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REVIEW PAPER

FENUGREEK: PRODUCTIVITY, NUTRITIONAL VALUE AND USES*

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Abstract

This paper reviews the available literature about the botanical aspects and productivity, properties and applications of fenugreek. The source of this species are seeds and leaves. The high yield of fenugreek is influenced on the environmental and agricultural factors. The unique properties of this species are determined by variety, agricultural technology and habitat conditions, too. One of this species is a crop fenugreek (*Trigonella foenum – graecum* L.). Fenugreek belongs to the legume plants and is an environmentally friendly plant. The yields of plants depend on the genotype, climate, environmental conditions, cultivation practices, use of fertilizers, irrigation. The seeds are rich in biogenic element such as phosphorus, sulfur, magnesium, calcium but were less abundant in zinc, manganese and copper. Fenugreek seeds and leaves contain biologically active substances (protein, amino acids, biogenic elements, lipids and fatty acids), and they are used in traditional medicine, as functional food and in the cosmetics industry. In traditional medicine, fenugreek is used to prepare infusions, water and alcohol extracts, tinctures, meads, tonics with antidepressant and psychotonic properties, and muscle growth supplements. Fenugreek constitutes high-quality feed for dairy cattle which improves the health status of livestock. The findings presented in this review paper will be useful for consumers hoping to improve their health by incorporating healthy biogenic elements and fatty acids into their diets.

Keywords: *Trigonella foenum-graecum*, chemical compounds, benefits.

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INTRODUCTION

Legume plants, including fenugreek (*Trigonella foenum – graecum* L.), constitute high-quality foods that deliver nutritional and functional advantages at a low price. Fenugreek is grown mainly in China, India, Turkey, Canada, Australia, northern and southern Africa, and southern Europe (Moyer et al. 2002, Ahmad et al. 2016). Fenugreek is one of India's main exports. Fenugreek has been long known as a potent herb in traditional medicine. Its seeds contain protein with a desirable amino acid profile, lipids and biogenic elements. Fenugreek seeds are also a rich source of saponins, flavonoids, choline, carotene, essential oils containing trigonelline and other functional elements (Srinivasan 2006, Meghwal, Goswami 2012). The protein content of fenugreek seeds was determined in the range of 235.0 g kg^{-1} (Issa et al. 2014) to 246.0 g kg^{-1} (Mahfouz et al. 2012), and lipid content – in the range of 40 to 100 g kg^{-1} (Sulieman et al. 2008*a*). Fenugreek seeds contain significant amounts of Fe, P, Ca, Zn and Mn, and they are abundant in vitamins A, B_1, C and nicotinic acid (Moradi kor, Moradi 2013). Due to their unique anti-diabetic, blood glucose-lowering, cholesterol-lowering, anticarcinogenic and antimicrobial properties, both leaves and seeds are consumed as a remedy for various health conditions. Both seeds and leaves are also used in food preparation, including in stews in Iran, cheese flavoring in Switzerland, syrup and bitter rum in Germany, mixed seed powder for baking flat bread in Egypt, curries, dyes, roasted seeds as coffee substitute in Africa, whereas young seedlings are consumed as vegetables (Moradi kor, Moradi 2013). Fenugreek is an ecofriendly plant that fixes atmospheric nitrogen (Pietrzak 2011). Therefore, the aim of this paper was to present the existing knowledge on the nutritive properties and practical applications of fenugreek.

BOTANICAL ASPECTS AND PRODUCTIVITY

Fenugreek (*Trigonella foenum-graceum* L.) is an annual diploid plant ($2n$ = 16) of the family Leguminosae, which is known under various names around the world. The species has a long taproot and a weakly branched main stem which reaches the height of 30 to 60 cm. Leaves consist of three -lobed inversely ovate leaflets with short petioles, serrated edges and oval stipules. Fenugreek is a honey plant that blossoms in June and July. *Papilionaceous* flowers have a boat-shaped structure with short wings and keel petals, and they vary in color from white or cream, to yellow and light purple. Flowers emerge individually or in pairs in leaf nodes. The seeds mature at the turn of August and September. Fenugreek plants have a distinctive and long-lasting spicy aroma (Bieńkowski et al. 2016).

