Bull. Chem. Soc. Ethiop. **2012**, 26(1), 55-64.
Printed in Ethiopia
DOI: http://dx.doi.org/10.4314/bcse.v26i1.6
ISSN 1011-3924

CHARACTERISTICS OF OILS AND NUTRIENT CONTENTS OF *NIGELLA SATIVA* LINN. AND *TRIGONELLA FOENUM-GRAECUM* SEEDS

M. Abbas Ali[1*], M. Abu Sayeed[2], M. Shahinur Alam[2], Mst. Sarmina Yeasmin[3], Astaq Mohal Khan[3] and Ida I. Muhamad[1]

[1]Department of Bioprocess Engineering, Faculty of Chemical Engineering, Universiti Teknologi Malaysia, UTM Skudai, 81310 Johor, Malaysia
[2]Department of Applied Chemistry and Chemical Engineering, Rajshahi University, Rajshahi-6205, Bangladesh
[3]BCSIR Laboratories, Rajshahi-6206, Bangladesh

(Received December 6, 2010; revised October 25, 2011)

ABSTRACT. The core objective of this research was to determine the oil characteristics and nutrient contents of *Nigella sativa* and *Trigonella foenum-graecum* seeds. Characteristics of seed oils revealed higher degree of unsaturation and as determined by gas liquid chromatography (GLC) reported herein the major unsaturated fatty acids were linoleic acid (52.6% in *N. sativa* and 42.5% in *T. foenum-graecum*), followed by oleic acid (23.5% in *N. sativa* and 20% in *T. foenum-graecum*), while the main saturated fatty acid was palmitic acid (16% in *N. sativa* and 10.5% in *T. foenum-graecum*). Triacylglycerols and neutral lipids were found to be most abounded components recorded to 78.4 and 93.2% for *N. sativa* and 84.8 and 93.2% for *T. foenum-graecum*, respectively. The seed oils, therefore, have potential for use as domestic and industrial oils. Compositional analysis revealed that both samples contained considerable amounts of protein (20% in *N. sativa* and 28% in *T. foenum-graecum*) and high amount of lipid (37%) in *N. sativa* seeds. The seeds are shown to be rich sources of potassium, calcium and sodium and other elements. Nutrient information reported herein illustrates the benefits to public health for consumers of these plant seeds.

KEY WORDS: Seed oil, Fatty acids, Nutrient contents, *Nigella sativa*, *Trigonella foenum graecum*

INTRODUCTION

Nigella sativa L. is an annual herbaceous plant belonging to the Ranunculaceae family [1]. It tastes slightly bitter and peppery with a crunchy texture. Seeds are angular, of generally small size (1-5 mg), dark grey or black color. *N. sativa* seeds are used for edible and medicinal purposes in many countries. They are used as a condiment in bread and other dishes [2, 3]. They are also used in the preparation of a traditional sweet dish, composed of black cumin paste, which is sweetened with honey or syrup, and in flavoring of foods, especially bakery products and cheese. *N. sativa* seed oil is considered as one among newer sources of edible oils, thanks to its important role in human nutrition and health [4]. On the other hand, *Trigonella foenum graecum* is an annual herb belonging to the legume family; it is widely grown in India, Egypt, and Middle Eastern countries. *T. foenum graecum* has historically been utilized mainly as whole seed; it is a potential protein source with high nutritive value [5]. The seeds of this ancient herb have been used as both a spice and an herbal remedy in the Middle East, India, and Egypt and slightly shorter time in Europe, China and other parts of the world [6].

Some research works on proximate and fatty acids composition of the seeds of *N. sativa* and *T. foenum-graecum* from different origins have been reported. Sultan *et al.* characterized the indigenous variety of black cumin (*Nigella sativa* L.) and its fixed and essential oils and concluded that black cumin holds nutraceutical potential against various physiological threats owing to its rich phytochemistry especially due to the presence of thymoquinone, tocopherols,

