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Potential of *Moringa oleifera* as a functional food ingredient: A review

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Abstract

Nowadays, with continuously changing socio-economic status, people have become more concerned about their health. Utilization of natural products of plant origin having lesser side effects has gained popularity over the years. There is immense scope for foods that can impart health benefits beyond traditional nutrients. *Moringa oleifera* (Drumstick tree) is one such tree having enormous nutritional and medicinal benefits. It is rich in macro and micro nutrients like protein, carbohydrate, calcium, phosphorus, potassium, iron, vitamins, beta carotene and other bioactive compounds which are important for normal functioning of the body and prevention of certain diseases. Most of the parts of *Moringa oleifera* including leaves, flowers and seeds are edible and other parts like bark, pods have use in biodiesel production and water purification. *Moringa oleifera* has tremendous therapeutic properties including anticancer, antiulcer, antimicrobial, antioxidant. Various researches have concluded that *Moringa* should be used as functional ingredient in food products. This review aims to highlight the use of *Moringa oleifera* as a potential ingredient in food products as well as in other industries to serve as a background for future research works.

Keywords: *Moringa oleifera,* functional foods, macro and micro nutrients, therapeutic properties, food use

1. Introduction

There are several foods or food components that provide health benefits. These foods, also known as "functional foods," provide benefits beyond basic nutrition and may play a role in reducing or minimizing the risk of certain diseases and other health conditions [1]. Functional foods may be whole, fortified, enriched or enhanced. Functional components of food include beta carotenes which are known to scavenge free radicals; calcium reduces the risk of osteoporosis; potassium reduces the risk of high blood pressure; flavonoids, fatty acids known to reduce coronary heart diseases and dietary fiber supports gastro intestine health etc.

With the rapidly changing socio-economic status, consumers have become aware and are looking for products that provide benefits beyond nutrition. Functional food market is the fastest growing segment in the food market all over the world. One such natural food source which can be utilized to add functionality to other foods or act as functional food itself is *Moringa oleifera.* The tree is claimed to have potential to improve nutrition, increase food security, and encourage rural development [2]. The drumstick tree is a small fast growing ornamental tree which is native to India. The trees are said to have been originated from Agra and Oudh in North Western region of India to South of the Himalayan Mountains. They are cultivated in Asian, African, Middle Eastern and South American regions [3]. It propagates relatively easily both by sexual and asexual means. It has a low soil nutrient and water demand making its production and management easy. They are drought resistant, and hence are able to withstand a wide range of soil and rainfall conditions and are therefore available throughout the year [3]. People often call it a "Miracle Tree" as the drumstick leaves are also available in summers when other vegetables are scarce.

There are thirteen species of *Moringa*. Few species which include *Moringa stenopetala*, *Moringa drouhardii*, *Moringa hildebrandtii* are known to have fat, protein and other nutrients profile comparable to *Moringa oleifera* to some extent (Table 1). Out of these thirteen species *Moringa oleifera* is the most studied so far. As a source for protein and essential amino acids (EAA), *M. oleifera* leaves are superior to the leaves of *M. hildebrandtii* and *M. drouhardii* [4].

Table 1: Comparison of nutritional content of leaves of different *Moringa* species

Nutrient	*Moringa oleifera* (Malawi origin)	*Moringa drouhardii* (Madagascar)	*Moringa hildebrandtii* (Gran canary)
Crude protein (CP) (g/kg)	277	197	222
Essential Amino acids (%CP)			
Methionine	1.66	1.67	1.31
Valine	4.69	5.00	4.01
Isoleucine	4.01	4.22	3.24
Leucine	7.65	7.71	6.08
Phenylalanine	6.28	5.16	4.37
Histidine	2.35	2.34	2.25

Lysine	5.20	5.26	4.46
Threonine	4.26	4.32	4.05
Tryptophan	2.06	1.93	1.80
Crude Lipid (g/kg)	-	37	52
Calcium (g/kg)	22.2	11.9	15.7
Phosphorus (g/kg)	3.70	2.19	4.66
Magnesium (g/kg)	8.79	9.06	4.90
Potassium (g/kg)	13.5	12.3	19.5
Sodium (g/kg)	0.60	9.78	5.04

1.1 Use of different parts of *Moringa Oleifera*

Almost all part of the plant which includes root, bark, seed, flowers, pods, seed oil, leaf, resin have potential food, agriculture and industrial uses. It has versatile utility as medicine, functional food, nutraceutical and water purifying properties and is thus considered to be world's most useful plant [2]. In some part of the world the tree is known as mother's best friend because its consumption is known to increase milk production and can also treat anemia which is common in lactating women [5].

