International Journal of Ecology and Environmental Sciences 43 (3): 251-261, 2017
ISSN: 2320-5199 (Online)

Nutritional Attributes and Bioprospects of Leaves, Fruits and Seeds of *Nyctanthes arbor-tristis* L.

IRANI BISWAS[1*], AMBARISH MUKHERJEE[2] AND SUBRATA LASKAR[3]

[1]*Department of Botany, M.U.C. Women's College, Burdwan 713104, West Bengal, India*
[2] *Department of Botany, University of Burdwan, Burdwan 713104, West Bengal, India*
[3] *Department of Chemistry, University of Burdwan, Burdwan 713104, West Bengal, India.*
Emails: [1] ibrrrm@gmail.com; [2] amukhrjee.bu@gmail.com; [3] slaskar01@yahoo.co.in
* Corresponding author;

ABSTRACT

Nutritional aspects of *Nyctanthes arbor-tristis* L., a well known ethno-medicinal plant of India were investigated with an objective to establish its capability of tackling issues of food security too. Analyses of nutritional composition using standard methods of food analysis and comparison with recommended dietary allowances (RDA) reveal that the plant leaf is a good source of protein, dietary fibre, ascorbic acid, essential minerals like K, Ca, P, Mg, Fe and absence of sodium proclaims its use as a diuretic. Oils obtained from leaf, fruit and seed revealed the presence of fatty acids like gamma-linolenic acid, nervonic acid, omega-3 and omega-6 fatty acids of which eicosapentaenoic acid and linoleic acid are potent antioxidants in association with ascorbic acid, phenols and tannins which are also present in appreciable amounts. Apart from nutritional benefits, the plant has the prospect of combating skin diseases like dermatitis, atopic eczema, hair fall etc, as source of natural antioxidants and essential fatty acids for maintaining skin health and formulation of cosmetic products whereas the seed oil may be used as bio-fuel for its significant oil content after proper transesterification and processing.

Key Words: Antioxidants; Fatty Acids; Food Security; Non-conventional Vegetable; Nutraceutical

INTRODUCTION

Nyctanthes arbor-tristis L. is an indigenous medicinal plant being well reputed in Unani, Siddha and Ayurvedic systems of medicine (Girach et al. 1994). The plant is a native of India, belonging to the family Oleaceae and is used in the treatment of many common diseases. The leaves of the plant are extensively used by tribals throughout India for treatment of cough, cold, fever, influenza and dysentery (Pal and Jain 1998). Leaf decoctions are used as an effective worm repellant (Sharma et al. 2001) and as laxative, diaphoretic and diuretic (Kirtikar and Basu 2000) and in the treatment of eczema (Bhatt et al. 2001). It is also traditionally used in various skin diseases, as hair tonic (Priya and Ganjewala 2007) for the treatment of high blood pressure and diabetes (Sandhar et al. 2011). The powdered seeds are useful in preventing baldness, graying of hairs and scurfy affections of scalp and skin diseases (Warrier et al. 1995). The different parts of the plant, especially leaves also possess diverse pharma-cological and biological activities like anti-inflammatory (Saxena et al. 1984), antimalarial (Badam et al. 1988), analgesic, antipyretic, ulcerogenic (Saxena et al. 1987), amoebicidal (Chitra-vanshi et al. 1992), anti-allergic (Gupta et al. 1993), anthelmintic (Das et al. 2010), anti-diabetic (Rathore et al. 2008), hepatoprotective (Hukkeri et al. 2006), anti-oxidant (Akki et al. 2009), immuno-stimulatory (Puri et al. 1994) and antidiabetic (Suresh et al. 2010) activities.

Although there have been reports of compositional, evaluation and nutritional properties of various types of medicinally useful wild edible plants in the developing countries (Lockeett et al. 2000, Akubugwo et al. 2007, Ismail et al. 2008, Aberoumand 2011), *Nyctanthes arbor-tristis* L., an Indian plant of ethnomedicinal reputation has remained unattended in this regard.

Pertinent literature is very meagre regarding its edible use. Its leaves are often eaten as a fry with peaflour (personal observation) and as vegetable (Kar and Borthakur 2008) in dal or curries (Watt 1891, Patiri and Borah 2007) and the fried flowers form a palatable preparation of Assamese cuisine being served hot with plain hot rice (www.downtoearth.org.in/content/flower-delicacies-northeast, Patiri and Borah 2007). The considerable use of leaves of *Nyctanthes arbor-tristis* along with other leafy vegetables by the local people in their diet motivated the present author to carry out the present work on proximate and nutrient analysis so as to find its suitability as a nutraceutical and to gain entry in human nutrition. To the best of the authors' knowledge, there are no published studies on the nutritional composition of the leaves of *Nyctanthes arbor-tristis*. Since the fruits and seeds are non-edible, analyses of oil extracted from them along with leaves have been taken up along with estimation of important metabolites like phenols and tannins which are found to be present in moderate amounts. By virtue of the presence of such important compounds the plant have bioprospects in combating various diseases like dermatitis, atopic eczema, cardiovascular diseases, inflammations, neuro-muscular diseases etc, act as good source natural antioxidants in maintaining skin health and formulation of cosmetic products and significant oil content in fruit and seed might well be used as a blend with bio-fuel after proper transesterification and processing of the oil.

MATERIALS AND METHODS

Collection of Plant Material and Treatment

Fresh young tender leaves, mature fully expanded undamaged leaves and green mature fruits of *N. arbor-tristis* were plucked randomly from five selected adult trees (about 8-10m tall) growing in and around localities of Burdwan town (23°14' 24.75" N and 87°52' 02.54" E) within Burdwan district, West Bengal (India). The leaves were collected from July to September, the green fruits during the months of December to January and mature seeds were collected from brown ripened fruits during the month of February. The leaves and fruits were destalked, washed carefully with distilled water to get rid off the surface dust and then rinsed with deionized water, air dried for two hours to get rid off surface moisture and then oven-dried at 50°C for 72 h. Identification and authentication of the plant were done by Prof. Ambarish Mukherjee, Department of Botany, Burdwan University and the voucher specimen at fruiting stage (Fr. Biswas and Mukherjee 14) had been deposited in the Departmental Herbarium bearing acronym BURD for future reference. The seeds were not washed since they were taken out afresh from dried mericarps of ripe fruits and oven- dried for 48 h. After proper drying all the samples were ground in mixer and grinder into fine powder and kept air-tight in polythene bags within refrigerator for future use. The powdered samples were used for both proximate and mineral analysis whereas for moisture analysis, the dust freed fresh samples were assessed.

Analysis of Proximate Principles

Proximate composition included moisture, ash, crude protein, crude lipid, crude fibre which were analyzed by the methods recommended by the Association of Official Analytical Chemists (1990). Estimation of nitrogen content was done by micro Kjeldahl method (Vogel 1958). Crude protein was estimated by multiplying the value obtained for percentage nitrogen content by a factor of 6.25.

