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著者	Rahman Ismail M.M., Barua Suman, Nazimuddin M., Begum Zinnat A., Rahman Azizur M., Hasegawa Hiroshi
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PHYSICOCHEMICAL PROPERTIES OF *MORINGA OLEIFERA* LAM. SEED OIL OF THE INDIGENOUS-CULTIVAR OF BANGLADESH

ISMAIL M. M. RAHMAN [1, 2*], SUMAN BARUA[2], M. NAZIMUDDIN[2], ZINNAT A. BEGUM[2], M. AZIZUR RAHMAN[1], HIROSHI HASEGAWA[1]

[1]Graduate School of Natural Science and Technology, Kanazawa University, Kakuma, Kanazawa 920-1192, Japan
[2]Department of Chemistry, University of Chittagong, Chittagong-4331, Bangladesh

ABSTRACT

Moringa oleifera Lam. seed oil of the indigenous-cultivar of Bangladesh was extracted using n-hexane (H), light petroleum ether (b.p. 40–60C) (LPE) and chloroform/methanol (50:50, v/v) mixture (CM). The oil content ranged from 37.50% (H) to 40.20% (CM). The moisture, protein, ash and crude fiber contents of seed residues, and the density, refractive index, color, acidity, saponification value, iodine value, unsaponifiable matter content, oxidative state, sterols, tocopherols and fatty acid composition of the extracted oil were determined. The oil contained a high amount of oleic acid ($C_{18:1}$) of up to 74.41% and a high ratio of monounsaturated to saturated fatty acids with moderate oxidative stability. The results of the present study were compared with those reported in literature for different regional habitats, and species variants.

PRACTICAL APPLICATIONS

A high-oleic oil with a good potential for edible and industrial use can be produced from *Moringa oleifera* Lam. (*M. oleifera*) oilseeds of the indigenous-cultivar of Bangladesh. Thus, mature seeds of *M. oleifera* can be considered as an alternative source of vegetable oil in Bangladesh provided that it is cultivated on a large scale.

KEYWORDS
Moringa oleifera Lam.; seed oil; solvent extraction; properties; composition; stability

INTRODUCTION

Moringa oleifera Lam. (*M. oleifera*), a small deciduous tree, is the most widely naturalized species of *Moringaceae* family and is commonly known as the horseradish or drumstick tree (Morton 1991; Sengupta and Gupta 1970). It is native in Asia Minor, Africa, the Indian subcontinent (Bangladesh, India & Pakistan) (Somali *et al.* 1984), and is also distributed in the Philippines, Cambodia, Central America, North and South America, and the Caribbean Islands (Morton 1991). The tree ranges in height from 5 to 12 m and the fruits (pods) are around 50 cm long. When mature, the fruit of *M. oleifera* becomes brown and has 10–50 seeds inside. Fully mature dry seeds are round or triangular in shape and the kernel is surrounded by a light woody shell with three papery

*Corresponding author: Tel/Fax: +81-76-234-4792; Email: I.M.M.Rahman@gmail.com

wings (Abdulkarim *et al.* 2005; Vlahov *et al.* 2002). All parts of the *Moringa* tree–leaves, flowers, fruits, and roots are edible and have long been consumed as vegetables (Anwar and Bhanger 2003; Siddhuraju and Becker 2003). *Moringa* seed oil, also known as Ben oil, has been used in salads, for industrially as fine machine lubrication, and in the manufacture of perfume and hair care products (Tsaknis *et al.* 1999). In Africa and some parts of Asia, particularly India, the oil has been used for cooking purposes (Dahot and Memon 1985; Dietz *et al.* 1994).

In recent years, considering the gap between demand and production of vegetable oils in many developing countries (Dietz *et al.* 1994), research focusing on the use of unconventional oilseeds as a source of vegetable oils has become important. There are some reports on the composition and characteristics of *M. oleifera* seed oil varieties from different countries of origin e.g.: India (Lalas and Tsaknis 2002), Kenya (Tsaknis *et al.* 1999), Malawi (Tsaknis *et al.* 1998), Malaysia (Abdulkarim *et al.* 2005) and Pakistan (Anwar *et al.* 2005; Anwar and Bhanger 2003; Anwar and Rashid 2007; Anwar *et al.* 2006) considering its prospect as an alternative vegetable oil source.