1) **Leaves-** Drumstick tree leaves are packed with nutritional properties and are 100% edible. They are a rich source of nutrients like protein, carbohydrate, fiber, Beta carotene, vitamin C and minerals like calcium, potassium, iron and phosphorous [6]. The protein content of the dried *Moringa oleifera* leaf powder is equivalent to the protein content of some pulses viz. moth beans, soybeans, kidney beans etc., which contain (22 - 24%) protein, thus used in food. Leaves contain essential amino acids such as methionine, cysteine, tryptophan and lysine, are thus ideal for regular diet [7]. The leaves contain various types of antioxidant compounds such as ascorbic acid, flavonoids, phenolic compounds and carotenoids and act as a natural antioxidant [8].

The nutrient content of the plant varies with soil, climate and other environmental conditions. Processing and storage adds on to the variations. Though Fresh leaves contain nutrients in higher amount, processing of leaves is important to extend the shelf life. *Moringa oleifera* leaves can be dried using various methods which include sun drying, shadow drying and oven drying. The most common method used is oven drying. All the drying mechanism follows same preliminary steps which are, procuring leaves sample, washing them under running water and, removing excess water by spreading them. These leaves are accordingly then dried under sun, shadow or a mechanical drier. Pretreatment like blanching and cutting decreases the time of moisture removal but at the same time these processes darken the color and change the flavor of the dehydrated product [9].

2) **Flowers-** The flowers, which are bisexual and are pleasantly fragrant, and 2.5cm wide. They are white or cream colored and the base is yellow doted [10]. *Moringa* flowers are good source of nectar for honey production. They can be eaten raw with salads, can be used to make tea, can be eaten after blanching etc.
3) **Pods-** The fruits which hang down from the branches are three lobed pods and are 20-60cm in length when they are dry open into 3 parts, each pods contains between 12-35 seeds [10]. Pods contain the polysaccharide d-galactose, 6-O-Me-D-galactose, D-galacturonic acid, l-arabinose, and l-rhamnose in a molar ratio of 1:1:1:1 and Nitriles, an isothiocyanate and thiocarbamates [11]. Pods can be boiled and eaten like beans. Fibre content in the pod increase when it grows and hence should be consumed when they can be easily broken [7].
4) **Seeds-** Around 15,000 to 25,000 seeds are produced from a single tree in a year. The seeds have brownish semi permeable seed hull and are round in shape. Seeds contain average amount of Vitamin A and E. The seed contain polypeptides, which act as coagulant and are therefore used to treat river water with suspended solids and groundwater [12] and as a source of oil for biodiesel production [13]. Seeds are used commercially to produce oil known as "ben oil". The sweet smell and potential to absorb and retain volatile substances of oil makes it useful in perfume and hair care products. Seeds contain between 30-42% oil which is brilliant yellow in color and the press-cake obtained as a by-product of the oil extraction process contains a very high level of proteins. Physicochemical properties and fatty acid composition of *Moringa* seed oil [4] are presented in Table 2. Seeds also have use in waste water treatment as they contain cationic polyelectrolyte which neutralizes the negatively charged colloids present in dirty and muddy water [7]. Seed oil also possesses antimicrobial activity. The antimicrobial activities are attributed to the compound 4(α-L-rhamnosyloxy) benzyl iso-thiocynat [5] whose mode of action includes either inhibiting the essential enzymes or disrupting the cell membrane [14].