Fenugreek plants produce horn-shaped pods with a length of up to 11 cm,

which are straight or curved in shape, narrow, with a sharply pointed tip. Each pod contains 10 to 20 cuboid seeds divided by a ridge into two unequal parts. Green-brown seeds are lobulated and very hard. They retain their germination capacity for 2 years. According to Zapotoczny et al. (2016), application of herbicides and fungicides influence the color of fenugreek seeds. *Trigonella foenum-graecum* seeds are small, angular and flattened, 4-5 mm in length, 2.35-2.60 mm in width, with a characteristic oblong rhomboidal outline (Altuntas et al. 2005, Moradi kor, Moradi 2013). Thousand seed weight is 14-15 g (Bieńkowski et al. 2016). A seed holds a central hard yellow embryo bound by large, corneous white and semi-transparent endosperm (Betty 2008). According to Altuntas et al. (2005), the bulk density of fenugreek seeds with a moisture content of 8.9-20.1% ranges from 1165.25 to 1240.36 kg m^{-3}

The yield and quality of fenugreek is influenced by genotype, climate, environmental conditions, cultivation practices, use of fertilizers, irrigation and the methods of processing seeds into local spices (Al Jasass, Al Jasser 2012, Pavlista, Santra 2016). Fenugreek yields were higher in years with higher precipitation during the growing season (Basu et al. 2008). In the work of Petropoulos (2002), fenugreek yields were higher in years characterized by annual precipitation of 300-1500 mm and annual mean temperature of 7.8-27.5°C. Żuk-Gołaszewska et al. (2015) demonstrated that soil water deficit decreased plant height by 15.5%, the number of pods – by 18.3%, the number of seeds per pod – by 20%, seed weight – by 28%, the weight of the plant's aerial parts – by 18.0%, and the harvest index by – 13.2%. Drought also significantly decreased the chlorophyll content of fenugreek leaves. Fenugreek is particularly sensitive to delayed sowing and competition from weeds. In a study by Bieńkowski et al. (2016), the average yield from all cultivation variants was 759 kg ha^{-1}. A 20-day sowing delay reduced seed yield by 3-10% when medical weed control techniques were applied and by 3-13% when herbicide was used. Parida et al. (2003) demonstrated that the Fe content of plants increased and Cu and Zn concentrations decreased with a rise in the Ni dose (max - 300 mg kg^{-1} soil).

NUTRITIONAL VALUE

Protein and amino acids

Fenugreek seeds contain 260.3 to 295.0 g kg^{-1} of protein, whose quality is determined by the composition of different protein fractions and amino acids. In a study by Leela and Shafeekh (2008), fenugreek seeds had the following amino acid profile: albumins (438.00 g kg^{-1}), globulins (272.00 g kg^{-1}), glutelins (172.00 g kg^{-1}) and prolamins (74.00 g kg^{-1}). The differences in the amino acid profiles of fenugreek, white lupine and durum wheat are responsible for variations in their functional properties (Table 1).

Table 1

Total protein content and amino acid composition of fenugreek seeds compare in other agricultural crops

Total protein/ amino acids	Fenugreek (Mahfouz et al. 2012)	White lupine (Mahfouz et. al. 2012)	Durum wheat (Acquistucci et al. 1995)
Protein (g kg^{-1})	246.00	364.00	134.20
Essential amino acids – EAA (g kg^{-1} of protein)			
Isoleucine (Ile)	41.00	36.50	36.50
Leucine (Leu)	62.60	66.40	67.00
Lysine (Lys)	57.70	40.30	28.50
Methionine (Met)	13.00	5.70	18.90
Phenylalanine (Phe)	37.80	31.00	47.50
Threonine (Thr)	33.00	32.90	29.10
Valine (Val)	38.20	36.50	44.50
Histidine (His)	21.50	19.20	23.00
EAA total	304.80	268.50	295.00
Nonessential amino acids – NAE (g kg^{-1} of protein)			
Alanine (Ala)	36.90	30.20	35.30
Glycine (Gly)	47.50	34.80	36.10
Proline (Pro)	39.40	34.80	115.00
Arginine (Arg)	91.00	101.90	47.00
Serine (Ser)	47.10	41.20	44.10
Cysteine (Cys)	22.00	14.80	29.90*
Tyrosine (Tyr)	29.60	41.20	30.20
Aspartic acid (Asp)	102.00	97.80	49.20
Glutamic acid (Glu)	160.50	196.90	287.00
Non EAA total	576.00	593.6	673.80