Estimation of available carbohydrate (FAO 1985, 2003)

100 – (percentage of ash + percentage of moisture + percentage of fat + percentage of lipid + percentage of fibre).

Estimation of Energy:

It was calculated in kJ by multiplying the percentages of crude protein, crude lipid and carbohydrate by the factors 16.7, 37.7 and 16.7 respectively as per AOAC (1990) guidelines.

Analyses of Mineral Elements:

As much as 1 g of the dried powdered plant material was taken in a 250 ml conical flask within which sufficient dilute HNO_3 (conc. HNO_3 : distilled water = 2:1) was added. The flask was boiled vigorously till all the materials were completely digested. It was allowed to cool to room temperature and evaporated to dryness. Some amount of double distilled water was added to the conical flask and filtered in a 250 ml volumetric flask. The residue in each case was washed repeatedly with dilute HNO_3. The washed liquid was collected in the volumetric flask and the volume made upto 250 ml. In case of calcium a further dilution by 100 times was needed. The analyses of Ca, Mg, K, Na, Cu, Fe, Zn and

Mn were performed in atomic absorption Spectrophotometer (Model ─ Varian AA 575 series). Sodium and potassium were analysed by flame photometer. All analyses were conducted in triplicates and results were based per 100 g of dried sample. All the values were statistically expressed in terms of standard error of the mean values.

Estimation of Antinutrients

The presence of phenols and tannins considered as antinutrients detected in various parts of the plant was quantitatively estimated. Phenol was determined by Bray and Thorpe (1954) method using catechol as standard and tannin was determined by Van-Burden and Robinson (1981) method using standard curve of tannic acid. Both the results are expressed in mg g^{-1} of sample materials.

Estimation of Ascorbic Acid and Phosphorus

Since the leaves are edible hence estimation of ascorbic acid and phosphorus content were done only in case of leaves to substantiate its nutritive values. Ascorbic acid was estimated by Oser method (1979) and phosphorus was estimated by Fiske and Subbarow method (1925).

Isolation and Estimation of Fatty Acids

The oil obtained from leaf, fruit and seed were quantitatively estimated by converting the constituent fatty acids to their methyl esters following standard protocols (Gupta et al. 2011).

Analysis of the Fatty Acid Methyl Esters

The purified fatty acid methyl esters (FAME) were analysed by capillary gas liquid chromatography (GLC) on a Shimadzu Gas Chromatograph (Model GC-2010) with flame ionization detector (FID) on a split injector. A SP-2560 capillary column (100 m long x 0.25 mm i.d) was used for FAME analysis. The temperature of the injection and detector ports were set at 260°C. The oven temperature programme was initially at 140^{0}C for 5 minutes, then raised at 4^{0}C min g^{-1} to 240°C and finally held at 20 minutes at 240^{0}C. The carrier gas nitrogen with a total flow rate 33.9 mL min g^{-1} ; volume injected 1 μL; split ratio 1:30. Peaks were identified by comparison of their retention times with Supelco 37 component FAME standard mixture (Catalog no.18919 - 1 AMP). The percentage composition of the fatty acids of leaf and seed was computed from GLC peak areas and the relative percentages were presented in Tables 4 and 6 respectively. Depending upon the time of fruiting and availability of standards, GLC analyses of fruit was done separately in a different column [Hewlett Packard Gas Chromatograph (HP) Palo Alto, CA, USA) Model, Agilent 6890 Series plus instrument fitted with a HP- 5 capillary column (30m x 0.25mm internal diameter)] with comparatively fewer fatty acid standards (methyl esters of myristic acid, palmitic acid, linoleic acid, oleic acid, stearic acid, arachidonic acid, eicosanoic acid and DHA), the results of which are presented in Table 5.

RESULTS

Proximate Composition of the Plant Parts

The proximate values of leaf, fruit and seed of *N. arbor-tristis* are shown in Table 1. The moisture content was highest (53.94%) in leaf followed by fruit (15.80 %) and seed (8.64 %). The value is moderate for the leaves since most of the fresh green leafy vegetables show higher values of moisture content Gopalan et al. 2004, Odhav et al. 2007) ranging from 60% to as high as 93 % as found in *Portulaca* (93 %), spinach (92 %), *Amaranthus hybridus* (83 %) or *Centella asiatica* (88 %). Although high moisture content in leafy vegetables is an index of freshness, it is however vulnerable to microbial attack and spoilage. The moisture content less than 12% is

Table 1. Proximate composition of selected plant parts of *Nyctanthes arbor-tristis*.

Plant parts	Ash (%)	Moisture content (%)	Crude fat (%)	Protein (%)	Crude fibre (%)	Carbohydrate (%)	Calorific value Energy (kJ)
Leaf	15.38 ± 0.80	53.94 ± 0.12	3.60 ± 0.17	14.63± 0.15	6.19 ± 0.50	6.26± 0.35	484.58
Fruit	5.38 ± 0.68	15.80 ± 0.27	18.75 ± 0.07	19.56± 0.15	14.60 ± 0.64	25.91± 0.72	1466.22
Seed	6.02 ± 0.32	8.64 ± 0.36	22.70 ± 0.25	23.46± 0.48	2.86 ± 0.21	36.32± 0.31	1854.11

Values are means of three replicates ± S.E.M.

conventionally recommended as resistant to microbial attack and thus can withstand long storage. Thus the seeds can be stored for longer time. The ash content in leaves (15.38%) is considered high enough when compared with commonly consumed leafy vegetables like lettuce, spinach, legumes, cowpea etc where the values lie within 5.8% (Abitogun and Ashogbon 2010). The low ash values of fruit (5.38%) and seed (6.02%) reflect their low mineral content and high organic content and in fact this is in conformity with high fat content of fruit and seed (18.75% and 22.70%). The crude protein in leaves (14.63%), fruit (19.56%) and seeds (23.46%) are satisfactorily high and fairly comparable with protein-rich foods like soybean, cowpea, pigeon pea, groundnut etc where the value ranges between 20.40 - 22.40% (Oshodi et al. 1993). The lipid content in leaves were found to be 3.60 % which is comparable to *Portulaca oleracea* (2.90 %) (Gopalan et al. 1997). This value is quite low as compared to the value of water spinach (11.0%) (Umar et al. 2007) and *Amaranthus hybridus* (4.65%) (Akubugwo et al. 2007). However, according to Gopalan et al. (2004), the value is a bit higher as compared to most of the commonly available green leafy vegetables. Our analysis shows that the fibre content is highest (14.60 %) in case of fruits, moderate (6.19 %) in case of leaves and lowest (2.86 %) in case of seeds. The carbohydrate content of leaf of *Nyctanthes arbor-tristis* was found to be 6.26% which is very close to those of the leafy vegetables like *Amaranthus gangeticus*, bottle gourd leaves, beet greens, fenugreek leaves, coriander (6% in each case) and *A. spinosus*, Brussels sprouts, colocasia leaves (7% in each case) [Gopalan et al. 2004] and greater than that of cabbage (5%), *Amaranthus viridis* (4%) and lettuce (2%). The fruits and seeds of *Nyctanthes arbor-tristis* are very rich in carbohydrate content being 25.91% and 36.32% respectively. The former value is very close to that of jackfruit seeds (26%). The values obtained with fruits and seeds when referred to the nutritive values of fruits and seeds established by Gopalan et al. (2004), the carbohydrate content, especially of the seeds, appears to be much higher than those of others lying very close to water chestnut fresh (23%), [Gopalan et al. 2004]. The calorific value of leaf (484.58 kJ) is significantly low as compared to those of fruits (1466.22 kJ) and seeds (1854.11 kJ) and this is in good agreement with general observations that vegetables have low energy values (Lintas 1992) since such value is mainly associated with high content of carbohydrate and fat.