Table 2: Physicochemical properties and fatty acid composition of *Moringa* seed oil

Properties	**Value**
Saponification value	182.9
Iodine value	66.4
Density at 20 ˚C (g/ml)	0.89737
Refractive Index at 20 ˚C	1.4670
Solidification point	6
Free fatty acids (%)	Upto 2.98
Fatty acid composition (% crude lipid)	
Lauric	Trace
Myristic	0.08
Pentadecenoic	Trace
Palmitic	5.45
Stearic	5.42
Oleic	72.9
Linoleic	0.76
Linolenic	0.14
Arachidic	3.39
Eicosadieroic	-
Other fatty acids	11.86

The dry seeds can be dried and made to powder for seasoning purposes. There are works which emphasize on considering *Moringa oleifera* seeds for bioethanol production as it has a high content of cellulose. The husk hydrolyzed using NaOH and fermented using *Saccharomyces cerevisiae* produced considerable bioethanol. Bioethanol is an effective alternative of conventional fossil fuels in terms of cost, biodegradability and effects on environment [15]. The resin from trunk can also be used as a thickening agent for sauces. The *Moringa* foliage contains more polyunsaturated fatty acids (PUFA) than saturated fatty acids, which is good for health [16].

2. Nutritional constituents of *Moringa oleifera*

Moringa oleifera is a good source of many nutrients (Table 3) like:

1. Protein which is required for tissue growth and deficiency of which can lead to growth retardation, kwashiorkor etc. The leaves and other parts of the tree contain high amount of crude proteins and amino acids, comparable to soy bean [17].
2. Vitamins like vitamin A which is important for health of eyes & hair, vitamin C and other B group vitamin.
3. Minerals like calcium which helps in building bones & teeth and its deficiency can cause rickets, bone pain, osteoporosis etc. It is claimed that eight ounces of *Moringa* leaves give 1000 mg of calcium and dry *Moringa* powder can give 4000 mg calcium while milk only gives 300-400 mg of calcium [18].
4. Potassium which transmits nerve impulses & its deficiency can cause loss of appetite and sometimes coma.
5. Phosphorus which has role in the formation of bones and teeth, is also needed for the body to make protein for growth, make ATP, maintenance, repair of cells & tissues.
6. Iron and can replace iron tablets. Zinc content of *Moringa* is also in accordance of the dietary requirements, which is important for the RNA & DNA synthesis [18].
7. Fiber which helps in maintaining a healthy gut.
8. Bioactive compounds like tannins, alkaloids, phenolic compounds, amino acids, sterols and carbohydrates [11].

Table 3: Nutritional content of fresh and dried *Moringa oleifera* leaves (per 100gm) [6]

Nutrient	Fresh leaves	Oven dried
Moisture (%)	75.9	6
Energy (Kcal)	92	271.54
Protein (g)	6.7	23.78
Carbohydrates(g)	12.5	28.32
Fat (g)	1.7	7.014
Fibre (g)	0.9	11.8
Vitamin C (mg)	220	56
Beta – carotene (µg)	6780	37800
Iron (mg)	0.85	19
Calcium (mg)	440	3467
Phosphorus (mg)	70	215
Beta carotene (µg)	6780	37800

3. Therapeutic importance

Moringa oleifera is found to contain non-nutritive chemicals which they use as self-defense mechanism also known as Phytochemicals. These phytochemicals include catechol tannins, gallic tannins, steroids, triterpenoids, flavonoids, saponins, antraquinones, alkaloids and reducinfg sugars (Table 4). These chemicals have significant medicinal uses like as antibiotics, anti-inflammatory, for skin treatment, blood pressure regulation, anemia treatment and diabetes. Leaves of *Moringa* are known to have various biological activities, including antitumor, anticancer, prevention of cardiovascular diseases and antioxidant [19]. It has been used traditionally to treat constipation [5].

Table 4: Phytochemicals present in *Moringa oleifera* leaves [20].

Phytochemical	Ether extract	Ethanol extract	Water extract
Gallic tannins	+	+	++
Catechol Tannins	+	-	++
Coumarins	-	-	-
Steroids and Triterpenoids	+++	++	++
Flavonoids	++	++	++
Saponins	+	+	++
Anthraquinones	+	++	+++
Alkaloids	+	-	++
Reducing sugars	-	++	++

-:not detected; +: present in low concentration; ++: present in moderate concentration; +++ present in high concentrations.