*Corresponding author. E-mail: md.abbas@cheme.utm.my

etc [7]. Salma *et al.* determined physicochemical properties of two Nigella seed varieties, having a Tunisian and Iranian origin and results suggested that Nigella seed oil could deserve further consideration and investigation as a potential new multi-purpose product for industrial, cosmetic and pharmaceutical uses [4]. Bahman *et al.* studied the chemical composition of the extracted fixed oil and volatile oil of *Nigella sativa* L. seeds grown in Iran by GC and GC/MS and identified eight fatty acids (99.5%) and thirty-two compounds (86.7%) in the fixed and volatile oils, respectively [8]. Nazar and Tinay determined the proximate composition and physicochemical properties of a protein concentrate prepared from fenugreek (*Trigonella Foenum graecum* L.) seed. Results showed that fenugreek protein concentrate had high oil absorption capacity, water absorption capacity and bulk density [9]. Abdel-Nabey and Damir investigated the changes in some nutrients of fenugreek seeds during water boiling and concluded water boiling of fenugreek seeds for various lengths of time lowers to some extent its nutrients through leaching out into the boiling water or the brew [10]. Hemavathy and Prabhakar estimated lipid composition of fenugreek seeds and identified at least five glycolipids and seven phospholipids [11].

Review suggests that comprehensive and systematic studies to create database on oil characteristics and nutrient contents of *Nigella sativa* and *Trigonella foenum-graecum* seeds are still limited. It has therefore, decided to make the necessary measurements to characterize seed oils of *N. sativa* and *T. foenum-graecum*, including acylglycerol class, lipid class and fatty acid composition and also nutrient contents of their seeds.

EXPERIMENTAL

Plant materials and chemicals

The seeds of *N. sativa* and *T. foenum-graecum* were purchased in April, 2007 from local market in Rajshahi city, Bangladesh. The seeds were dried in sunlight for four consecutive days and then in an electric oven at 40 ^{o}C until a constant weight was reached. The seeds were ground to a fine powder, packaged, and stored in a refrigerator at 4 ^{o}C prior to the analysis. Solvents were obtained from Merck (Darmstadt, Germany) and BDH (Poole, England). Silica gel (60-120 mesh) and Silica gel (HF_{254}) were products of Merck (Darmstadt, Germany). Esters of fatty acids and bovine serum albumin were from Sigma Chemical Co. (St. Louis, MO, USA). All other chemicals were of analytical grade unless otherwise specified and results were expressed on dry weight basis.

Analysis of N. sativa and T. foenum-graecum seed oils

The oil from the powdered seeds was extracted with light petroleum ether (40-60 ^{o}C) in a soxhlet apparatus for about 24 h and the solvent was removed by rotary vacuum evaporator (Buchi Labortechnik AG, Postfach, Switzerland). The percentage of oil content was computed.

Physical and chemical characteristics

Specific gravity of the oil was determined with the help of a specific gravity bottle. Refractive index (method 2.102) and iodine value (method 2.205, Hanus) were determined following the IUPAC methods [12]. Unsaponifiable matter (method Ca 6a-40), saponification value (method Cd 3-25), percentage of free fatty acids (method Cd 3a-63), peroxide value (method Cd 8-53), Reichert-Meissl value (method Cd 5-40) and acetyl value (method Cd 4-40) were determined by the AOCS methods [13].

Separation of acylglycerols

The oil was separated into mono-, di- and triacylglycerols by IUPAC method no 2.321 [12] using silica gel (60-120 mesh) column chromatography. For quantitative determination of acylglycerol classes, the sample was adsorbed on the top of the column; triacylglycerols were eluted with benzene, diacylglycerols with a mixture of diethyl ether and benzene (1:9, v/v), and monoacylglycerols with diethyl ether. Approximately 1.5-2 mL/min fractions were collected. Elution was monitored by thin layer chromatography (TLC). The percentage of diacylglycerols was calculated by subtracting the weight of free fatty acid (FFA) from the weight of diacylglycerols fraction.

Fractionation of lipids

A total of 598 mg lipid extracted from the seeds by the method of Bligh and Dyer [14], was fractionated into three major lipid groups: neutral lipid, glycolipid, and phospholipid by silica gel column chromatography [15]. Neutral lipids were eluted with chloroform, glycolipids with acetone and phospholipids with methanol. Approximately 0.5-1.0 mL fractions were collected per minute and elution was monitored by TLC. Solvents were evaporated in vacuum rotary evaporator and percentages of these fractions were determined by gravimetric method.

Fatty acid composition of oil

Fatty acid composition of seed oil was determined as their methyl esters prepared by boron-trifluoride methanol complex method [16]. A GCD PYE Unicam gas chromatograph (PYE Unicam Ltd., Cambridge, UK) equipped with a flame ionization detector was used to determine the fatty acid methyl esters. Nitrogen carrier gas was used at a flow rate of 30 mL/min. Fatty acids were separated on a 1.8 m × 2 mm i.d. glass column packed with 6% BDS (butanediol succinate polyesters) on solid support, Anakorm ABS (100/120) mesh. Analysis was carried out at isothermal column temperature 190 ^{o}C, injector and detector temperatures for all GLC analysis were 240 ^{o}C. The peaks were identified by comparison with standard fatty acid methyl esters.