Assesssment of Mineral Elements

Data in Table 2 show that the amounts of Ca and K were highest among all the minerals in cases of leaf and fruit and followed by Mg content. Calcium content of *N. arbor-tristis* ranged from 157.25 mg $100g^{-1}$ (in green fruits) to 561.00 $mg100g^{-1}$ (in dry mature leaves). The green young leaves contain 477.92 mg calcium per 100 g. An enhancement in Ca content is seen by 83.08 mg with leaf maturity. Magnesium content ranged from 89.45 $mg100g^{-1}$ of green fruits to 144.30 $mg100g^{-1}$ of mature leaves. The green edible leaves contain as much as 126.05 mg $100g^{-1}$ which seems to be quite low when compared with such non-conventional leafy vegetables as *Amaranthus spinosus*, *Cassia tora* and somewhat closer to that of *Adansonia digitata* (120 mg $100g^{-1}$) and *Moringa olifera* (135 $mg100g^{-1}$;Barminas et al. 1998). It is interesting to note that Na was not detected in any of the plant parts, instead K was found in highly appreciable amounts -ranging from 499.15 mg 100 g^{-1} of young leaves to 584.01$mg100g^{-1}$ of dry mature leaves, the increment being 84.86 mg which is quite likely to happen since there is a tendency to accumulate such alkali metal which can antagonize sodium and promote drying of the leaf and subsequent abscission. The potassium content of the fruit is also greater than that of young green leaves by 15.44 mg 100 g^{-1} keeping parity with the drying required for attainment of maturity. By

Table 2. Mineral analysis of selected plant parts of *Nyctanthes arbor-tristis*.
All values expressed in mg 100g g^{-1} of plant tissues. Values are mean of three replicates ± S.E.M.

Samples	Ca	Mg	K	P	Cu	Fe	Zn	Mn
Fresh young leaf	477.92 ± 0.15	126.05 ± 0.04	499.15 ± 0.02	156 ± 0.08	0.81 ± 0.07	18.40 ± 0.26	16.11 ± 0.04	3.38 ± 0.04
Dry mature leaf	561 ± 0.11	144.30 ± 0.09.	584.01 ± 0.08	284 ± 0.14	1.55 ± 0.14	25.12 ± 0.19	22.36 ± 0.06	14.35 ± 0.11
Mature fruit	157.25 ± 0.08	89.45 ± 0.21	514.59 ± 0.05.	—	2.23 ± 0.7	16.36 ± 0.31	16.82± 0.08	2.15 ± 0.15

comparing the data of mineral content of each plant part under study with the daily dietary allowance as recommended by NRC (2005) and Gopalan et al. (1997, 2004) the threshold value for human consumption of macro- as well as micro elements can be adjudged. The ascorbic acid of leaf was estimated as 21.18 mg $100g^{-1}$ (mean value of three determinants) which is quiet high and appreciably comparable to that of sweet potato (22.7 mg $100g^{-1}$), radish (20 mg $100g^{-1}$), tomato (26 mg $100g^{-1}$) etc among vegetables (Hanif et al. 2006, Bangash et al. 2011). The role of Vitamin C is not unknown in that it prevents scurvy diseases and also aids in the formation of folic acid derivatives (Chatterjea and Shinde 1998) which is essential for pregnant ladies and lactating mother. A growing children as well as an adult needs about 40 mg ascorbic acid per day (Gopalan et al. 2004).

Antinutrients

The phyto-antinutrients like phenols, tannins have been estimated in all the three plant parts under study in view of the fact that the leaves are edible and the fruits and seeds are not usually eaten by herbivores and even birds. The estimation of the aforementioned anti-nutrients (Table 3) reveal that the seeds possess the highest amount of tannins and phenols followed by fruit and leaf. However, the fruit contains the lowest amount of phenol in comparison to seed and leaf.

Table 3. Concentration (mg g^{-1}) of antinutrients present in selected plant parts of *Nyctanthes arbor-tristis*.

Plant Part	Tannin	Phenol
Leaf	20 ± 0.15	8.23 ± 0.25
Fruit	35 ± 0.11	2.6 ± 0.18
Seed	42.1 ± 0.24	47.1± 0.15

Values are mean of three replicates ± S.E.M.

Fatty Acid Content of Leaf-, Fruit- and Seed- Oils

Fatty acid content of petroleum ether (60-80ºC) extract of mature leaf, ripe fruit and mature seeds of *Nyctanthes arbor-tristis* L. has been analyzed by GLC using standard fatty acids. The data are presented in Tables 4, 5 and 6 with the fatty acids arranged in the order of their retention time and carbon number (under GC analyses). Total yield of oil from the leaves ranged between 6.3-7.5%, that of oil from fruits between 8-10%, and of seed from 10.8 to 18.0%. A total of 22 fatty acids were identified in leaf (Table 4) which accounted for 73.62 % of the total fatty acids. The predominant fatty acids found in leaf were eicosapentonic acid (16.91%), heneicosanoic acid (16.86%), palmitic acid (11.34%) and oleic acid (10.58%). In addition to these nervonic acid (3.11%), elaidic acid (2.91%), γ-linolenic acid (2.81%), arachidic acid (1.47%) and linolaidic acid (1.01%) like rare fatty acids are also present. However, stearic acid (0.13%) was found in trace amounts.

Table 4. Fatty acid composition of leaf oil.