* total content cysteine and cystine

Mahfouz et al. (2012) compared the quality of protein in fenugreek and other legumes, such as white lupine, and demonstrated that white lupine had a higher protein content than fenugreek. The content of essential amino acids was determined at 268.50 g kg^{-1} in white lupine, whereas fenugreek seeds contained the highest amounts of both essential amino acids (304.80 g kg^{-1} protein) and total amino acids (576.00 g kg^{-1} protein). In fenugreek, the content of methionine and cysteine was higher than in white lupine by approximately 128% and 49%, respectively. Isikli and Karababa (2005) noted that fenugreek has a high content of free amino-acids, in particular isoleucine and histidine, which may stimulate insulin secretion. James and Heather (2011) demonstrated that protein-rich legumes, such as lupine, are as potent as soybeans in lowering serum cholesterol levels. Fenugreek is also abundant in lysine, whose quality is comparable to soybean lysine, which is why fenugreek

seeds are consumed as a dietary supplement (Mandal, Deb Mandal 2016). Feyzi et al. (2015) found significant concentrations of Glu, Asp, Lue, Thr and Arg in fenugreek seeds and concluded that fenugreek protein isolate is a source of protein with remarkable functional properties. Among the analyzed species, the grain of durum wheat was richer in leucine, phenyloalanine and valine (Acquistucci et al. 1995) – Table 1. Unlike cereal grain proteins, fenugreek proteins are rich in Lys and low in His and Met, therefore, they could be used to enhance the nutritional value of cereals and snack foods such as bread, biscuits and cakes (Feyzi et al. 2015).

In a study by Hooda and Jood (2007), germinated fenugreek seeds had a significantly higher content of total protein (29%) and total lysine (64.80 g kg^{-1} of protein) than unprocessed seeds. Germination decreased the content of dietary fiber and starch, thus increasing sugar levels in seeds. Additionally, *in vitro* digestibility of starch and protein and the availability of Ca, Fe and Zn also increased considerably due to a reduction in the content of antinutrients (phytic acid and polyphenols). Meghwal and Goswami (2012) found that fenugreek protein is more soluble at alkaline pH. Fenugreek has a beneficial influence on digestion and it can modify food properties.

Biogenic elements

Fenugreek is grown for both its seeds and leaves. According to Abou-Shleel (2014), Wierzbowska and Żuk-Gołaszewska (2014), the concentrations of biogenic elements in fenugreek seeds are determined by the genotype, cultivation practices and environmental factors. The mineral content of different seeds is presented in Table 2.

Table 2

Mineral content of fenugreek seeds

Elements	Abbas Ali et al. (2012)	Khorshidian et al. (2016)	Wierzbowska, Żuk-Gołaszewska (2014)	Al-Jasass, Al Jasser (2012)	Recommended daily allowance per 100 g seeds (%)
K (g kg^{-1})	10.80	nd	17.50	6.03	13-37
Na (g kg^{-1})	0.29	nd	0.47	nd	2-3
P (g kg^{-1})	2.00	2.96	8.28	nd	28-118
Mg (g kg^{-1})	0.78	1.91	2.24	0.42	10-53
Ca (g kg^{-1})	2.26	1.76	1.50	0.75	7-23
Fe (mg kg^{-})[1]	116.0	335.0	nd	258.00	116-335
Zn (mg kg^{-1})	44.0	25.0	nd	24.00	22-40
Cu (mg kg^{-1})	54.0	nd	nd	9.00	100-600
Mn (mg kg^{-1})	16.0	1.22	nd	9.00	nd
Se (μg kg^{-1})	nd	6.30	nd	nd	1.10

