International Dairy Foundation method described in detail by Gharibzahedi *et al.* (2011a). The oxidative stability was determined by Rancimat analysis. Air flow rate was set at 20 l/h and temperature of the heating block was maintained at 120 °C (Martínez *et al.*, 2008). Colour value was determined using a Lovibond tintometer (Model F; Greenwich, UK). The oil viscosity was determined using a Brookfield digital viscometer (model DV-II+Pro; Brookfield Engineering Labs., Inc., Middleborough, MA, USA). The oil density was determined by a digital densitometer (DMA 46; AP-PAAR, Ostfildern, Germany) with an accuracy of 10^{-4} g/cm^3. The refractive index of oil samples was analysed according to the AOAC method (AOAC, 1990) with an Abbe refractometer (model G; Carl-Zeiss, Oberkochen, Germany). All chemical experiments were performed in triplicate and the results represented as a mean of the three values with the standard deviation.

3. Results and discussion

Physical properties

Table 1 shows the physical properties of *M. peregrina* seeds and their kernels at a constant moisture content of 4.40% (w.b.). The axial seed dimensions have an important role in determining aperture sizes determination used in design of seed handling machinery (Gharibzahedi *et al.*, 2011b). As considered in this table, the average major, intermediate and minor diameters for the seeds and kernels were 18.45 and 11.42 mm, 10.24 and 8.92 mm, and 7.21 and 5.12 mm, respectively. The sphericity is an expression of a solid shape relative to that of a sphere of the same volume while the aspect ratio relates the width to the length of the seed, which is an indicative of its tendency toward being oblong in shape (Ogunsina *et al.*, 2011). The values of these attributes were

Table 1. Physical properties of Iranian *Moringa peregrina* seed.

Physical properties	No. of observations	Mean (±SD)	
		Seed	Kernel
Major diameter (mm)	200	18.45±0.01	11.42±0.03
Intermediate diameter (mm)	200	10.24±0.03	8.92±0.03
Minor diameter (mm)	200	7.21±0.02	5.12±0.01
Aspect ratio	200	0.55±0.07	0.78±0.00
GMD (mm)	200	11.05±0.04	8.03±0.05
AMD (mm)	200	11.96±0.01	8.48±0.02
Sphericity (%)	200	59.85±0.12	70.31±0.08
Shell ratio	200	42.15±0.05	-
Volume (mm^3)	200	735.03±5.02	294.52±3.11
Surface area (mm^2)	200	383.40±0.78	202.47±1.12
Unit mass (g)	200	2.39±0.11	1.94±0.02
Thousand seed mass (g)	200	2,384.21±0.09	1,925.87±0.14
True density (kg/m^3)	10	1,121.21±2.10	1,245.31±0.65
Bulk density (kg/m^3)	10	598.31±4.01	625.45±0.29
Porosity (%)	10	46.63±0.79	49.77±0.08
Angle of repose (°)	10	29.11±0.24	31.42±0.11
Terminal velocity (m/s)	10	10.47±0.06	13.56±0.00
Static coefficient of friction			
Glass	10	0.366±0.01	0.325±0.06
Stainless steel	10	0.312±0.02	0.321±0.04
Plywood	10	0.375±0.05	0.412±0.01
Mild steel sheet	10	0.335±0.01	0.364±0.03

AMD = arithmetic mean diameter; GMD = geometric mean diameter.

higher in the kernels compared to the seeds. Aspect ratio and sphericity of the seeds and kernels were 0.55 and 0.78, and 59.85 and 70.31%, respectively (Table 1).

Regarding to the high aspect ratio and sphericity of *M. peregrina* kernels, it may be concluded that they would slide on their flat surfaces rather than roll. This tendency to either roll or slide is very important in the hoppers design, because most flat seeds slide easier than spherical seeds, which roll on structural surfaces (Ixtaina *et al.,* 2008). Ogunsina *et al.* (2011) found that the sphericity of kariya nuts and kernels seeds was 79.26 and 80.45%, respectively. Therefore, the sphericity of the *M. peregrina* seeds and kernels has less tendency to behave as a sphere than kariya nuts and their kernels. Patel *et al.* (2011) also reported the grain as spherical when the sphericity value was more than 0.80 and 0.70, respectively.

Information of the AMD, GMD, volume and surface area of the seeds is necessary in determining aperture sizes in the design of oil extraction and processing equipment from *M. peregrina* kernels (Gharibzahedi *et al.,* 2011a). The values for AMD, GMD, volume and surface area for seeds were 11.96 mm, 11.05 mm, 735.03 mm^3 and 383.40 mm^2, respectively, while the corresponding values for kernels were 8.48 mm, 8.03 mm, 294.52 mm^3 and 202.47 mm^2, respectively (Table 1).