Fatty Acids	Retention Time (min)	Relative amount (%)
Caproic acid	11.420	0.11
Unidentified	17.331	0.72
Tridecanoic acid	17.880	1.55
Unidentified	18.103	0.24
Unidentified	18.700	0.82
Myristoleic acid* (C14:1)	21.196	0.71
Unidentified	22.475	0.59
cis-10-Pentadecanoic acid* (C15:1)	22.940	0.47
Palmitic acid	24.724	11.34
Heptadecanoic acid	26.115	0.66
cis-10-Heptadecanoic acid* (C17:1)	26.401	0.41
Stearic acid	27.787	0.13
Elaidic acid* (C18:1)	28.062	2.91
Oleic acid* (C18:1)	29.179	10.58
Linolaidic acid* (C18:2)	29.539	1.01
Arachidic acid	30.733	1.47
γ- Linolenic acid* (C18:3)	31.223	2.81
cis-10-Eicosenoic acid* (C20:1)	31.993	0.20
Linolenic acid* (C18:3)	32.283	0.16
Heneicosanoic acid	32.650	16.86
cis-11-14-Eicosadienoic acid* (C20:2)	32.869	1.06
Erucic acid* (C22:1)	35.520	0.07
Arachidonic acid* (C20:4)	36.002	0.92
*cis-5,8,11,14,17-Eicosapentanoic acid (C20:5)	38.918	16.91
Nervonic acid* (C24:1)	39.692	3.11
Unidentified	41.158	8.39
Unidentified	41.582	14.71
Unidentified	44.027	0.80
Cis-4,7,10,13,16,18-Docosohexanoic acid* (C22:6)	44.308	0.17
Unidentified	44.967	0.11
Total		100.00

* Unsaturated fatty acids

In the fruit oil (Table 5) five fatty acids have been identified which matched with the given fatty acid standards and account for 47% of the total oil with oleic acid (25.48%) as the predominant one followed by palmitic acid (10.15%), arachidonic acid (4.61%), eicosanoic acid (4.47%) and stearic acid (3.13%).

Table 5. Fatty acid composition of fruit oil.

Fatty Acids	Retention Time (min)	Relative amount (%)
Palmitic acid (16 : 0)	11.493	10.15
Unidentified	13.238	6.74
Oleic acid (18 : 1)	16.093	25.48
Stearic acid (18 : 0)	16.809	3.13
Unidentified (M^+ 294)	17.924	18.06
Unidentified (M^+ 294)	18.661	3.28
Arachidonic acid (20 : 4)	20.999	4.61
Unidentified	21.353	1.80
Eicosenoic acid (20 : 1)	21.663	4.47
Unidentified	20.329	2.10
Unidentified	22.864	2.91
Unidentified	23.085	6.04
Unidentified	23.601	4.25
Unidentified	24.365	2.54
Unidentified	25.219	4.44
Total		100.00

In the seed oil (Table 6) about 17 fatty acids were identified accounting for about 89% of total fatty acids with linoleic acid (54.55%) , arachidic acid (13.0%) and palmitic acid (11.06%) as the predominant one. Here, cis-eicosapentaenoic acid, oleic acid and γ-linolenic acid contributes only 4.38%, 3.11% and 1.15% respectively. The leaf contains 41.5% unsatu-rated fatty acids and 32.12% saturated fatty acid (SFA). Monounsaturated fatty acids (MUFA) account for 18.46% and polyun-saturated fatty acids (PUFA) were found to be 23.04%. In the leaf, presence of Omega -3 fatty acids was quiet high and accounted for 17.24% whereas Omega-6 fatty acid was found to be 4.79%. So ratio of omega-3: omega -6 fatty acid was about 3.6:1 which was a good ratio for maintaining health. In the seed oil, SFA was 25.55%, MUFA was 3.92%, PUFA was 61.97% and thus there was a high degree of unsaturation i.e. 65.89%. Here omega -6 fatty acids were quiet high (57.52%) whereas omega-3 fatty acid accounted for only 4.45%.

Table 6. Fatty acid composition of seed oil.

Fatty Acids	Retention Time (min)	Relative amount (%)
Caprylic acid	11.915	0.01
Capric acid	18.828	0.01
Tridecanoic acid	17.858	0.05
Myristoleic acid* (C14:1)	21.194	0.04
Cis-10—Pentadecanoic acid* (C15:1)	22.943	0.04
Palmitic acid	24.935	11.06
Heptadecanoic acid	26.006	0.32
Cis-10- Heptadecanoic acid* (C17:1)	26.427	0.03
Unidentified	26.952	0.01
Stearic acid	27.617	0.04
Oleic acid* (C18:1)	28.806	3.11
Linoleic acid* (C18:2)	29.868	54.55
Arachidic acid	31.128	13.00
γ-Linolenic acid* (C18:3)	31.496	1.15
Unidentified	32.220	0.02
Heneicosanoic acid	32.506	0.47
Cis-11-14-Eicosadienoic acid* (C20:2)	32.814	1.69
Behenic acid	34.068	0.02
Erucic acid* (C22:1)	35.239	0.03
Cis-11,14,17-Eicosatrienoic acid* (C20:3)	35.656	0.04
Unidentified	35.841	0.01
Arachidonic acid* (C20:4)	36.160	0.13
Lignoceric acid	38.002	0.57
Cis-5,8,11,14,17-Eicosepentaenoic acid* (C20:5)	38.988	4.38
Nervonic acid* (C24:1)	39.254	0.67
Unidentified	39.756	0.71
Unidentified	41.205	1.82
Unidentified	43.877	5.74
Unidentified	44.087	0.26
Cis-4,7,10,13,16,18-Docosohexanoic acid* (C22:6)	44.468	0.03
Total		100.00

* Unsaturated fatty acids

DISCUSSION

The high ash content of leaves as compared to fruits and seeds implies that the leaves could be a good source of mineral elements. The values of crude protein as found in different plant parts are greater than 12% which suggest that they could be good sources of protein (Pearson 1976) and thus could be used as protein supplements when conventional protein rich foods are in shortage. Furthermore, adults, children and lactating mothers require 34-56, 13-19 and 71 g of protein respectively on a daily basis (FNB 2002). In this respect, the leaves can contribute 26- 34% of protein in adults, 77-112.5% in children and about 20% in lactating mother. As a matter of fact, since vegetables mainly contribute to minerals, vitamins and fibre to the diet, the amount of available fat in the leaves of *N. arbor-tristis* may be safely consumed even by people suffering from obesity. The fat contents in fruit and seed were found to be 18.75 % and 22.70 % and as such these could be used as source of oil for industrial or domestic purpose. High fibre content in food is good for health since it as acts as roughage, facilitating peristaltic movement and is usually obtainable from fruits and vegetables in diet. There is no upper limit of dietary intake of fibre as such but large amount of fibre requires increased intake of water. This is because fibres carry water out of body and thus too much fibre consumption without sufficient water intake can cause dehydration, intestinal irritation or discomfort (Aletor and Adeogun 1995, Vadivel and Janardhanan 2000) and even painful stool elimination (Boyle 2001). High fibre content also decrease nutrient bioavailability (Aberoumond 2011). Apart from negative effect, the positive roles played by fibres in diet are many. Intake of adequate dietary fibres lowers cholesterol level Eromosele and Eromosele (1993), risks of coronary heart disease, hypertension, constipation, diabetes, colon and breast cancer (Ishida et al. 2000, Rao and Newmark 1998). The carbohydrate content of leaf is found to be 6.26% which is quiet low from the range (12-13%) mostly observed in vegetables (Gopalan et al. 2004) and such low content is ideal for diabetic and hypertensive patients requiring low sugar diets.