nd – not detected

Fenugreek seeds are characterized by varied mineral content, and some minerals, such as phosphorus and sulfur, are found in significant concentrations (El Nasri, El Tinay 2007). Wierzbowska and Żuk-Gołaszewska (2014) demonstrated that inoculation significantly increased phosphorus, calcium and sodium concentrations in seeds. In fenugreek seeds cultivated in Poland, potassium and phosphorus were the major minerals. The seeds examined by Al Jasass and Al Jasser (2012) were rich in potassium, calcium, magnesium and iron (6.03, 0.75, 0.42 and 0.25 g kg^{-1} DM, respectively), but were less abundant in zinc, manganese and copper. Jani et al. (2009) reported that curry containing fenugreek seeds was a rich source of calcium, iron and zinc. Mineral elements play a host of important roles in the human body. Potassium is a component of cellular and bodily fluids which regulate the heart rate and blood pressure by countering the effects of sodium. Magnesium is important for energy production and transport, it is involved in glycolysis and oxidative phosphorylation and is required for maintaining normal heart rhythm. This element participates in muscular activity and is required by more than 300 enzymes to catalyze various functions in the body, including protein synthesis, muscle and nerve function (Soetan et al. 2010). The recommended daily intake of this bioelement is 300-380 mg for adults, and diets deficient in this mineral may lead to osteoporosis (Barzegar et al. 2007). In turn, iron is essential for the production of red blood cells (Akbari et al. 2012). Selenium is also an essential element which has antioxidant and anticarcinogenic properties and regulates thyroid function (Güngör et al. 2014). The mineral content of fenugreek seeds has also been investigated by other authors. Shakuntala et al. (2011) reported high levels of Ca, K and Mg in all seed fractions. In a study by Srinivasan (2006), fenugreek seeds were characterized by a high content of K at 5.30, P at 3.70, Ca at 1.60 and Mg at 1.60 g kg^{-1} DM.

In 7 fenugreek genotypes native to Iran, calcium content was determined at 2.00 to 4.55 g kg^{-1} on a fresh weight basis, and 100 g of leaves supplied 200.66-455.25 mg kg^{-1} of calcium (20-45% of the recommended daily allowance for this mineral). Phosphorus content was determined at 182-205 g kg^{-1} and potassium content – at 26.13- 36.40 g kg^{-1} on a fresh weight basis (Table 3). The Ca:P ratio, which is very important for human growth, ranged from 0.8 to 2.0 in the examined leaves. This value is almost ideal (1:2) from the nutritional point of view. The discussed minerals are essential for plant growth, and most of the phosphorus in plant cells is associated with calcium. The Mg content of the analyzed fenugreek genotypes ranged from 1.30 to 3.70 g kg^{-1} on a fresh weight basis, and 100 g of leaves supplied 34-97% RDA of magnesium. Sodium concentrations in the examined Iranian genotypes ranged from 0.28 to 0.59 g kg^{-1} on a fresh weight basis (Gharneh, Davodal -hosseini 2015). The analyzed varieties were also a rich source of Zn.

Table 3

Mineral content of fenugreek leaves

Elements	Srinivasan (2006)	Gharneh, Davodalhosseini (2015)
K (g kg^{-1})	0.31	0.26-0.36
Na (g kg^{-1})	0.76	0.28 -0.59
P (g kg^{-1})	0.51	1.82-2.50
Mg (g kg^{-1})	0.67	1.30-3.70
Ca (g kg^{-1})	3.95	2.00-4.55
Fe (mg kg^{-1})	165.0	56.3.-302.30
Zn (mg kg^{-1})	nd	10.40-41.30
Cu (mg kg^{-1})	2.60	5.00-25.40
Mn (mg kg^{-1})	nd	1.00-8.70
Ca/P ratio	7.74	0.80-2.00

nd – not detected

Lipid content and fatty acid profile

The lipid content of fenugreek seeds is estimated at 100.0 g kg^{-1} DM. Fenugreek lipids contain mostly neutral fats, including diglycerides (6.3%), triglycerides (86.1%), glycolipids (5.4%) and phospholipids (10.5%). Fenugreek seeds also contain small amounts of monoglycerides, free fatty acids and sterols (Hemavathy, Prabhakar 1989). In the different study the content of linoleic acid $C_{18:2}$ was determined in the range of 34.85 to 42.2%, α-linolenic acid $C_{18:3}$ at 22.0-30.8%, myristic acid $C_{14:0}$ at 0.10-1.38%, palmitic acid $C_{16:0}$ at 3.85-13.10%, oleic acid $C_{18:1}$ at 13.30-19.05%, and stearic acid $C_{18:0}$ at 1.78-4.50% (Table 4).