Moringa oleifera Lam. is a widely-planted variety in Bangladesh, principally as a vegetable crop (Hossain 1998; Khair 2006; Millat-e-Mustafa *et al.* 1997) and the composition of the *M. oleifera* seed oil variety of Bangladesh has not yet been reported. In this study, a detailed characterization of the oil extracted from the Bangladesh-cultivar *M. Oleifera* seed is carried out to check its suitability as an indigenous resource of vegetable oil, and results are compared with those reported in the literature.

MATERIALS AND METHODS

Mature pods of *M. oleifera* were collected to obtain approximately 15 kg of seeds from a *drumstick* cultivation in Chittagong, Bangladesh. The seeds were removed from the pods, sorted, sun-dried and stored at ~20C until further use.

All chemicals used were of analytical or HPLC grade from Merck (Darmstadt, Germany) or Sigma-Aldrich (St. Louis, MO, USA). Standards of sterols, tocopherols and fatty methyl esters were obtained from Fluka Chemie (Buchs, Switzerland) and Sigma Chemical Co. (St. Louis, MO, USA).

Oil extraction from clean, dried, dehulled and crushed seeds of *Moringa oleifera* Lam. was carried out using a 5–liter Soxhlet extractor assembly by using each of the following solvents: *n*-hexane (H), light petroleum ether (b.p. 40–60C) (LPE) and chloroform/methanol (50:50, v/v) mixture (CM) (AOAC 1984). Solvent extracted oil variants were recovered with a rotary evaporator (Eyela N–1, Rikakikai Co., LTD, Tokyo, Japan) followed by oven drying (60C, 1 h) and flushing with a stream of nitrogen (99.9%) for residual solvent removal. Degumming of oils was carried out according to the method described by Anwar *et al.* (2005).

The moisture and protein content of seed residues, after the oil extraction, were determined using the methods described by Pearson *et al.* (1987), while determination of ash and crude fiber contents was done according to Pomeranz and Meloan (1994).

Standard methods were followed to measure different physical and chemical parameters such as density, refractive index, acidity, saponification value, iodine value, unsaponifiable matter (USM) (AOCS 1998) and viscosity (Findlay and Levitt 1973) of

the different solvent-extracted variants of *M. oleifera* seed oil. Colour was measured with a Lovibond tintometer (The Tintometer Ltd., Salisbury, England).

The oxidative state of the seed oil was determined by measuring peroxide value and specific extinctions at 232 and 270 nm. The method suggested by AOCS (1998) was adopted for the measurement of peroxide value and the specific extinctions were determined with a spectrophotometer (U–2001, Hitachi Instruments Inc., Tokyo, Japan) using the IUPAC (1987) method. Susceptibility to oxidation (Rancimat method) was determined using the method described by Tsaknis *et al.* (1998).

Tocopherol (α, γ and δ) analysis was performed using an HPLC system consisting of a L–6000 Merck-Hitachi high pressure pump connected to an L–4000 Merck-Hitachi UV detector (Hitachi Instruments Inc., Tokyo, Japan) set at 295 nm. Tocopherol contents were identified by comparing the retention times with those of pure standards as described by others (Anwar and Rashid 2007; Xu 2002). A D–2500 Chromato Integrator (Merck, Darmstadt, Germany) was used for data acquisition and processing.

The AOAC (1990) method was used for the determination of sterols using a Shimadzu GC 17A Gas Chromatograph with FID Detector (Shimadzu Corporation, Kyoto, Japan). Sterols were identified and quantified by comparing the retention times and peak areas of the unknown components with those of a known sterol standard mixture.

Fatty acid methyl esters, as converted from the corresponding fatty acids in the seed oil according to the IUPAC (1987) method, were analyzed by Philips Pye Unicam PU 4500 (Philips Electronics UK Ltd, Guildford, Surrey, UK) gas chromatography equipped with a flame ionization detector. The column (internal diameter 2 mm, length 1.5 m) (Philips Scientific, Cambridge, UK) was filled with 10% diethyl glycol succinate on a 100 to 200- (British standard sieve) mesh (Mallinckrodt Chemical Works, St. Louis, MO). Injection and detector temperatures were 230 and 250C, respectively. The column temperature was increased from 100 to 225C, with a temperature increase gradient of 4C min^{-1}. Nitrogen gas was used as the carrier gas at a flow rate of 11.3 mL min^{-1}. The chromatograms were recorded with Spectra Pycis 4290 integrator (Spectra Physics, Irvine, CA). The amount of each fatty acid was given as a percentage of the total fatty acid content.