Minerals are very important and essential ingredients of diet required for normal metabolic activities of body tissues and play a key role as physiological components as well as participators in different processes of life. Interestingly, vitamins cannot be properly assimilated without the correct balance of minerals (Sonni Alvarez 2002). These necessary ingredients of food however prove to be toxic if ingested in excess, hence the term 'trace' is prefixed with minerals. The Ca content of young leaves of *N. arbor-tristis* when compared with those of the six non-conventional leafy vegetables consumed by the rural people of Nigeria (Barminas et al. 1998) appears to be greater than those of *Colocassia esculenta*, *Corchorus tridens*, *Cassia tora* and *Amaranthus spinosus*. Moreover, the dry mature leaves of *N. arbor-tristis* are more enriched in calcium than the leaves of *Adansonia digitata*. However, the values are much higher than those of ten selected leafy vegetables as determined by Bangash et al. (2011) which include *Portulaca oleracea*, *Brassica rapa*, *Raphanus sativus*, *Momordica charantia*, *Luffa acutangula*, etc. Calcium content of water spinach as detailed by Umar et al. (2007) is somewhat close to that of *N. arbor-tristis* leaves. Regarding Mg, when the values of Mg content of the leaves of *N. arbor-tristis* are put into comparison with those of 20 traditional vegetables studied by Odhav et al. (2007) viz. *A. spinosus, Centella asiatica*, *Chenopodium album, Portulaca oleracea* etc and with 10 vegetables as determined by Bangash et al. (2011) they were found higher in *N. arbor-tristis*. The dry mature leaves being the repository of minerals shows an enhancement in case of *N. arbor-tristis* by 18.25 mg100g^{-1} of Mg content from that of young leaves. On the contrary in case of fruits there is a decline by 36.60 mg over the content of Mg registered for young leaves. Incidentally potassium content of all these samples of *N. arbor-tristis* is much higher than that of *Amaranthus hybridus* leaves (54.20 mg 100g^{-1}) as revealed by Akubugwo et al. (2007). Furthermore, the plant samples studied did not show detectable quantities of sodium. Moreover, the Na/K ratio less than 1 is recommended for controlling high blood pressure (NRC 1989). Thus, high potassium level in *N. arbor-tristis* is likely to impart diuretic property to the leaves which as such can be recommended as food for consumption by people suffering from diabetes, hypertension and atherosclerosis (Yoshimura *et al*. 1991). Likewise, the Ca/P ratio greater than one is considered as to possess good food value (Adeyeye and Fagbohun 2005) and in this respect our results aptly fits the need. According to Gopalan et al. (1997,2004), an average Indian man of 60 kg body weight requires 60 g protein, 20 g fat, 28 mg iron and 40 mg Vitamin C in his daily diet and as per FNB (2005), calcium (800 - 1000 mg), Phosphorus (800 mg), Copper (0.9 g), Zn (10-15 mg), Mg (400 mg), Mn (7-0 mg) are recommended per day for an adult. Regarding the elements like Zn, Mn, Cu and Fe the RDA (recommended dietary allowance) is essential to follow since high amounts may produce adverse effects. In this respect the values obtained for leaf are all within the range and thus can be safely used as dietary vegetables without any risk. However fruits have high range of Mn and Cu and thus they could be used after thorough roasting or frying to make it edible atleast as animal fodder to get the benefit of its other food values.

In order to establish any nutritional aspects of plant, the presence of antinutruients (if any) needs to be estimated not only to avoid unnecessary health hazards but it also lowers the food value. The phyto-antinutrients like phenols, tannins estimated in all the three plant parts (Table 3) reveals that the leaves can be safely consumed whereas the fruits and seeds are not and these may be one of the reasons as to why they are not usually eaten by herbivores and even birds. Tannins reached the highest value followed by phenol and it is because of tannins that the plant parts are bitter to taste and less palatable although nutritional quality evaluated is highly appreciable and recommendable. However such draw-backs can be overcomed by detoxifying those antinutri-ents through proper cooking, boiling, frying or at least soaking (Jimoh et al. 2011, Akubugwo et al. 2007). It has been reported that stirred frying or roasting can increase palatability and Vitamin C content and minerals are not degraded on such heat exposure (Ghidurus et al. 2010) and this corroborate the fact that the leaves are usually consumed in fried form.

The oils obtained from fruit and seed although inedible, are likely to play a promising role in the cosmetic industry as well as excellent sources of essential fatty acids, especially omega-6-fatty acids which have crucial role to play in skin care. As per a report published in the Journal of American College of Toxicology (1987), in cosmetic industry for formulation of skin care and beautification products, such quantities of oleic acid (10.58%), palmitic acid (11.34%) and stearic acid (0.13%) are adequately within the range of concentration of the fatty acids (from 0.1% to 25%), the alkali salts of which are, in turn used as emulsifiers, emollients and lubricants in a variety of cosmetic creams, cakes, soaps and pastes. Hence the leaves may also be used as base components (of the oil phase) of many cosmetic formulations. In the same way the oleic acid may separately be used primarily in preparation of hair colouring and age - make up products. Palmitic acid found in leaves, fruits and seeds can find placement in products formulated for skin care, non-colouring hair preparations and personal cleanliness products. The leaf oil shows higher degree of unsaturation than saturation and monounsaturated components (18.46%) are considered as healthful fats having beneficial role in human health. A high oleic acid content help to reduce raised levels of total plasma cholesterol without reducing the high density lipoprotein (HDL) cholesterol level (Natali et al. 2007). Thus presence of high amount of oleic acid in fruit (25.48%) and leaf (10.58%) can be tapped as a source of this fatty acid and the leaves which are edible can provide this component directly through diet. Oleic acid also reduces expression of breast cancers. The presence of EPA (Eicosapentaenoic acid) as 16.91%, DHA (Docosa hexaenoic acid) as 0.17% and linolenic acid (0.16 %) in leaf as omega -3-fatty acids also proclaims of the dietary significance of this leaf for our health benefit in that they help to reduce the risk of a fatal heart attack (Kitamura et al. 2011). EPA increase the level of calcium in blood and improve the bone density. Omega-3-fatty acids help to reduce high blood pressure and reduce tenderness and inflammation in the joints and thus presence of these compounds substantiate the traditional uses of leaves in inflammation and the findings of Nirmal et al (2012) who established that the anti-inflammatory effect of pet-ether extract of leaf is due to β-sitosterol. EPA has been tested for the galactosamine induced liver damage in mice and results indicated that EPA was able to present hepatoprotective effects (Roy et al. 2007). It has also therapeutic properties, such as immunomodulatory, antioxidant, and anti-tumour activities, among others (Mandal et al.2010, Gapeyev et al. 2011, Li et al. 2011). Moreover, in a recent study, EPA was found the most effective fatty acid in free radical-scavenging potential (Richard et al,.2008) and also plays role in anti-ageing effect and skin protection by virtue of its antioxidant property (Kim et al. 2006). EPA exhibited significant neuroprotective potential in neurological injuries (Dyall and Michael-Titus, 2008). The leaf also possess a rare fatty acid nervonic acid (3.11%) of marine origin which is widely used as a neutrophic factor in food supplements and nutraceuticals (Straccia et al. 2012) and in this respect due to presence of both EPA and nervonic acid, the leaf provide enough scope of research for formulating neuroprotective drug for neuromuscular diseases. From mostly available literature it is known that the most widely available source of EPA and DHA is cold water oily fish. From our study it can be recommended that this leaf could very well act as a good plant based substitute for source of EPA and can also supplement this fatty acid directly through diet.