Analysis of N. sativa and T. foenum-graecum seeds

Moisture, ash and crude fiber contents were determined by AOAC methods [17]. Lipid content was estimated by the method of Bligh and Dyer [14] using a solvent mixture of chloroform and methanol (2:1 v/v). The micro-Kjeldahl (Buchi Labortechnik AG, Switzerland) method [17] was employed to determine the total nitrogen and protein content was calculated from total nitrogen by using N × 6.25. Water soluble protein was determined by the method of Lowry *et al*. [18] using bovine serum albumin as the standard. Determination of starch content was based on analytical method outlined elsewhere [19]. Total sugar content was determined by colorimetric method [20] and total carbohydrate was calculated by the difference. The samples for mineral analysis were subjected to acid digestion and analyzed following the procedures described by AOAC [17]. Phosphorus was determined by vanadomolybdate method while other elements were estimated by using AAS (atomic absorption spectrometer, Pye Unicam model SP9, Cambridge, UK).

RESULTS AND DISCUSSION

The solvent extracts of *N. sativa* and *T. foenum-graecum* seeds yielded 32 and 6.4% oil, which are close to the values 28.5% [4] and 7% [9], respectively. Information on detailed characteristics of oil and nutritional composition of seeds from same species are too scanty for meaningful comparisons.

Physico-chemical characteristics

As shown in Table 1, specific gravities estimated with *N. sativa* (0.9071 at 25 ^{o}C) and *T. foenum-graecum* (0.9200 at 25 ^{o}C) seed oils were higher than the value 0.8840 at 30 ^{o}C for *Cucumis prophetarum* seed oil reported by Mariod *et al*. [21]. Refractive indices of the oils were found to be 1.4683 for *N. sativa* and 1.4742 for *T. foenum-graecum* at 30 ^{o}C, being higher than 1.4340 at 40 ^{o}C [21] for the *Cucumis sativus* seed oil. Refractive index of *N. sativa* is consistent with the reported values 1.4600-1.4700 at 40 ^{o}C for the same seed oil [4]. Iodine values estimated for *N. sativus* (115) and *T. foenum-graecum* (112) were consistent with the value 114 for *Cucumis sativus* seed oil [21]. Iodine value of *N. sativa* was lower than 119 reported by Salma *et al*. [4] for same seed oil of Tunisian variety. The iodine values obtained in this study indicate that the *N. sativus* and *T. foenum-graecum* seed oils contain high level of unsaturated bonds. Therefore, the samples in the present investigation have higher tendency to become rancid by oxidation. The comparatively low saponification value of *T. foenum-graecum* seed oil (177) as estimated indicates the presence of higher proportion of higher fatty acids than that contained in *N. sativus* seed oil (204). The investigated saponification value for *N. sativus* was lower than the values 211-218 mentioned by Salma *et al.* [4], but similar to 203 mentioned by Atta [1] for the same seed oil. The FFA content (12%) in *N. sativus* seed oil was similar to the value 11 cited in the literature [1], but much higher than 1.3 for *Cucumis sativus* [21] and 1.3 for *T. foenum-graecum* seed oils. Results regarding FFA contents indicate the suitability of the oil sample of *T. foenum-graecum* for probably edible purpose as it contained significantly lower percentage of FFA than that contained in the sample of *N. sativus*. The high acidity of oil may be related to the nature of *N. sativus* seed, akin to many oil-bearing seeds, such as olive, palm and rice bran, contain high acidity oils [22].

Table 1. Physical and chemical characteristics of *N. sativa* and *T. foenum-graecum* seed oils (n = 3).