Mean of the shell ratio for *M. peregrina* seed was 42.1. Unit mass and one-thousand seed mass are useful in determining the equivalent diameter, which can be used in the theoretical estimation of seed volume and in cleaning using aerodynamic forces (Gharibzahedi *et al.*, 2012a; Ixtaina *et al.,* 2008). These parameters for the seeds and kernels were 2.39 and 1.94 g, and 2,384.2 and 1,925.8 g, respectively. Thus, these values are much higher than the values reported by Ogunsina *et al.* (2011) for kariya nuts (0.47 and 485.6 g) and kernels seeds (0.35 and 396.2 g).

The density characteristics of the seeds are quite useful in computing product yield and output in processing machinery. The mean values of bulk density, true density and porosity of *M. peregrina* seeds was significantly more than of the kernels (Table 1). Optimum porosity values provide better aeration and water vapour diffusion during deep bed drying, and the data may be utilised for the design of aeration systems.

Angle of repose and terminal velocity of the seeds and kernels were determined to be 29.11 and 31.42°, and 10.47 and 13.56 m/s, respectively (Table 1). The values presented for angle of repose were smaller than for kariya nut (38.22°) and kernel (33.37°) (Ogunsina *et al.,* 2011). The higher value of terminal velocity of the seeds can be attributed to the higher mass of the individual seed per unit frontal area presented to the airflow (Darabi and Nejat Lorestani, 2012). The results obtained from the measurement of frictional properties showed that plywood had the highest static friction coefficient, followed by glass, mild steel sheet and stainless steel (Table 1). This may be due to the smoother surface of stainless steel compared to plywood (Ahmadi *et al.,* 2012). The data on frictional properties will be useful in hopper design for gravity flow since the angle of inclination of the hopper walls should be greater than the angle of repose to ensure continuous flow of the material. The coefficient of mobility, which represents the freedom of motion of a substance, is inversely related to the coefficient of friction (tangent of angle of internal friction). The higher the coefficient of friction, the lower the mobility coefficient, and hence the larger the hopper opening and hopper side wall slope and the steeper the angle of inclination is required in inclined grain transporting equipment. Optimum design will avoid immature flow (where some depth of granular particles remains stationary) and the arching phenomena to ensure a fully developed sliding flow (Gharibzahedi *et al.,* 2012).

Biochemical properties of *Moringa peregrina* seed

The biochemical composition and mineral content of *M. peregrina* seed kernels are illustrated in Table 2. Dry matter content, ash and nitrogen were 95.6, 2.7 and 3.74%, respectively. The values of total protein, crude fat and carbohydrate were found to be 23.4, 55.7 and 14.8%, respectively. The fat content of this seed is much higher than the fat content extracted from *Moringa concanensis* seed (38.82%). However, *M. concanensis* seed had a higher protein content (30.07%) compared to the obtained results presented in the current paper (Manzoor *et al.,* 2007).

The mean of mineral contents of the *M. peregrina* seed for potassium, calcium, iron, manganese, zinc, magnesium, phosphorus, sodium and copper is given in Table 2. Potassium (43.21 g/100 g) was the most abundant element in these seeds, followed by phosphorus (541.0 mg/100 g) and zinc (274.19 mg/100 g).

Table 2. Kernel chemical composition and mineral content of Iranian *Moringa peregrina* seed.

Proximate composition	Value[a] (±SD)
Dry matter (%)	95.6±0.56
Ash (% d.b.)	2.7±0.03
Fat (% d.b.)	55.7±1.01
Carbohydrate (% d.b.)	14.8±0.47
Crude protein (% d.b.)[b]	23.4±0.23
Potassium (g/100 g)	43.21±0.54
Calcium (mg/100 g)	92.13±0.54
Iron (mg/100 g)	14.15±0.02
Manganese (mg/100 g)	89.31±2.13
Zinc (mg/100 g)	274.19±1.01
Magnesium (mg/100 g)	232.65±3.26
Phosphorus (mg/100 g)	541.00±0.06
Sodium (mg/100 g)	24.12±0.48
Copper (mg/100 g)	52.30±0.87

[a] Each value is expressed as the mean of three replications.
[b] Calculated as: N × 6.25; N ≈3.744.
d.b. = dry basis.