MS Excel-2003 was used for tabulation and data processing. SPSS (version 13.0 for Windows) was used for the statistical processing of the data. Results, means and standard deviation (SD) of three simultaneous assays were carried out for all the analyses.

RESULTS AND DISCUSSION

The oil content of *Moringa oleifera* Lam. (Bangladesh) seeds, extracted with *n*-hexane (H), light petroleum ether (b.p. 40–60C) (LPE) and chloroform/methanol (50:50, v/v) mixture (CM), are listed in Table 1. The oil extraction with CM had a higher yield than those of H– and LPE–extraction. Lalas and Tsaknis (2002) reported similar observations, and it may be due to the increased ability of the polar solvent to overcome forces that bind lipids within the sample matrix (Lumley and Colwell 1991). Better yield performance has also been observed for different *Moringa* varieties, e.g. *M. peregrina* (49.8–54.3%) (Somali *et al.* 1984; Tsaknis 1998) and *M. stenopetala* (40.5–44.9%) (Lalas *et al.* 2003). Such variation in oil content across habitat and species might be

attributable to the variety of plant, environmental and geological conditions of the regions and the extraction methods used (Ibrahim *et al.* 1974). The solvent-extracted oil yield (35.6–40.2%) for *M. oleifera* seeds in the present analysis was found to exceed those of four conventional oilseed crops: cotton (15.0–24.0%), soybean (17.0–21.0%), safflower (25.0–40.0%), and mustard (24.0–40.0%) (Pritchard 1991).

Proximate analysis of *Moringa oleifera* Lam. oilseed residues reveals the protein, moisture, fiber, and ash contents (Table 1). The protein content is high enough to be used as a fertilizer and as a potential animal foodstuff (Manzoor *et al.* 2007). Oilseed residues of *M. oleifera* can also be used as water-purifying agents (Anwar *et al.* 2005; Bhuptawat *et al.* 2007).

Various physical and chemical characteristics of the solvent-extracted *Moringa oleifera* Lam. oils are presented in Table 2. The density and viscosity depends on the method of extraction and was found to be highest for the CM–extracted variant of *M. oleifera* oil. Solvents used for extraction may not have any significant impact on the following properties: refractive index (RI), color index, saponification value (SV) and iodine value (IV). Values of density, RI, SV, IV and USM content are comparable with those reported for other *Moringa* species (Lalas *et al.* 2003; Manzoor *et al.* 2007; Somali *et al.* 1984; Tsaknis 1998). Moderate FFA content for *M. oleifera* oil in the present analysis was indicative of the good resistance of this oil to hydrolysis. SV value was in the range of mustard seed (170–184) but lower than olive (184–196), pumpkin (185–198), corn (maize) (187–195) and cottonseed (189–198) oils (Rossell 1991). USM content is within the range of almond (0.40–1.00%), groundnut (0.20–0.80%), palm (kernel) (0.20–0.80%), soybean (0.50–1.60%), and safflower (0.30–1.50%) oils (Rossell 1991).

The oxidative state of the *Moringa oleifera* oils native to Bangladesh as compared with the values available in the literature are shown in Table 3. The peroxide value (PV) (meq kg^{-1} of oil) for *M. oleifera* ranged from 0.86 to 1.50 with different solvent-extraction was quite low compared to those reported for different *Moringa* varieties (Lalas *et al.* 2003; Manzoor *et al.* 2007; Somali *et al.* 1984). PV measures the content of hydroperoxides in the oil (McGinely 1991) and its low value indicates high resistance to oxidation. The specific extinctions at 232 and 270 nm, with the values of 1.85–2.28 and 0.44–0.92 respectively, reveal the oxidative deterioration and purity of the oils (Yoon *et al.* 1985). The induction period (IP) (Rancimat method, h at 120C), which was a characteristic of the oxidative stability of the oils and fats (Anwar *et al.* 2003), of the non-degummed (NDG) *M. oleifera* ranged from 40.4 to 54.1 h indicating moderate stability. After degumming (DG), the induction period (IP) of the oil decreased to 11.7–20.7 h which could be attributed to the degumming process. Some earlier reports also revealed a sizeable reduction in IP of the crude *M. oleifera* oils after degumming (Anwar *et al.* 2005; Anwar and Bhanger 2003; Anwar and Rashid 2007; Anwar *et al.* 2006; Lalas and Tsaknis 2002; Tsaknis *et al.* 1999; Tsaknis *et al.* 1998). High IP values of *M. oleifera* oil as exhibited in the present analysis compared with those of common vegetable oils (Anwar *et al.* 2003) indicate the presence of a high level of monoenoic fatty acids, particularly, $C_{18:1}$, which was less prone to oxidation than polyenoics (Manzoor *et al.* 2007). High oxidative stability of seed fats of different *Moringaceae* species was also reported in the literature (Lalas *et al.* 2003; Manzoor *et al.* 2007; Tsaknis 1998).