Characteristics	*N. sativa*	*T. foenum-graecum*
Specific gravity at 25 °C	0.9071± 0.0041	0.9200 ± 0.0028
Refractive index at 28 °C	1.4683 ± 0.0030	1.4742 ± 0.0063
Iodine value (g of I_2/100 g of oil)	115 ± 0.8	112 ± 1.3
Saponification value (mg KOH/g)	204 ± 2	177 ± 2
Free fatty acids (%) as oleic	12 ± 0.1	1.3 ± 0.2
Unsaponifiable matter (g/100 g)	1.2 ± 0.7	3.2 ± 0.4
Peroxide value (mEq/kg of oil)	12.7 ± 0.1	13.7 ± 0.4
Reichert-Meissl value	0.97 ± 0.1	0.54 ± 0.1
Acetyl value	3.6 ± 0.2	2.4 ± 0.2

N. sativa seed oil contained 1.2% unsaponifiable matter which was similar to 1.1% in *Cucumis sativus* reported by Mariod *et al*. [21] and 1.0-1.8% in the same oil mentioned by Atta [1], this value being lower than 3.2% in *T. foenum-graecum* seed oils under present study. The lower percentage of unsaponifiable matters as obtained in the sample of *N. sativa* points to lower amounts of hydrocarbons, higher alcohols and sterols than that contained in *T. foenum-*

graecum. The peroxide value of *N. sativa* (12.7 mEq/kg) was within the range of 10.7-13.5 revealed by Atta [1], but much higher than 4.3-5.6 reported by Salma *et al*. [4] for the same oil. On the other hand, the sample of *T. foenum-graecum* exhibited peroxide value of 13.7 mEq/kg; being higher than the value 3.5 revealed by Mariod *et al*. [21] seed oil. The low Reichert-Meissl value as estimated for *T. foenum-graecum* (0.54) indicate the low content of lower volatile soluble fatty acids than that contained in *N. sativus* (0.97), and this value is also in agreement with the low saponification value as obtained in *T. foenum-graecum*. Acetyl values of *N. sativus* and *T. foenum-graecum* seed oils were found to have 3.6 and 2.4, respectively.

Acylglycerol and lipid composition

As shown in Table 2, mono-, di- and triacylglycerol contents were accounted to be 3.4, 5.3 and 78.4% for *N. sativus* and 2.9, 8.2 and 84.8% for *T. foenum-graecum* seed oils, respectively. The total recovery of acylglycerols in *T. foenum-graecum* was more than 95% (average) that indicated *T. foenum-graecum* seed oil contained lower amount of nonocylglycerol than that contained in *Mesua ferrea* [23] and *N. sativus* seed oils. Moreover, triacylglycerols content in *N. sativus* (78.4%) was found to be lower than *T. foenum-graecum* (84.8%) seed oil, but higher than the values 57.5-63.2% revealed by Atta [1] for the same seed oil. Neutral lipids account for 93.2% in both *N. sativus* and *T. foenum-graecum* of total lipids while only 3.2% in *N. sativus* and 3.4% in *T. foenum-graecum* glycolipids were detected. Phospholipids make up 2.1% in *N. sativus* and 2.3% in *T. foenum-graecum* of total lipids. Results indicated neutral lipids were found to be most abundant component of seed lipid recorded to over 93% of the total weight of the lipid. However, the amounts of glycolipids and phospholipids accounted from *N. sativus* and *T. foenum-graecum* seed oils were found to be lower than those for *Momordica charantia* seed oil; neutral lipids being higher [24].

Table 2. Acylglycerol and lipid composition of *N. sativa* and *T. foenum-graecum* seeds (weight %) (n = 3).

Parameter	Composition	*N. sativa*	*T. foenum-graecum*
Acylglycerol	Monoacylglycerols	3.4 ± 0.1	2.9 ± 0.2
	Diacylglycerols	5.3 ± 0.1	8.2 ± 0.2
	Triacylglycerols	78.4 ± 1	84.8 ± 0.7
Lipids	Neutral lipids	93.2 ± 1	93.2 ± 1
	Glycolipids	3.2 ± 0.1	3.4 ± 0.2
	Phospholipids	2.1 ± 0.7	2.3 ± 0.3

Fatty acid composition

The fatty acid patterns (Table 3) of *N. sativus* seed oil were qualitatively similar to those of other plants; the essential fatty acid linoleic (52.6%) being the major fatty acid followed by oleic acid (23.5%). Linolenic acid was detected in small amount in the sample. Also, it was noted that *N. sativus* oil contained mainly unsaturated fatty acids (78.4%), while saturated fatty acids detected were only 21.6%. Major saturated fatty acid was palmitic (16%). The most prominent feature of the fatty acid composition in *N. sativus* seed oil was the high amount of linoleic acid, being slightly higher than that reported by Atta [1] and Salma *et al*. [4] for the same oil. On the other hand, *T. foenum-graecum* seed oil contained higher amount of linoleic (42.5%) while linolenic acid, oleic acid and palmitic acid contents were found to be 18, 20 and 10.5%, respectively. Besides these fatty acids, the oil also contained small amounts of stearic acid (6.5%) and arachidic acid (2%). Moreover, the amount of linoleic acid detected in both plant seed oils, was comparable to many seed oils such as *Cucurbita maxima* (43-50.3%), *Cucurbita*