Fatty acid profile

Due to the low free fatty acid content in the extracted oil from the seeds, there was no need for oil neutralisation. However, there was a need for degumming because the oil was cloudy and the gums reduce the temperature at which an oil produces smoke. The degumming process produced transparent pale yellow liquids at ambient temperature with a characteristic odour and palatability. The major fatty acids found in the oil are oleic (C18:1, 77.9%), palmitic (C16:0, 9.3%), stearic (C18:0, 3.5%) and behenic (C22:0, 2.6%) acid. The small amounts of linoleic (C18:2, 0.6%), linolenic (C18:3, 1.6%), arachidic (C20:0, 1.8%), and palmitoleic (C16:1, 2.5%) acid were also detected. Comparing physical and chemical properties of *M. peregrina* seed oil with those of other vegetable oils, it is similar to olive oil. The *M. peregrina* seed oil contains a low amount (2.2%) of polyunsaturated fatty acid methyl esters (C18:2 and C18:3), which is a significant difference compared to other oils such as canola, soybean and sunflower. Therefore, this oil could be useful for edible purposes and for some industrial applications like hydrogenation, shortening production and others.

Oil physicochemical properties

The present analysis showed that the physical characteristics of *M. peregrina* seed oil including the refractive index at 20 °C, Lovibond values for red and yellow colour, density and viscosity were 1.4621, 0.99, 24.2, 0.9092 g/cm³ and 52.05 mPa·s, respectively. The results found in this study

Table 3. Fatty acid profile and physicochemical properties of Iranian *Moringa peregrina* seed oil.

Fatty acids	Value[a] (±SD)
Palmitic (C16:0)	9.3±0.05
Palmitoleic (C16:1)	2.5±0.09
Stearic (C18:0)	3.5±0.12
Oleic (C18:1)	77.9±0.12
Linoleic (C18:2)	0.6±0.02
Linolenic (C18:3)	1.6±0.01
Arachidic acid (C20:0)	1.8±0.05
Behenic acid (C22:0)	2.6±0.07
∑Polyunsaturated fatty acid[b]	2.2±0.08
∑Unsaturated fatty acid[c]	82.6±1.21
∑Saturated fatty acid[d]	17.2±0.31
Saturated/Polyunsaturated fatty acid	7.81±0.03
Unsaturated/Saturated fatty acid	4.80±0.20
Oil physical properties	
Refractive index (at 20 °C)	1.4621±0.0004
Colour (yellow)	24.2±1.75
Colour (red)	0.99±0.04
Density (g/cm³)	0.9092±0.000
Viscosity (10^{-3}×Pa·s)	52.05±1.21
Oil chemical properties	
Acid value (% oleic acid)	0.06±0.0
Peroxide value (meq O_2/kg oil)	0.66±0.04
Iodine value (g I_2/100 g oil)	91.70±1.44
Saponification value (mg KOH/g oil)	179.3±0.27
Unsaponifiable matter (g/kg oil)	0.32±0.01
Oil stability (h)	10.1±0.7
K_{232} (conjugated dienes)	1.77±0.11
K_{270} (conjugated trienes)	0.72±0.09

[a] Each value is expressed as the mean of three replications.
[b] Polyunsaturated fatty acid = C18:2 + C18:3.
[c] Unsaturated fatty acid = C16:1 + C18:1 + C18:2 + C18:3.
[d] Saturated fatty acid = C16:0 + C8:0 + C20:0+ C22:0.

were similar to those reported by Al-Kahtani (1995) for *M. peregrina* grown in Saudi Arabia. The oil extracted from the studied seeds had a low acid value (0.06% oleic acid). The peroxide value of the oils from samples of *M. peregrine* seeds ranged from 0.62 to 0.70 meq O_2/kg. This parameter is very useful in quality determination of fats and oils because it indicates the oxidative stability of the fat or oil during storage. Processing of fat or oil from good quality oilseed kernels results in the fresh peroxide value to look like the oil. The unsaponifiable matter (0.32±0.01 g/kg oil) and saponification value (179.3±0.27 mg KOH/g) of oil were lower compared to olive oil. The low saponification value indicated that the oils have larger molecular weight than the common oils. This characteristic of the oil depends on its level of unsaturation which is a function of both the iodine number as well as the free fatty acid value. The iodine value, K_{232}, K_{270} and oil stability of the oil obtained were 91.70 mg/g, 1.77, 0.72 and 10.1 h, respectively. The high oil stability could be attributed to a higher natural antioxidants like tocopherols content and also lower polyunsaturated fatty acids compared to other vegetable oils (Gharibzahedi *et al.,* 2011a).

4. Conclusions

This study deals with physicochemical properties of Iranian *M. peregrina* seeds, enlarging the knowledge about this species and providing useful data for its industrial processing.

The values of sphericity, aspect ratio, true and bulk densities, porosity, angle of repose, terminal velocity and static coefficient of friction on stainless steel, plywood and mild steel sheet surfaces of kernels were higher than that of the seeds.

M. peregrina seeds are a rich source of many essential nutrients that appear to have a very positive effect on human health.

Analysis of the physicochemical properties of *M. peregrina* seed oil showed that the oil can be a rich source of oleic acid and has the potential to be used as a nutrient rich food oil.

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