The GLC analysis seed oil reveals high amount of polyunsaturated fatty acids especially the Omega-6 fatty acids accounting for 57.52% of the total oil which is in sharp contrast with the fatty acid constituents of leaf. The seed is non-edible and this is perhaps in conformity with the fact that omega-6 fatty acid (Linoleic acid). content is too high in comparison to health promoting omega-3 fatty acids and in addition to it presence of high phenolic content which obviously negates its edible property. However, some positive roles played by omega -6 fatty acids as recommended by Ellen Marmur and Gina Way in their book "Simple Skin Beauty" (2009) are

- they help to promote hair growth, support skin health, improve nerve and vascular function, and acts as a natural antioxidant. Arachidonic acid found in fruit oil is also an omega - 6 polyunsaturated fatty acid which is necessary for growth and protection of skin (Cakir 2004). The combination of omega-3 and omega-6 fatty acid helps to calm skin conditions like rosacea and eczema due to the strong anti-inflammatory properties of the fatty acids and they act as emolluents which are very essential for skin smoothening (Zielinska and Nowak 2014). LA is known to be a natural component of sebum. The above facts provide ample support as to why the seeds in powdered form with an oil base are being traditionally used in scalp treatment, baldness and hair fall and also used in treatment of eczema. Since phenol, EPA and linoleic acid can act as good antioxidants (Ismail et al 2010) so they can be tapped as an excellent source of antioxidant compounds.

Regarding the suitability of the very much wasted and unattended fruits and seeds as biofuel, it may be said that they may be used as a blend with well established biofuels like jatropha oil, sunflower oil, linseed oil, soyabean oil, palm oil etc which have higher iodine values than *Nyctanthes* (Aluyor and Ori-Jesu 2008) and have certain disadvantages. To act as a proper biofuel, low volatility, low melting point, low sp. gravity low iodine value, good lubricant property, high oxidation stability and higher amount of saturated fatty acids or monounsaturated fatty acids are some of the requisites that a crude oil should possess. Although high degree of unsaturation is found in *Nyctanthes* seed oil which would lower combustibility and decrease oxidation stability, however they would lower the melting point and presence of oleic acid in good amounts will enhance the lubricating property and oxidation stability and presence of linoleic acid might impart additive property as an antioxidant. Nowadays microemulsified hybrid fuels are in use in modern technology which prefers polyunsaturated fatty acids more to produce microemulsion of alcohols with diesel fuels (Uriarte 2010). The oil might prove its worth as a bio-fuel if transesterification and proper processing is done which might change certain properties essential for fuel combustion.

CONCLUSION

The findings of proximate and mineral analyses of leaves in particular speak of nutritional importance appreciable enough to contribute towards human health, the praiseworthy among which are the protein content, Ca, P and K content, dietary fibre and omega-3- fatty acids which could be extracted and used in the development of nutraceuticals or functional food product. Since the leaves have proven itself as a good source of antioxidants like phenols, EPA and ascorbic acid and the threshold level of antinutrients in it also speaks of its safe consumption it can be recommended as a non-conventional vegetable to be taken in diet either fried or cooked and thus capable of addressing issues of food security and scarcity. The plant have also bright prospect in beauty and health care and since marketed formulations made out of flower oil have already been reported (Meshram et al. 2012) and a sunscreen cream from flower has been formulated (Bambal et al. 2011), our findings will definitely inspire in future formulation of such herbal care products from leaves, fruits and seeds too. The leaves and seeds are excellent source of antioxidant compounds to be tapped for preparation of food supplements and the non-edible dry fruits and seeds might be utilized as a blend with biofuels of vegetable origin which otherwise usually get wasted uncared and unattended.

REFERENCES

Aberoumand, A. 2011. Screening of less known two food plants for comparison of nutrient contents: Iranian and Indian vegetables. Functional Foods in Health and Disease 10: 416-423.

Abitogun, A.S. and A.O. Ashogbon. 2010. Nutritional assessment and chemical composition of raw and defatted *Luffa cylindrica* seed flour. Ethnobotanical Leaflets 14: 225-35.

Adeyeye, E.I. and E.D. Fagbohun. 2005. Proximate, mineral and phytase profiles of some selected spices found in Nigeria. Pakistan Journal of Scientific and Industrial Research 48 (1): 14-22.

Akki, K.S.; G. Krishnamurthy and H.S. Bhoja naik. 2009. Phytochemical investigations and in vitro evaluation of Nyctanthes arbor-tristis leaf extracts for antioxidant property. Journal of Pharmacy Research 2(4): 752-755.

Akubugwo, I.E.; N.A. Obasi, G.C. Chinyere and A.E. Ugbogu. 2007. Nutritional and chemical value of Amaranthus hybrids L. leaves from Afikpo, Nigeria. African Journal of Biotechnology 6(24): 2833 - 2839.

Aleter, V. and O. Adeogun. 1995. Chemical analysis of the fruit of Vitex doniana (Verbenaceae). Food Chemistry 53: 375-379.

Aluyor E.O. and M.O. Ori-Jesu. 2008. The use of antioxidants in vegetable oils — A review. African Journal of Biotechnology 7(25): 4836-4842.

Alveez S. 2002. Importance of minerals and trace minerals in human nutrition. Web site: http://www.mgwater.com/impor.shtml (15 April 2004).

AOAC 1990. Official Methods of Analysis, Volume 1. 15th edition. Association of Official Analytical Chemists, Washington, DC. 770 pages.

Assameese Food: www.downtoearth.org.in/content/flower-delicacies-northeast

Badam, L.; Deolankar, R.P.; Rojatkar, S.R.; Nagsampgi, B.A. and Wagh, U.V. 1988. In vitro antimalarial activity of medicinal plants of India. Indian Journal of Medicinal Research 87: 379-383.

Bambal, V.; Wyawahare, N.; Turaskar, A. and Mishra, M. 2011. Study of sunscreen activity of herbal cream containing flower extract of *Nyctanthes arbor-tristis* L. and *Tagetes erecta* L. International Journal of Pharmaceutical Sciences Review and Research, 11(1): 142-146.