argyrosperma (35.6-45.3%) and *Cucurbita argyrosperma* (56%) reported by Applequist *et al.* [25]; it is likely to satisfy the essential fatty acid requirement for humans. The nutritional value of linoleic acid is due to its metabolism at tissue levels, which produce the long chain polyunsaturated fatty acids and prostaglandins [26]. Vegetable oils high in unsaturated fatty acids have been well documented to provide numerous health benefits [27]; therefore, incorporation of *N. sativus* and *T. foenum-graecum* seed oils into the diet would be salubrious. Palmitic acid, which was the highest in the saturated acid profile in the present investigation, may be the precursor for higher fatty acids. The percentages of the fatty acids evaluated in *N. sativus* and *T. foenum-graecum* seed oils were slightly different from the previously reported works mentioned above, that might be due to the genetic factors and environmental conditions during fruit development and maturity [28].

Table 3. Percentage composition of fatty acids of *N. sativa* and *T. foenum-graecum* seed oils (n = 3).

Seed Oils	Fatty acids	Composition (%)
N. sativa	Myristic acid ($C_{14:0}$)	1.7 ± 0.1
	Palmitic acid ($C_{16:0}$)	16 ± 0.2
	Stearic acid ($C_{18:0}$)	4 ± 0.3
	Oleic acid ($C_{18:1}$)	23.5 ± 0.5
	Linoleic acid ($C_{18:2}$)	52.6 ± 0.7
	Linoleinic acid ($C_{18:3}$)	2.3 ± 0.1
T. foenum-graecum	Palmitic acid ($C_{16:0}$)	10.5 ± 0.1
	Stearic acid ($C_{18:0}$)	6.5 ± 0.1
	Oleic acid ($C_{18:1}$)	20 ± 0.1
	Linoleic acid ($C_{18:2}$)	42.5 ± 1
	Linoleinic acid ($C_{18:3}$)	18 ± 0.2
	Arachidic acid ($C_{20:0}$)	2 ± 0.1
	Behenic acid ($C_{22:0}$)	0.5 ± 0.1

Nutritional composition

Nutritive composition of *N. sativus* and *T. foenum-graecum* seeds were determined and the results are shown in Table 4. It is found that moisture content (4.2%) of *N. sativus* was lower than the reported value of 7% for the same source [1] and also lower than 5.6% for *Cucumis sativus* seed [29] and 8.1% estimated herein for *T. foenum-graecum* seed. Knowledge of moisture content is important to determine a product that can be stored for a long time without the probability of being attacked by bacterial and fungal agents that could alter the quality through decomposition [30]. Total lipid contents (37% for *N. sativus* and 12% for *T. foenum-graecum*) as estimated, were higher than the reported value 31.8% for *N. sativus* [31] and 7.1% for *T. foenum-graecum* seeds [9]. The ash content of *N. sativus* (4%) was close to reported values of 3.7% [1] and 4.2% [7] for the same source. *T. foenum-graecum* seed contained 2.6% ash; being lower than the reported value 3.3% [9] for the same seed. Total protein content of *N. sativus* seed was found to be 20% in which 4.5% of it was water soluble, and this value for total protein was similar to 20.8% as quantified by Atta [1], but lower than 28.6% [29] for *Cucumis sativus* seeds. On the other hand, the total protein in *T. foenum-graecum* seed was 28% in which 10.7% of it was water soluble; this quantity for total protein was similar to 28.4% reported elsewhere for the same source [9]. The present results reveal that both seed samples are qualified as protein-rich to satisfy the protein needs of consuming population. Starch contents of *N. sativus* and *T. foenum-graecum* were determined to be 4.1 and 4.8%, being lower with respect to 23.3% for *Cucumis melo* var. inodorus and 19.0 % for *Cucumis melo* hybrid AF-522

seeds [32]. Crude fiber content in *N. sativus* (5.1%) was lower than 6.0% reported for the same seed sample [7]. *T. foenum-graecum* seed contained crude fiber 4.7% that was lower than the reported value 9.3% [9]. There is evidence that crude fiber has a number of beneficial effects related to its indigestibility in the small intestine [33]. Total sugar content was estimated as 1% and carbohydrate content as 30% from *N. sativus* seeds. Carbohydrate content in *N. sativus* is slightly lower than the value 33.7% reported by Atta [1], but higher than 19.8% for *Cucumis melo* var. inodorus seeds [32]. *T. foenum-graecum* seed contained total sugar 1.7% and carbohydrate 45 %. The carbohydrate content was slightly lower than the 47.4% reported by Nazar and Tinay [9].