3.1 Antibacterial activity

The methanolic, ethanolic and chloroform extract of leaves has antibacterial activity against Gram negative bacteria such as: *Shigellashinga, Pseudomonas aeruginosa, Shigellasonnei* and *Pseudomonas spp.* and six Gram-positive bacteria: *Staphylococcus aureus, Enterobacter aerogenes, Escherichia coli, Salmonella typhi, Streptococcus-B- haemolytica, Bacillus subtilis, Sarcinalutea*and *Bacillus megaterium.* The extracts of leaves are also found to be active against various strains of fungus as *Alternaria* species (sp), *Colletotrichum*sp, *Curvularia*sp and *Fusarium* sp. [11]. It has also been investigated that the fresh leaf juice and aqueous extracts from the seeds inhibit the growth of Pseudomonas aeruginosa and Staphylococcus aureus [21]. One of the antibacterial compound found in *Moringa* is "pterygospermin" [22]. The activity of plant is comparable to synthetic antibiotic kanamycin [23].

3.2 Antioxidant Activity

The morphological parts of *Moringa* like seed coat, seed cotyledon, stem bark, root bark are known to possess antimicrobial activity. Several studies on the antioxidant activity of the leaves and flowers of the *Moringa oleifera* have been done and the results are compared to those of particular vegetables (cabbage, spinach, broccoli, cauliflower and peas). Pakade *et al.*, [24] determined the total phenolic content (TPC) and total flavonoid content (TFC) of dried *Moringa* leaf samples and observed that the TPC was almost twice for of the *Moringa* samples to those of the selected vegetables, whereas the TFC was almost three times more than those of the selected vegetables. It can be concluded that *Moringa* exhibited greater antioxidant activity than the selected vegetables. *Moringa* has also been reported to contain different types of tocopherols that are α, γ and $^{\delta}$ at a fairly high

amount. The leaf extract of *Moringa oleifera* has higher phenolic content than the fruit and seed thus possess higher antioxidant activity. Both tender and mature leaves extract are found to scavenge the DPPH (2,2-Diphenyl-Picrylhydrazyl) free radical. The scavenging activity is attributed to its hydrogen donating ability which is more in the mature leaf than the tender ones [25].

3.3 Antiulcer activity
Moringa oleifera has also been investigated for its antiulcer activity. There are studies thatshow that the extract of leaves and fruits of *Moringa oleifera* has ability to heal chronic gastric ulcers induced via acetic acid [26].

3.4 Anti-inflammatory activity
The phytochemicals like phenolic acids and flavanols present in *Moringa* are associated with its anti-inflammatory effect [27].

3.5 Antihypertensive, diuretic and cholesterol lowering activities
It has been found to contain Nitrile, mustard oil glycosides and thiocarbamate glycosides which are considered to be responsible for the blood pressure lowering effect. Almost all the part of the tree has been reported to possess diuretic activity. *Moringa* fruit has been reported to reduce the lipid profile of liver, heart and aorta in hypercholestremic rabbits [28]. Moreover, vitamins and phenolic acids present in *Moringa oleifera* also help to fight against many ailments such as coronary heart disease and blood clots which can lead to strokes and cancers (Ananias. It has also been studied that *Moringa* can be used to treat anemia. Anita *et al.*, [29] studied this property using animal model in which they treated rats with different iron sources. The different groups were treated with *E. durans, Moringa* plus *E. duran*s and *E. durans* plus iron supplement (1ml/rat). It was observed that the rats treated with probioticated *Moringa* leaf extract had higher level of hemoglobin. Thus, it can be used as a nutraceutical supplement to treat anemia.

3.6 *Moringa* contains an anti-aging compound called Zeatin, which is naturally occurring cytokinins [30]. It is a strong antioxidant, effective against prostate and skin cancers, and anti-tumor.

3.7 Leaves of *Moringa oleifera* are also known to have anti diabetic and anti-obese properties. Studies have shown that on orally administering the ethanolic leaves extract to the obese rats for 12 consecutive weeks, decreased the body weight. This treatment also normalized the insulin and blood glucose level of the obese group of rats [31].

3.8 It is also effective against snake and scorpion bites and act as detoxifying agent. Certain nervous disorders including headaches, migraines, hysteria, and epilepsy can also be cured to some extent with *Moringa oleifera*.

3.9 *Moringa* can also be useful in treatment of Hyperthyroidism since aqueous leaf extract has been found to regulate thyroid hormone [5].

3.10 Dry stem powder of *Moringa* is used as an antidote to poisonous bites in locals of Tamil Nadu [32].

3.11 Anti-nutritional components like tannins are present in leaves which when consumed have adverse effect on the health and productivity of animals. Other anti-nutritional components which have been reported are raffinose and stachyose which produce flatulence.