In the work of Srinivasan (2006), the fatty acid profile of fenugreek seeds included oleic acid $C_{18:1}$ at 35.1%, linoleic acid $C_{18:2}$ at 33.7%, α-linolenic acid $C_{18:3}$ at 13.8%, palmitic acid $C_{16:0}$ at 9.6%, stearic acid $C_{18:0}$ at 4.9%, and arachidic acid $C_{20:0}$ at 2.0%. In another study, the content of linoleic acid was estimated at 34.85% and the content of total unsaturated fatty acids at 92.99% (Al Jasass, Al Jasser 2012). Fenugreek oil is a potent antimicrobial agent against *Escherichia coli*, *Staphylococcus aureus*, *Salmonella typhimurium* and *Aspergillus niger*. Fenugreek seeds and oil can be effectively used as food preservatives or in the pharmaceutical industry (Sulieman et al. 2008*b*).

Table 4

Lipid content and fatty acid profiles of fenugreek oil in different studies

Specification	Ciftci et al. (2011)	Bieńkowski et al. (2017) Unpublished data	Sulieman et al. (2008*a*)	Al-Jasass, Al Jasser (2012)
Lipid content (g kg^{-1})	93.20	47.70	84.00	nd
Saturated fatty acids – SFAs (%)				
Lauric (C 12:0)	nd	0.025	nd	nd
Myristic (C 14:0)	0.10	0.18	0.20	1.38
Pentadecanoic (C 15:0)	0.10	0.19	nd	nd
Palmitic (C 16:0)	10.50	13.10	11.00	3.85
Margaric (C 17:0)	0.30	0.43	nd	nd
Stearic (C 18:0)	4.00	3.78	4.50	1.78
Arachidic (C 20:0)	nd	nd	1.50	nd
Heneicosanoic (C 21:0)	0.10	1.40	nd	nd
Behenic (C 22:0)	nd	0.08	0.50	nd
Lignoceric (C 24:0)	0.20	nd	0.10	nd
Total SFAs	16.14	20.00	17.80	7.01
Monounsaturated fatty acids – MUFAs (%)				
Palmitoleic (C 16:1)	0.10	0.07	0.20	8.29
Heptadecenoic (C 17:1)	0.20	0.15	nd	nd
Erucic (22:1)	0.10	nd	nd	nd
Oleic (C 18:1)	15.60	13.30	16.70	19.05
Eicosenoic (C 20:1)	0.30	0.27	0.10	nd
Total MUFAs	15.98	13.80	17.0	27.34
Polyunsaturated fatty acids – PUFAs (%)				
Linoleic (18:2)	41.30	37.90	43.20	34.85
Linolenic (C 18:3)	nd	nd	22.00	30.80
Linolenic (C 18: 3n-6)	1.20	nd	nd	nd
Linolenic (C 18: 3n-3)	46.50	nd	nd	nd
Eicosadienoic (C 20:2)	0.10	0.08	nd	nd
Total PUFAs	67.95	66.20	65.20	65.65
n-6/*n*-3	9.32	nd	nd	nd

nd – not detected

MEDICINAL USES

Fenugreek seeds have been valued for their medicinal properties. Microbiological analyses revealed that fenugreek extracts exhibit antimicrobial activity against numerous bacteria (Aqil, Ahmad 2003, Wagh et al. 2007). Aqueous extracts of fenugreek roots, seeds and shoots have antifungal properties (Haouala et al. 2008). Fenugreek seed preparations are used in the treatment of gastrointestinal disorders. Aqueous solutions and macerated fenugreek oils exert protective effects on the mucosa in ulcer disease (Pandian et al. 2002) and prevent colon cancer (Raju et al. 2004). The hepatoprotective effects of fenugreek are comparable to those of silymarin (Kaviarasan et al. 2008, Pribac et al. 2009). In Iran, fenugreek leaves are used in the treatment of eye diseases (Miraldi et al. 2001) and gynecological disorders (Bashtian et al. 2013). Fenugreek seeds contain the neuroprotective alkaloid trigonelline (Tohda et al. 2005), which can be effectively used in the prevention and treatment of neurodegenerative diseases. Fenugreek seeds also have anti-inflammatory, antipyretic and analgesic properties (Malviya et al. 2010). Active ingredients with hypoglycemic effects include coumarin, trigonelline and nicotinic acid (Abdel-Nabey, Damir 1990). Amin et al. (2005) demonstrated that fenugreek extracts effectively prevent and inhibit the progression of breast cancer. Flavonoids could also significantly contribute to fenugreek's anticarcinogenic properties. Fenugreek constitutes valuable raw material for the pharmaceutical industry that has long searched for effective cures for cancer. Fenugreek extracts have estrogenic properties, which makes them suitable for use in the treatment of impotence and the alleviation of menopausal syndromes. Pharmaceutical companies show a growing interest in fenugreek research due to the presence of diosgenin in the discussed species. Diosgenin significantly lowers cholesterol levels, and it can also be used in the production of oral hormones and steroids (Oncina et al. 2000). Fenugreek seed extracts lower blood glucose levels (Bashtian et al. 2013). In traditional medicine, fenugreek is used to prepare infusions, water and alcohol extracts, tinctures, meads, tonics with antidepressant and psychotonic properties, and muscle growth supplements. Fenugreek is used in the treatment of seborrhea, acne and dermatitis. The plant is widely used in cosmetology (Wijaya et al. 2013).