Table 4. Nutrient contents of *N. sativa* and *T. foenum-graecum* seeds (n = 3).

Parameters (g/100 g dry weight basis)	*N. sativa*	*T. foenum-graecum*
Moisture	4.2 ± 0.3	8.1 ± 0.3
Lipid	37 ± 0.4	12 ± 0.3
Ash	4 ± 0.3	2.6 ± 0.2
Total protein	19.8 ± 0.3	28 ± 0.3
Water soluble protein	4.5 ± 0.3	10.7 ± 0.3
Starch	4.1 ± 0.3	4.8 ± 0.2
Crude fiber	5.1 ± 0.3	4.7 ± 0.2
Total sugar	1 ± 0.2	1.7 ± 0.2
Total carbohydrate	30	45

The most challenging aspect of providing trace elements in plant-based material is to obtain a sufficient concentration for the supplement to be ingested without consuming large quantities of plant tissue. With regard to minerals, *N. sativus* seeds, on which we report herein (Table 5), appeared to contain useful quantities of calcium (611 mg/100 g) and copper (3.8 mg/100 g); these amounts being higher compared to the corresponding values 570.0 and 2.6 mg/100 g reported in the literature [7]. *T. foenum-graecum* seed contained 226 mg/100 g calcium and 5.4 mg/100 g copper. Calcium content was lower than 234 mg/100 g, but copper content being higher than 0.94 mg/100 g in *T. foenum-graecum* reported elsewhere [34]. The calcium content makes the *N. sativus* seed flour attractive as a natural source of calcium supplementation for pregnant and lactating women, as well as for children and the elderly people.

Table 5. Mineral contents of *N. sativa* and *T. foenum-graecum* seeds (n = 3).

Parameters (mg/100 g dry weight basis)	*N. sativa*	*T. foenum-graecum*
Calcium	611 ± 3	226 ± 2.3
Copper	3.8 ± 0.4	5.4 ± 0.3
Iron	10.2 ± 0.3	11.6 ± 0.2
Zinc	6.4 ± 0.3	4.4 ± 0.3
Potassium	702 ± 2.3	1080 ± 3
Magnesium	85.2 ± 0.2	78.4 ± 0.2
Phosphorus	108 ± 2.2	200 ± 1.2
Sodium	280 ± 1	290 ± 2
Manganese	1.4 ± 0.2	1.6 ± 0.2

Iron contents in *N. sativus* (10.2 mg/100 g) and *T. foenum-graecum* (11.6 mg/100 g) seeds were close to the reported values 9.7 mg/100 g for *N. sativus* [7] and 10.2 mg/100 g for *T. foenum-graecum* [10]. Thus, *N. sativus* and *T. foenum-graecum* seeds could contribute

significant amounts of iron in the diet. Iron is an essential microelement for haemoglobin formation, normal functioning of the central nervous system and in the oxidation of carbohydrate, protein and fats [35]. The high iron content in seed makes it a good source of iron particularly for menstruating and lactating women. The use of the seeds in soup may be encouraged.

N. sativus contained 6.4 mg/100 g zinc that was similar to 6.2 mg/100 g reported by Sultan *et al*. [7] whereas zinc content in *T. foenum-graecum* (4.4 mg/100 g) was lower than the value 5.4 mg/100 g [34], but higher than 2.3 mg/100 g [10] reported elsewhere. Potassium content in *N. sativus* (702 mg/100 g) was lower than the literature value, 808 mg/100 g [7]. On the other hand, *T. foenum-graecum* seeds contained 1080 mg/100 g potassium; being higher than the value found in *Detarium microcarpum* seeds [36]. Potassium is the most abundant element in all the plant parts analyzed. Magnesium and phosphorus contents in *N. sativus* seeds were found to have 85.2 and 108 mg/100 g, respectively. The corresponding values in *T. foenum-graecum* seeds were 78.4 and 200 mg/100 g.