The tocopherol profile (α–, γ–, and δ–) of *Moringa oleifera* Lam. oil (non-degummed) is given in Table 4. The α–tocopherol content (121–153 mg kg^{-1}), which has

the greatest vitamin E potency (Rossell 1991), was appreciably higher than palm kernel (44.0 mg kg^{-1}) and coconut (17.0 mg kg^{-1}) oils and fell in the range of soybean (9.0–352 mg kg^{-1}), maize (23.0–573 mg kg^{-1}), groundnut (49.0–304 mg kg^{-1}) and palm (4.0–185 mg kg^{-1}) oils (Rossell 1991). The γ–tocopherol content (ranging 62.2–77.4 mg kg^{-1}) was also higher than those of coconut (14.0 mg kg^{-1}) and sunflower (34.0 mg kg^{-1}) oils (Rossell 1991). The δ–tocopherol content (ranging 57.1–62.3 mg kg^{-1}), was found to be higher than coconut (2.0 mg kg^{-1}), cottonseed (17.0 mg kg^{-1}), groundnut (3.0–22.0 mg kg^{-1}) and sunflower (7.0 mg kg^{-1}) oils (Rossell 1991). The α–, γ–, and δ– tocopherol contents in the present analysis of *M. oleifera* were higher than those reported for *M. concanensis* oil (72.1, 9.26, 33.9 mg kg^{-1}) (Manzoor *et al.* 2007) and *M. peregrina* oil (145, 58.0 and 66.0 mg kg^{-1}) (Tsaknis 1998). Such high tocopherol content would be expected to contribute good oxidative stability and protection to the *M. oleifera* oil during storage and processing.

The sterol composition of the *Moringa oleifera* oil for H–, LPE– and CM–extracted fractions is shown in Table 4. β–sitosterol appeared to be the most predominant sterol in all the fractions followed by the following sterols: campesterol, stigmasterol and Δ5–avenasterol. The sterol compositions of the most conventional edible oils are varied from that of the investigated *M. oleifera* oil (Rossell 1991). Variation in the phytosterol contents among the *Moringa* species of different regions and inter-cultivars have also been observed (Anwar and Rashid 2007).

Table 5 illustrates the fatty acid (FA) composition of the *Moringa oleifera* oil indigenous to Bangladesh. The oil was found to contain a high amount of oleic acid ($C_{18:1}$) up to 74.4% with the predominant presence of the following saturated fatty acids: palmitic ($C_{16:0}$), stearic ($C_{18:0}$), arachidic ($C_{20:0}$), and behenic ($C_{22:0}$) acids. High-oleic oils are of great importance because of their superior stability and high nutritional value (Manzoor *et al.* 2007). *Moringa oleifera* Lam. oil of the indigenous-cultivar of Bangladesh is a high-oleic oil and contains a high ratio of monounsaturated to saturated fatty acids. Content of the major fatty acid ($C_{18:1}$) was also higher than that of both *M. concanensis* (68.0%) (Manzoor *et al.* 2007) and *M. peregrina* oil (70.5%) (Tsaknis 1998).

CONCLUSIONS

Bangladesh, an agriculture-based nation blessed with vast productive plains, has to spend a huge amount of foreign currency every year to import vegetable oils. Characteristics and quality features of the Bangladesh-cultivar *Moringa oleifera* Lam. oilseeds are nearly identical with those reported in literature with some variations across habitats and species that are attributable to the variety of plant, environmental and geological conditions of the regions and the extraction method. Present analysis demonstrates the potential of the indigenous-cultivar *M. oleifera* oilseed for edible and industrial use provided it is cultivated on a large scale.