4. Applications of *Moringa oleifera*
4.1 Agriculture Uses
1. Fertilizer- The seed cake, which is obtained during the processing of the seeds to extract oil, contains harmful substances and thus cannot be consumed. However, it contains high levels of proteins and makes a good fertilizer for use in agriculture. *Moringa oleifera* has also been known to fix nitrogenous compounds in soil.
2. Fuel wood- wood provides a fairly good fuel for cooking even being light in weight [33].
3. The trees also produce viscose resin that are used in the textile industries [34].
4. Sources of growth hormones- Effective growth hormones can be produced from Juice of fresh *Moringa* leaves, and yield can be increased by 25-30% for nearly any group of plants (maize, bell pepper, tomato, soya, onion, sorghum, tea, coffee. melon and chili). One of the active substances is zeatin, a plant hormone from cytokinin group [10].
5. Fodder- presence of high crude protein and availability of the protein and low content of anti-nutritional compounds make it ideal for use as fodder. Saponins present in some plants have adverse effect on the growth of animal but those present in *Moringa* do not show hemolytic activity. There are many problems like unavailability of feed during dry seasons, nutritional imbalances in feed; these problems can be fought by using *Moringa* as forage.
6. Source of biogas: With an average feed of 5.7 g of volatile solids the gas production was 580 liters of gas per 1 kg of volatile solids. The average methane content of the gas was 81 % [35].

4.2 Economic Uses
To avoid eutrophication of rivers or lakes by the discharge of high loads of both phosphorus and nitrogen, the seeds of *Moringa* can be used to coagulate and remove algae by this treatment. The seeds are usually used as anticoagulant. For every 1 liter of water to be purified, 30 to 300 milligrams of *Moringa* seed powder is found sufficient. The seeds not only just act as natural coagulant but also possess antimicrobial properties and are found to contain a recombinant protein which can flocculate Gram-positive and Gram-negative bacterial cells [36].

It is also useful in intercropping. The sole crop of maize and sweet potato were compared with the maize plus *Moringa* and sweet potato plus *Moringa*, the results indicated a decrease in soil acidity from 1.86 to 1.60. *Moringa* plus maize and *Moringa* plus sweet potato combination produced the highest crop growth than the sole crop [37].

Moringa oleifera leaves can be utilized as plant growth promoter. There are five different groups of growth regulators including auxins, gibberellins, abscisic acid, ethylene and cytokinins which enhance food production [38].

4.3 Human Consumption
Moringa is one of the most underutilized and unexplored tropical crop in the world. Though, none of the plant's part is

such that can be not used. Leaves are of special consideration. Leaves of *Moringa oleifera* could serve as a valuable source of nutrient for all age groups. It is inexpensive and available in abundance.

5. Potential food application of *Moringa oleifera* leaves

Consumers knowledge about the relationship between food, health and nutrition has increased as well as the need to develop foods with functional ingredients from plant source such as *Moringa oleifera*. *Moringa* is well known as 'natural nutrition of the tropics'. Food scientists and nutritionists encourage the cultivation, incorporation and consumption of *Moringa oleifera* in the diet. Deriving simple, acceptable and nutritionally rich foods out of it would help in fighting nutritional deficiencies across nations. Moreover, formulation of such foods will also provide a variety to the diet. Partic1ularly in developing nations where the number of people living under the poverty line is high, identification of inexpensive, easily available food items with rich source of nutrients will be a big boon to the food industry [6].

The leaves, pods and seeds of *Moringa oleifera* tree possess enormous nutritional and antioxidant properties. Both fresh and dried *Moringa* leaves can be included in meals and are in use in some African countries [19]. Leaves particularly when dried are easy to handle and store as they have a very good shelf life. Also, after drying, the nutrients are more concentrated, thereby making them even richer and more valuable.

Oduro *et al.*, [39] compared the crude fat content of sweet potato leaves and *Moringa oleifera* leaves and he found the crude fat content of *Moringa* was higher than the sweet potato. Since dietary fat absorbs and retains flavor, a diet containing *Moringa* leaves is considered to be more palatable.