Magnesium and phosphorus contents in *N. sativus* were lower compared to the reported values 265.0 and 543.0 mg/100 g [7]. Magnesium content in *T. foenum-graecum* was lower compared to the previously reported value 188.0 mg/100 g [10]. Magnesium is an important element in connection with circulatory diseases and calcium metabolism in bone [37]. Phosphorus is related to calcium for bones, teeth and muscles growth and maintenance [38]. Sodium contents in *N. sativus* and *T. foenum-graecum* were found to be 280 and 290 mg/100 g respectively; these values are higher than 17.6 mg/100 g for *N. sativus* seeds reported by Sultan *et al.* [7], but lower than 438.6 mg/100 g for *Detarium microcarpum* seeds [36]. *N. sativus* and *T. foenum-graecum* seeds contained 1.4 and 1.6 mg/100 g manganese. The present value of manganese content in *N. sativus* was lower than 8.5 mg/100 g reported by Sultan *et al.* [7], but that in *T. foenum-graecum* being close or similar to 1.5 mg/100 g observed by Abdel-Nabey and Damir [10] and 1.6 mg/100 g observed by Kan *et al*. [34].

From the results, it becomes evident that *N. sativus* and *T. foenum-graecum* seeds could be considered as a good source of some important macro and micro elements. The mineral contents in *N. sativus* and *T. foenum-graecum* seeds have shown to a certain extent similar sequences in the order K > Ca > Na > P > Mg > Fe > Zn > Cu > Mn and K > Na > Ca > P > Mg > Fe > Cu > Zn > Mn, respectively. The contents were found to be different in some elements from what has been reported in the literatures as stated above. Such variation in nutrient contents may be related to the variations of cultivated regions, storage conditions and maturity stage. It may also be due to geographical and climatic differences where the sample seeds had been grown [1].

CONCLUSIONS

From the quality point of view, *N. sativus* and *T. foenum-graecum* seed oils are comparable to other oils and can be utilized in the paint, varnish and ink industries and also recommended for human consumption after properly refining. They constitute a good alternative source of essential fatty acids compared with common vegetable oils and could contribute to the overall dietary intake. On the other hand, in terms of both quantity and quality, these seeds are potentially attractive source of protein, lipid (only for *N. sativus*) and some common minerals that appear to have a very positive effect on human health. Nutrient information would be critical to the success of efforts to promote the wider use of indigenous plant foods as part of a broader program aimed at educating local populations with regard to the nutritional benefits of the many cultivated plant foods that exist in their environment.