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TABLE 1
CONTENT OF MAJOR COMPONENTS (%) OF *MORINGA OLEIFERA* LAM. SEEDS OF BANGLADESH*

Solvent[a] →	H					LPE		CM			
Origin[b]→	BD[c]	IND	KEN	M'WI	PAK[d]	BD[c]	MAL	BD[c]	IND	KEN	M'WI
Oil	37.5±2.9	38.3	35.7	35.3	36.2	35.6±3.9	30.8	40.2±1.0	41.4	31.2	39.5
Moisture	7.10±1.28	–	–	–	6.82	6.80±0.91	7.90	7.40±2.12	–	–	–
Protein	31.8±3.2	–	–	–	19.6	33.6±3.9	38.3	25.5±4.2	–	–	–
Fiber	6.84±0.46	–	–	–	6.89	6.49±1.36	4.50	6.53±0.01	–	–	–
Ash	6.30±0.61	–	–	–	18.6	6.50±0.46	6.50	8.33±3.29	–	–	–

*'–', Not Reported
[a]Solvent used for extraction: H (*n*-hexane), LPE (Light Petroleum Ether, b.p. 40–60C), CM (chloroform/ methanol, 50:50).
[b]Country of origin: BD (Bangladesh), IND (India), KEN (Kenya), M'WI (Malawi), PAK (Pakistan), MAL (Malaysia).
[c]Values are means of triplicate determinations ± standard deviation.
[d]Average value of the seed oil data reported from Pakistan (Anwar *et al.* 2005; Anwar and Bhanger 2003; Anwar and Rashid 2007; Anwar *et al.* 2006).

TABLE 2
PHYSICAL AND CHEMICAL CHARACTERISTICS OF *MORINGA OLEIFERA* LAM. SEED OIL OF BANGLADESH*

Solvent[a] →	H					LPE		CM			
Origin[b]→	BD[c]	IND	KEN	M'WI	PAK[d]	BD[c]	MAL	BD[c]	IND	KEN	M'WI
Density (24C) (mg mL^{-1})	0.898±0.011	0.909	0.881	0.888	0.904	0.892±0.013	–	0.908±0.009	0.911	0.918	0.915
Refractive index (40C)	1.459±0.004	1.457	1.455	1.456	1.459	1.457±0.003	–	1.459±0.001	1.459	1.458	1.459
Color (Red Unit)	0.82±0.56	0.80	–	1.20	1.56	0.73±0.53	0.70	1.25±0.35	2.00	3.30	1.50
Color (Yellow Unit)	33.7±5.5	35.0	40.0	70.0	25.3	6.04±2.22	5.90	34.5±6.4	35.0	72.0	79.0
Viscosity (mPa.s)	56.5±6.3	45.1	57.0	62.0	–	59.5±3.5	–	69.5±1.0	56.1	66.0	71.0
Saponification value (mg of KOH g^{-1} oil)	180±2.1	188	178	184	182	178±10.2	164	184±4.0	186	176	187
Free Fatty Acid (FFA) (% as oleic acid)	0.73±0.16	1.12	0.85	0.82	0.50	1.14±0.92	2.48	0.74±0.34	1.39	0.91	0.98
Iodine value (g of I per 100 g oil)	68.9±1.7	65.6	66.8	65.7	68.7	66.9±1.8	65.4	67.3±2.4	65.5	66.7	65.6
Unsaponifiable matter (%)	0.77±0.05	–	–	–	0.81	0.82±0.11	0.74	0.75±0.06	–	–	–

*'–', Not Reported
[a]Solvent used for extraction: H (*n*-hexane), LPE (Light Petroleum Ether, b.p. 40–60C), CM (chloroform/ methanol, 50:50).
[b]Country of origin: BD (Bangladesh), IND (India), KEN (Kenya), M'WI (Malawi), PAK (Pakistan), MAL (Malaysia).
[c]Values are means of triplicate determinations ± standard deviation.
[d]Average value of the seed oil data reported from Pakistan (Anwar *et al.* 2005; Anwar and Bhanger 2003; Anwar and Rashid 2007; Anwar *et al.* 2006).