FENUGREEK AS FOOD

In addition to its medicinal properties, fenugreek is also recognized for its culinary value. The plant is widely used as a spice that not only improves the taste of food, but also contributes to metabolic functions and overall health. Biscuits supplemented with 10% germinated fenugreek had the highest

polyphenol content and were characterized by high nutritional value. Supplementation of wheat flour with 5% and 10% of fenugreek flour increased vitamin B_2 and carotene concentrations in biscuits (Mahmoud et al. 2012). According to the cited study, fenugreek products have restorative properties and may be beneficial for patients suffering from iron-deficiency anemia. However, according to Folwarczna et al. (2014), low dietary intake of fenugreek seeds could exert favorable skeletal effects, whereas high doses could damage the skeletal system.

Fenugreek seeds are used as spice for flavoring selected types of cheese, mainly parmesan. Powdered or crushed seeds are added to salads and cottage cheese spreads. Fenugreek seeds enhance the flavor and aroma of dishes. They are added to curry sauce and are a traditional ingredient of the Bulgarian spice chubritza. Fenugreek seeds are also used to flavor coffee and vanilla extracts (Szczyglewska 2000). Fenugreek seeds and extracts aid digestion and enhance nutrient absorption, in particular amino acids. They contribute to muscle and body mass growth and have nourishing and strengthening properties. Food supplements containing fenugreek have hypoglycemic properties and are recommended for diabetic patients. Fenugreek seeds are roasted for direct consumption and are added to broth and tea. Fenugreek leaves are fried in butter, added to salads and used as spice in the powdered form. A study comparing the quality of honey with various pollen content revealed that the most nutritious types of honey were heterofloral, and samples with the highest antibacterial activity against *Pseudomonas aeruginosa, Escherichia coli* and *Staphylococcus aureus* were characterized by a predominance of fenugreek pollen (Mercan et al. 2007). The examined honey was more effective in eliminating the said bacteria than antibiotics. Fenugreek does not have adverse effects on the human body, even if consumed in large amounts (Muralidhara et al. 1999). In India, normal consumption of fenugreek seeds by adults is estimated at 0.3 to 0.6 g per day. In both humans and animals, diets where the above intake levels were exceeded 50- to 100-fold delivered health benefits. Such diets include dishes with liberal amounts of fenugreek seeds, which are very popular in southern India (Srinivasan 2006). Fenugreek hay contains more soluble protein than alfalfa hay, and there is a growing interest in Canada in fenugreek as an alternative feed crop for dairy cows (Alemu, Doepel 2011). The addition of fenugreek to cattle diets improved milk quality parameters and animal metabolism (Rjat, Taparia 1990). Ground fenugreek seeds and fenugreek oil are also used in the production of fish bait in the form of protein balls.

CONCLUSIONS

Fenugreek is a unique spice crop whose properties are being discovered with the renewed interest in traditional medicine. As rich sources of protein,

lipids, fatty acids and minerals, fenugreek seeds and leaves cater to the body's needs for essential nutrients and deliver numerous health benefits. This ecofriendly plant has a high number of potential applications in the production of food and feed, medicine, cosmetics and pharmaceutical industries due to its nutrient and nutraceutical content. The findings presented in this review paper will be useful for consumers hoping to improve their health by incorporating healthy biogenic elements and fatty acids into their diets.

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