The use of this plant as an ingredient in foods to add functionality has increased recently. Many studies have shown the potential use of different parts of *Moringa oleifera* in food applications such as:

1. Soups, *Moringa* leaves alone or in combination with spinach, melon etc. can be used as ingredient in soups [40].
2. Weaning foods, *Moringa oleifera* flower powder or *Moringa oleifera* leaves powder is known to increase nutritional value of weaning foods [41]
3. *Moringa* paneer, Paneer with extract of *Moringa oleifera* leaf of different concentration were investigated and it was found to have high nutrient content than normal paneer [42]
4. *Moringa* incorporated chocolate and Halawa Tahinia were prepared and estimated for its nutritional content, it was found that the protein, crude fiber and ash content increased appreciably with increasing concentration of *Moringa* leaf powder [2]
5. Herbal biscuits, biscuits incorporated with *Moringa oleifera* leaf powder at the rate of 5% was reported to increase protein content by 14% [43].
6. Bread fortified with 5% of *Moringa oleifera* was found to have 17% and 88% increase in protein and dietary fiber content [44].
7. Cakes were made by using whole wheat flour with different quantities of *Moringa* leaf (2g, 4g, 6g, 8g and 10g). The cakes were checked on Nutritional and sensory parameters. It was found that moisture, crude protein, crude fiber and total ash showed an increase while total fat and carbohydrate content decreased with increasing concentration of *Moringa* [44].
8. Yoghurt: Hekmat *et al*. [45] fortified yoghurt with *Moringa* oleifera leaves. The product was not rated as good as the control with respect to sensory parameters at the same time it did not negatively affect the growth of lactobacillus rhamnosus GR-1 in yoghurt.
9. Khakhra: Dried drumstick leaves with high antioxidant activity were incorporated in khakhras in proportion 0, 2, 4, 6, 8, 10 % and were evaluated for physicochemical and sensory analysis. Incorporation of such treated leaves (sun dried, shadow dried and mechanically dried) increased the moisture, fat, ash, protein, carbohydrate and antioxidant activity of the khakhras [46].
10. Chin Chin: Chin chin is a Nigerian snack product which is made of wheat flour, butter, egg, milk. It is a deepfried product and hence has a crispy texture. Emilike *et al*., [47] studied the effect of different drying techniques (sun dried, oven dried, shadow dried) used to dry *Moringa* leaves on the *Moringa* incorporated chin chin. They found that oven dried samples had a reduced fat and moisture content compared to the control. Elemental analysis revealed that Oven dried sample had the highest calcium (190.5mg/100g), sun dried highest zinc (7.1mg/100g) and shade dried highest iron content of 51.3mg/100g.
11. Fortified ice milk: *Moringa oleifera* dry leaves powder has been recommended to fortify foods. Salama *et al*., [48] reported that addition of 0.5% of *Moringa oleifera* dried leaves and 6% of *Moringa oleifera* oil can be done to prepare fortified ice milk with increased nutritional qualitities as well as sensory parameters.
12. *Moringa* Muffin: *Moringa oleifera* dried powder has also been used in the production of muffin, where up to 12 % concentration (per 55gms of flour used) of dried leaves powder were incorporated. At this concentration, the muffin can be produced successfully with enhanced nutritional qualities and acceptable sensory qualities. The values for ash content increased significantly from the controlled muffin. The *Moringa* muffin was found to contain significantly high amount of protein, fat, beta carotene, and vitamin C. The mineral content was also high for *Moringa* muffin. Calcium, iron and Potassium content of the *Moringa* muffin was found to increase significantly than the controlled one. Phosphorus content also increased in the *Moringa* muffin though not significantly [49].

6. Conclusion

Moringa oleifera is an excellent source of macro and micro nutrients including antioxidants. *Moringa oleifera* leaves are not as popular as other leafy vegetables like spinach, fenugreek around the world but are used as their substitutes in soups, lentils and other preparation in Southern and Eastern parts of India. There is a knowledge gap in potential uses of *Moringa* and its use in food fortification. *Moringa* has enormous potential uses but is very less explored. It can be utilized to make foods that could be a step towards curbing

malnutrition. The available literature gives the total overview of the chemical constituents, nutritional content, potential uses and pharmacological activities of the plant. Very less literature is available regarding the toxicity of this plant. The identification, isolation and standardization of plant extracts may be considered for detailed studies which can be useful for the further development of the promising food products with health benefits and nutrients to cure malnutrition.

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