TABLE 3
DETERMINATION OF THE OXIDATIVE STATE OF *MORINGA OLEIFERA* LAM. SEED OIL OF BANGLADESH*

Solvent[a] →	H					LPE		CM			
Origin[b]→	BD[c]	IND	KEN	M'WI	PAK[d]	BD[c]	MAL	BD[c]	IND	KEN	M'WI
Peroxide value (meq of O_2 kg^{-1} oil)	1.50±0.24	1.83	1.80	0.23	1.19	0.87±0.10	–	0.86±0.08	1.48	0.94	0.15
Conjugated diene [$\varepsilon^{1\%}_{1cm}$ (λ232)]	2.28±0.75	3.00	3.15	1.44	1.88	2.10±0.92	–	1.85±0.08	2.65	1.17	1.19
Conjugated triene [$\varepsilon^{1\%}_{1cm}$ (λ270)]	0.92±0.18	–	1.13	0.16	0.77	0.54±0.06	–	0.44±0.04	–	0.89	0.12
Susceptibility to oxidation (Rancimat method, h at 120C)											
Non-degummed oil	40.4±2.8	31.7	36.8	83.2	9.94	43.3±4.5	–	54.1±3.5	32.5	46.2	123
Degummed oil	11.7±1.2	8.70	10.8	23.7	8.69	14.4±0.98	–	20.7±1.3	14.3	16.5	31.8

*'–', Not Reported
[a]Solvent used for extraction: H (*n*-hexane), LPE (Light Petroleum Ether, b.p. 40–60C), CM (chloroform/ methanol, 50:50).
[b]Country of origin: BD (Bangladesh), IND (India), KEN (Kenya), M'WI (Malawi), PAK (Pakistan), MAL (Malaysia).
[c]Values are means of triplicate determinations ± standard deviation.
[d]Average value of the seed oil data reported from Pakistan (Anwar *et al.* 2005; Anwar and Bhanger 2003; Anwar and Rashid 2007; Anwar *et al.* 2006).

TABLE 4
TOCOPHEROL AND STEROL COMPOSITIONS OF *MORINGA OLEIFERA* LAM. SEED OIL OF BANGLADESH*

Solvent[a] →	H					LPE		CM			
Origin[b]→	BD[c]	IND	KEN	M'WI	PAK[d]	BD[c]	MAL	BD[c]	IND	KEN	M'WI
Tochopherol composition (mg kg^{-1})											
α–tocopherol	127±6.6	15.4	98.8	131	120	121±6.5	–	154±6.2	2.42	105	167
γ–tocopherol	62.2±5.0	4.47	27.9	70.4	77.5	64.0±6.7	–	77.4±2.6	5.52	33.5	68.1
δ–tocopherol	62.3±2.3	15.5	71.2	54.0	60.2	57.7±4.0	–	58.2±1.8	12.7	77.6	54.4
Sterol composition (%)											
Cholesterol	0.13±0.01	0.10	0.13	0.09	ND	0.11±0.03	–	0.16±0.01	0.12	0.12	0.16
Brassicasterol	0.06±0.004	0.05	0.06	0.08	ND	0.07±0.01	–	0.14±0.01	0.05	0.06	0.14
24–Methylenecholesterol	1.12±0.33	0.08	0.88	0.96	1.22	1.11±0.33	–	1.20±0.41	0.09	0.98	0.91
Campesterol	16.7±1.2	15.3	15.1	23.8	16.3	18.3±4.8	–	20.2±4.48	14.6	14.1	23.3
Campestanol	0.39±0.13	0.33	0.35	0.40	0.41	0.38±0.04	–	0.35±0.03	0.33	0.35	0.35
Δ7–Campestanol	0.60±0.17	ND	ND	ND	0.58	0.50±0.04	–	0.40±0.03	ND	ND	ND
Stigmasterol	18.0±1.1	23.1	16.9	17.0	18.0	17.6±1.2	–	17.8±1.8	22.5	16.8	16.5
Ergostadienol	0.38±0.03	0.35	0.39	ND	ND	0.39±0.03	–	0.29±0.02	0.36	0.28	ND
Clerosterol	2.29±0.58	1.22	2.52	0.62	2.13	1.70±0.98	–	1.34±0.87	1.80	0.84	0.72
β–Sitosterol	47.4±2.1	43.7	50.1	47.1	47.7	47.9±1.9	–	46.2±1.3	44.1	50.0	47.1
Stigmastanol	0.86±0.24	0.64	0.86	0.77	0.85	0.88±0.12	–	1.00±0.13	0.74	0.80	0.91
Δ5–Avenasterol	9.79±0.97	11.6	8.84	2.94	9.97	7.49±0.45	–	6.10±0.70	10.4	11.4	1.15
Δ7–Avenasterol	1.04±0.18	ND	1.11	0.19	1.18	0.75±0.05	–	0.78±0.08	1.15	1.04	0.31
28–isoavenasterol	0.95±0.38	0.25	1.40	0.25	0.78	0.72±0.06	–	0.45±0.07	0.40	1.14	0.40
Δ7,14–stigmastanol	0.60±0.23	0.85	0.44	0.39	0.76	0.42±0.04	–	0.40±0.03	0.51	0.52	0.40