Bangash, J.A.; Arif, M.; Khan, M.A.; Khan, F.; Rahman, A. and Hussain, I. 2011. Proximate composition, minerals and vitamins content of selected vegetables grown in Peshawar. Journal of the Chemical Society of Pakistan 33(1): 118-122.

Barlingame, B. 2000. Comparison of total lipids, fatty acids, sugars and nonvolatile organic acids in nuts from Castanea species. Journal of Food Composition analysis 13: 99-100.

Barminas, J.T.; Charles, M. and Emmanuel, D. 1998. Mineral composition of non-conventional leafy vegetables. Plant Foods for Human Nutrition 53: 29-36.

Bhatt, D.C.; Mitaliya, K.D. and Mehta, S.K. 2001. Observations on ethnoveterinary herbal practices in Gujarat. Ehnobotany 13: 91-95.

Boyle, Marie A. 2001. Personal Nutrition. 9th edition. Wadsworth/ Thompson Learning, Belmont, CA. 425 pages.

Bray, H.G. and Thorpe, W.V. 1954. Analysis of phenolic compounds of interest in metabolism. Methods of Biochemical Analysis 1: 27-52.

Cakir, A. 2004. Essential oil and fatty acid composition of the fruits of *Hippophae rhamnoides* L. (sea buckthorn) and *Myrus communis* L. from Turkey. Biochemical Systematics and Ecology 32: 809-816.

Chatterjea, M.N. and Shinde, R. 1998. Text Book of Medical Biochemistry. Third Edition. Jaypee Brothers Medical Publishers, New Delhi.

Chitravanshi, V.C.; Singh, A.P.; Ghosal, S.; Prasaad, B.N.K.; Srivastava, V. and Tandon, J.S. 1992. Therapeutic action of *Nyctanthes arbor-tristis* against caecal amoebiasis of rat. International Journal of Pharmacognosy 30 (1): 71-75.

Das, S.; Sasmal, D. and Basu, S.P. 2010. Antispasmodic and anthelmintic activity of *Nyctanthes arbortristis* Linn. International Journal of Pharmaceutical Sciences and Research 1(2): 51-55.

Deshmukh S.R. and Rathod, V. 2013. Nutritional composition of wild edible *Ceropegia* tubers. Advances in Applied Science Research 4(1): 178-181.

Dyall, S.C. and Michael-Titus, A.T. 2008. Neurological benefits of omega-3 fatty acids. Neuromolecular Medicine 10: 219-235.

Eromosele, I.C. and Eromosele, C.O. 1993. Studies on the chemical composition and physico-chemical properties of seeds of some wild plants. Plant Foods for Human Nutrition 43: 251-258.

Fiske, C.H. and Subbarow, Y. 1925. The colorimetric determination of phosphorus. Journal of Biogical Chemistry 66: 375.

FNB (Food and Nutrition Board). 2002. Dietary Reference Intake for Energy, Carbohydrate, Fibre, Fat, Fatty acids, Cholesterol, Protein and Amino acid (Micro-Nutrients). Food and Nutrition Board, Institute of Medicine. National Academy of Sciences, Washington, DC. www.nap.edu (retrieved on 14/05/2007).

Gapeyev, A.B.; Kulagina, T.P.; Aripovsky, A.V. and Chemeris, N.K. 2011. The role of fatty acids in anti-inflammatory effects of low-intensity extremely high-frequency electromagnetic radiation. Bioelectromagnetics 32: 388-395.

Ghidurus, M.; Turtoi, M.; Boskou, G.; Niculita, P. and Stan, V. 2010. Nutritional and health aspects related to frying (I). Romanian Biotechnological Letters 15(6): 5675-5682.

Girach, R.D.; Aminuddin; Siddiqui, S.A.; Siddiqui, P.A. and Khan, S.A. 1994. Ethnomedicinal studies on Harsinghar (*Nyctanthes arbor-tristis* L.)- A less known medicinal plant in unani medicine. Hamdard Medicus 37(2): 60-66.

Gopalan, C.; Rama Sastri, B.V. and Balasubramanian, S.C. 1997. Nutritive Value of Indian Foods. (Revised by Narasinga Rao, B.S.; Deosthale, Y.G. and Pant, K.C.). National Institute of Nutrition, Indian Council of Medical Research, Hyderabad. 156 pages.

Gopalan, C.; Rama Sastri, B.V. and Balasubramanian, S.C. 2004 (Reprint). Nutritive Value of Indian Foods. (Revised by Narasinga Rao, B.S.; Deosthale, Y.G. and Pant, K.C.). National Institute of Nutrition, Indian Council of Medical Research, Hyderabad.

Gupta, P.P.; Srimal, R.C. and Tandon, J.S. 1993. Anti-allergic activity of some traditional Indian medicinal plants. International Journal of Pharmacognosy 31(1): 15-18.

Hanif, R.; Iqbal, Z.; Iqbal, M.; Hanif, S. and Rasheed, M. 2006. Use of vegetables as nutritional food: Role in human health. Journal of Agricultural and Biological Science 1(1): 18-22.

Hukkeri,V.I.; K.S. Akki, R.R. Sureban, B. Gopalakrishna, V.V. Byahatti and S.V. Rajendra. 2006. Hepatoprotective activity of the leaves of *Nyctanthes arbortristis* Linn. Indian Journal of Pharmaceutical sciences, 68(4): 542-543.

Indrayan,A.K. S. Sharma, D. Durgapal, N. Kumar and M. Kumar. 2005. Determination of nutritive value and analysis of mineral elements for some medicinally valued plants from Uttaranchal. Current Science 89 (7): 1252-1255.

Ishida, H.; Suzuno, H.; Sugiyama, N.; Innami, S.; Tadokoro, T. and Maekawa, A. 2000. Nutritional evaluation of chemical component of leaves, stalks and stems of sweet potatoes (*Ipomoea batatas* Poir). Food Chemistry 68: 359-367.

Ismail, A.; Ikram, E.H.K. and Nazri, H.S.M. 2008. Roselle (*Hibiscus sabdariffa* L.) seeds- Nutritional composition, protein quality and health benefits. Food 2(1): 1-16.

Ismail, M.; Mariod, A.; Bagalkotkar, G. and Ling, H.S. 2010. Fatty acid composition and antioxidant activity of oils from two cultivars of Cantaloupe extracted by supercritical fluid extraction. Grasas y Aceites 61(1): 37-44.

Jimoh, W.A.; Fagbenro, O.A. and Adeparusi, E.O. 2011. Effect of processing on some minerals, antinutrients and nutritional composition of sesame (*Sesamum indicum*) seed meals. Electronic Journal of Environmental, Agricultural and Food Chemistry 10(1): 1858-1864.

Kar, A. and Borthakur, S.K. 2008. Wild vegetables of Karbi-Anlong district, Assam. Natural Product Radiance 7(5): 448-460.