REFERENCES

1. Atta, M.B. *Food Chem*. **2003**, 83, 63.
2. Aboutabl, E.A.; El-Azzouny, A.A.; Hammerschmidt, F.J. *Progress in Essential Oil Research* in *Aroma Volatiles of Nigella sativa L. Seeds*, Walter de Gruyter and Co.: New York; **1986**; pp 49-55.
3. Merfort, I.; Wray, V.; Barakat, H.H.; Hussein, S.A.M.; Nawwar, M.A.M.; Willuhn, G. *Phytochemistry* **1997**, 46, 359.
4. Salma, C.R.; Souhail, B.; Basma, H.; Christophe, B.; Claude, D.; Hamadi, A. *Food Chem*. **2007**, 101, 673.
5. Flammang, A.M.; Cifone, M.A.; Ereson, G.L.; Stankowskci, L.F. *J. Food Chem. Toxicol.* **2004**, 42, 205.
6. Peirce, A. *Practical Guide to Natural Medicines*, William Morrow and Company Inc.: New York; **1999**; pp 262-265.
7. Sultan, M.T.; Butt, M.S.; Anjum, F.M.; jamil, A.; Akhtar, S.; Nasir, M. *Pak. J. Bot*. **2009**, 41, 1321.
8. Bahman, N.; Faraz, M.; Katayoun, J.; Mohammad, A.R.A. *Z. Naturforsch* **2003**, 58, 629.
9. Nazar, A.E.N.; Tinay, A.H.E. *Food Chem*. **2007**, 103, 582.
10. Abdel-Nabey, A.A.; Damir, A.A. *Plant Food Hum. Nutri*. **1990**, 40, 267.
11. Hemavathy, J.; Prabhakar, J.V. *Food Chem*. **1989**, 31, 1.
12. International Union of Pure and Applied Chemistry (IUPAC) *Standard Methods for the Analysis of Oils, Fats and Derivatives*, 7th ed. (revised and enlarged), Blackwell Scientific Publications: London; **1987**; pp 34-145.
13. American Oil Chemists' Society (AOCS) *Official Methods and Recommended Practices of the American Oil Chemists' Society*, 4th ed., AOCS Press: Champaign; Illinois; **1990**.
14. Bligh, E.G.; Dyer, W.A. *Can. J. Biochem. Physiol*. **1959**, 37, 911.
15. Gofur, M.A.; Rahman, M.S.; Ahmed, G.M. *Bangladesh J. Sci. Ind. Res*. **1993**, 28, 100.
16. Morrison, W.R.; Smith, L.M. *J. Lipid Res*. **1964**, 5, 600.
17. Association of Official Analytical Chemists (AOAC) *Official Methods of Analysis*, 15th ed., Association of Official Analytical Chemists: Washington, DC; **1990**.
18. Lowry, O.H.; Rosebrough, N.J.; Fan, A.L.; Randal, R.J. *J. Biol. Chem*. **1951**, 193, 265.
19. Clegg, K.M. *J. Sci. Food Agric*. **1956**, 7, 40.
20. Dubois, M.; Gilles, K.; Hamilton, J.K.; Rebers, P.A.; Smith, F. *Nature* **1951**, 168, 167.
21. Mariod, A.A.; Ahmed, Y.A.; Matthaus, B.; Khaled, G.; Siddig, A.; Gabra, A.M.; Abdelwahab, S.I. *J. Am. Oil Chem. Soc*. **2009**, 86, 1181.
22. Patterson, A.B.W. *Handling and Storage of Oil Seeds, Oils, Fats and Meal*, Elsevier Applied Science: New York; **1989**; p 123.
23. Abu Sayeed, M.; Abbas Ali, M.; Sohel, F.I.; Khan, A.M.; Yeasmin, M.S. *Bull. Chem. Soc. Ethiop*. **2004**, 18, 157.
24. Abbas Ali, M.; Abu Sayeed, M.; Sultanur Reza, M.; Yeasmin, M.S., Khan, A.M. *Czech J. Food Sci.* **2008**, 26, 275.
25. Applequist, W.L.; Avula, B.; Schaneberg, B.T.; Wang, Y.H.; Khan, I.A. *J. Food Comp. Anal.* **2006**, 19, 606.
26. Sayanova, O.V.; Beaudoin, F.; Michaelson, L.V.; Shewry, P.R.; Napier, J.A. *FEBS Letter* **2003**, 542, 100.
27. David, G.S.; Fred, J.E.; Liping, W.; Jay-Lin, J.; Tong, W.; George, E.I. *J. Agric. Food Chem.* **2007**, 55, 4005.
28. Egan, H.; Kirk, R.S.; Sawyer, R. *Pearson's Chemical Analysis of Foods*, 8th ed., Vol. 11, Churchill Livingstone: Edinburgh; **1981**; pp 519-536.

29. Mercy, B.A.; Elie, F.; Clergé, T.; Martin, F.; Felicité, M.T. *Afr. J. Biotech*. **2005**, 4, 1329.
30. Aguilera-Morales, M.; Casas-Valdez, M.; Carrillo-Dominguez, S.; Gonzalez-Acosta, B.; Perez-Gil, F. *J. Food Compos. Anal*. **2005**, 18, 79.
31. Javed Akhtar, M.; Akhtar, N.; Jabbar, A. *Pak. J. Sci. Ind. Res.* **2000**, 43, 23.
32. Yanty, N.A.M.; Lai, O.M.; Osman, A.; Long, K.; Ghazali, H.M. *J. Food Lipid* **2008**, 15, 42.
33. Aremu, M.O.; Olonisakin, A.; Atolaye, B.O.; Ogbu, C.F. *Electron. J. Environ. Agric. Food Chem*. **2006**, 5, 1640.
34. Kan, Y.; Kan, A.; Ceyhan, T.; Sayar, E.; Kartal, M.; Altun, L.; Aslan, S.; Cevheroğlu, Ş. *Turkish J. Pharm. Sci*. **2005**, 2, 187.
35. Adeyeye, E.I.; Otokiti, M.K.O. *Disco Inno*. **1999**, 11, 75.
36. Umar, K.J.; Hassan, L.G.; Ado, Y. *Int. J. Pure. App. Sci*. **2007**, 1, 43.
37. Ishida, H.; Suzuno, H.; Sugiyama, N.; Innami, S.; Todokoro, T.; Maekawa, A. *Food Chem.* **2000**, 68, 359.
38. Turan, M.; Kordali, S.; Zengin, H.; Dursun, A.; Sezen, Y. *Acta Agric. Scand*. **2003**, 53, 129.