*'ND', Not Detected; '–', Not Reported
[a]Solvent used for extraction: H (*n*-hexane), LPE (Light Petroleum Ether, b.p. 40–60C), CM (chloroform/ methanol, 50:50).
[b]Country of origin: BD (Bangladesh), IND (India), KEN (Kenya), M'WI (Malawi), PAK (Pakistan), MAL (Malaysia).
[c]Values are means of triplicate determinations ± standard deviation.
[d]Average value of the seed oil data reported from Pakistan (Anwar *et al.* 2005; Anwar and Bhanger 2003; Anwar and Rashid 2007; Anwar *et al.* 2006).

TABLE 5
FATTY ACID COMPOSITION (%) OF *MORINGA OLEIFERA* LAM. SEED OIL OF BANGLADESH*

Solvent[a] →	H					LPE		CM			
Origin[b]→	BD[c]	IND	KEN	M'WI	PAK[d]	BD[c]	MAL	BD[c]	IND	KEN	M'WI
$C_{8:0}$	0.03±0.002	0.03	0.03	0.02	ND	0.03±0.007	ND	0.02±0.002	0.03	0.02	0.02
$C_{14:0}$	0.11±0.01	0.13	0.11	0.10	0.18	0.10±0.006	0.10	0.10±0.01	0.13	0.11	0.10
$C_{16:0}$	6.17±0.21	6.46	6.04	5.51	7.36	6.46±0.98	7.80	5.72±0.37	6.36	5.81	5.46
$C_{16:1}$	1.10±0.26	1.36	1.46	1.10	1.84	1.44±0.54	2.20	1.11±0.01	1.40	1.44	1.11
$C_{17:0}$	0.09±0.003	0.08	0.09	0.04	ND	0.07±0.04	ND	0.04±0.003	0.08	0.09	0.04
$C_{18:0}$	4.77±0.59	5.88	4.14	5.86	4.33	5.82±1.42	7.60	5.15±0.96	5.74	4.00	5.82
$C_{18:1}$	74.4±1.3	71.2	73.6	67.7	74.4	71.3±4.1	67.9	71.9±5.8	71.2	73.9	67.8
$C_{18:2}$	1.21±0.38	0.65	0.73	0.71	0.94	0.96±0.29	1.10	0.95±0.36	0.66	0.71	0.69
$C_{18:3}$	0.24±0.05	0.18	0.22	0.21	0.25	0.21±0.01	0.20	0.19±0.02	0.17	0.20	0.19
$C_{20:0}$	3.51±0.55	3.62	2.76	3.78	3.08	3.39±0.60	4.00	3.64±0.19	3.60	2.70	3.77
$C_{20:1}$	1.61±0.60	2.22	2.40	2.60	2.20	2.88±1.50	1.50	2.01±0.86	2.25	2.46	2.61
$C_{22:0}$	6.16±0.44	6.41	6.73	6.81	5.52	6.58±0.33	6.20	6.22±0.80	6.28	6.38	6.78
$C_{22:1}$	0.14±0.01	0.12	0.14	0.11	0.29	0.13±0.02	ND	0.11±0.008	0.12	0.14	0.11
$C_{26:0}$	1.08±0.08	1.18	1.08	0.98	ND	1.12±0.16	1.30	0.96±0.07	1.23	1.06	0.96

*'ND', Not Detected
[a]Solvent used for extraction: H (*n*-hexane), LPE (Light Petroleum Ether, b.p. 40–60C), CM (chloroform/ methanol, 50:50).
[b]Country of origin: BD (Bangladesh), IND (India), KEN (Kenya), M'WI (Malawi), PAK (Pakistan), MAL (Malaysia).
[c]Values are means of triplicate determinations ± standard deviation.
[d]Average value of the seed oil data reported from Pakistan (Anwar *et al.* 2005; Anwar and Bhanger 2003; Anwar and Rashid 2007; Anwar *et al.* 2006).