Kim, K.H.; Cho, K.H.; Eun, H.C. and Chung, J.H. 2006. Photoprotective and anti-skin-ageing effects of eicosa-pentaenoic acid in human skin in vivo. Journal of Lipid Research 47: 921-930.

Kirtikar, K.R. and Basu, B.D. 2000. Indian Medicinal Plants. Vol. VII. Sri Satguru Publications, New Delhi.

Kitamura, K.; Shibata, R.; Tsuji, Y.; Shimano, M.; Inden, Y. and Murohara, T. 2011. Eicosapentaenoic acid prevents atrial fibrillation associated with heart failure in a rabbit model. American Journal of Physiology-Heart and Circulatory Physiology 300: 814-821.

Li, M.; Zhu, Q.; Hu, C.; Giesy, J.P.; Kong, Z. and Cui, Y. 2011. Protective effects of eicosapentaenoic acid on genotoxicity and oxidative stress of cyclophosphamide in mice. Environmental Toxicology 26: 217-223.

Lintas, C. 1992. Nutritional aspect of fruits and vegetable consumption. Options Mediterraennes 19: 79-87.

Lockeett, C.T.; Calvert, C.C. and Grivetti, L.E. 2000. Energy and micronutrient composition of dietary and medicinal wild plants consumed during drought: Study of rural Fulani, Northeastern Nigeria. International Journal of Food Science and Nutrition 51: 195-208.

Mandal, C.C.; Ghosh-Choudhury, T.; Yoneda, T.; Choudhury, G.G. and Ghosh-Choudhury, N. 2010. Fish oil prevents breast cancer cell metastasis to bone. Biochemical and Biophysical Research Communications 402: 602-607.

Meshram, M.M.; Rangari, S.B.; Kshirsagar, S.B.; Gajbhiye, S.; Trivedi, M.R. and Suhane, R.S. 2012. *Nyctanthes arbor-tristis* a herbal panacea. International Journal of Pharmaceutical Sciences and Research 3(8): 2432-2440.

Natali, F.; Siculella, L.; Sahati, S. and Gnoni, G.V. 2007. Oleic acid is a potent inhibitor of fatty acid and cholesterol synthesis in C_6 glioma cells. Journal of Lipid Research 48: 1966-1975.

Nesamvuni, C.; Steyn, N. and Potgieter, M. 2001. Nutrients analysis of selected western African foods. South African Journal of Sciences 97: 51-54.

NRC (National Research Council). 1989. Recommended Dietary Allowances. Tenth edition. National Academic Press, Washington, DC. 298 pages.

Odhav, B.; Beekrum,S.;Akula,U. and Bajinath, H. 2007. Preliminary assessment of nutritional value of traditional leafy vegetables in KwaZulu-Natal, South Africa. Journal of Food Composition and Analysis 20: 430-435.

Oser, B.L. 1979. Hawk's Physiological Chemistry. McGraw Hill, New York. 1472 pages.

Oshodi, A.A. and Adeladun, M.O.A. 1993. Proximate composition, some nutritionally valuable minerals and functional properties of three varieties of Lima bean (*Phaseolus lunatus*) flour. International Journal of Food Sciences and Nutrition 43 (4): 181-186.

Pal, D.C. and Jain, S.K. 1998. Tribal Medicine. Naya Prakash, Calcutta. 317 pages.

Pandey, M.; Abidi, A.B.; Singh, S. and Singh, R.P. 2006. Journal of Human Ecology 19(2): 155-156.

Patiri, B. and Borah, A. 2007. Wild Edible Plants of Assam. Director Forest Communication, Forest Department, Assam. 169+28 pages.

Pearson, D. 1976. Chemical Analysis of Foods. 7th edition. Churchill Livingstone, London. xii+575 pages.

Priya, K. and Ganjewala, D. 2000. Antibacterial activities and phytochemical analysis of different plant parts of *Nyctanthes arbortristis* (Linn.). Research Journal of Phytochemistry 1(2): 61-67.

Puri, A.; Saxena, R.; Saxena, R.P.; Saxena, K.C.; Srivastava, V. and Tandon, J.S. 1994. Immunostimulant activity of *Nyctanthes arbortristis* L. Journal of Ethnopharmacology, 42(1): 31-37.

Rao, C.V. and Newmark, H.L. 1998. Chemo-preventive effect of squalene on colon cancer. Carcinogenesis 19: 287-290.

Richard, D.; Kefi, K.; Barbe, U.; Bausero, P. and Visioli, F. 2008. Polyunsaturated fatty acids as antioxidants. Pharmacological Research 57: 451-455.

Roy, R.; Chandrasekhar, D. and Pujari, P. 2007. Dietary fish oil as hepatoprotective agent in *Mus musculus*. Indian Journal of Experimental Biology 45: 367-370.

Straccia, M.C.; Siano, F.; Coppola, R.; Cara, F.L. and Volpe, M.G. 2012. Extraction and characterization of vegetable oils from cherry seed by different extraction processes. Chemical Engineering Transaction 27: 391-396.

Suresh, V.; Jaikumar, S. and Arunachalam, G. 2010. Antidiabetic activity of ethanol extracts of stem bark of *Nyctanthes arbor-tristis* Linn. Research Journal of Pharmaceutical, Biological and Chemical Sciences 1(4): 311-317.

Umar, K.J.; Hassan, L.G.; Dangoggo, S.M. and Ladan, M.J. 2007. Nutritional composition of water spinach (*Ipomoea aquatica* Forsk.) leaves. Journal of Applied Sciences 7(6): 803-809.

Uriarte Jr., F.A. 2010. Biofuels from Plant Oils. ASEAN Foundation, Jakarta, Indonesia. Xx pages

Van-Burden, T.P. and Robinson, W.C. 1981. Formation of complexes between protein and tannic acid. Journal of Agricultural and Food Chemistry 17: 772-777.

Vadivel, V. and Janardhanan, K. 2000. Chemical composition of the underutilized legume *Cassia hirsuta* L. Plant Foods for Human Nutrition 55: 369-381.

Warrier, P.K.; Nambiar, V.P.K. and Ramankutty, C. (Editors). 1995. Indian Medicinal Plants: a Compendium of 500 Species. Volume 4. Orient Blackswan, Arya Vaidya Sala, Kottakal. 444 pages.

Watt, G. 1891. Dictionary of Economic Products of India. Volume V. Cosmos Publication, Delhi. 680 pages.

Yoshimura, M.; Takahashi, H. and Nakanishi, T. 1991. Role of sodium, potassium, calcium, magnesium on blood pressure regulation and antihypertensive dietary therapy. Japanese Journal of Nutrition 49: 53-62.

Zielinska, A. and Nowak, I. 2014. Fatty acids in vegetable oils and their importance in cosmetic industry. CHEMIK 68: 103-110.

Received 12 November 2016
Accepted 23 June 2017