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REVIEW

Nutritional and therapeutic perspectives of Chia (*Salvia hispanica* L.): a review

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Abstract The ancient grain is becoming enormously popular in modern food regimen in many countries; the higher proportion of α-linolenic acid makes chia the superb source of omega-3 fatty (about 65 % of the oil content). Omega-3 fatty acid has been associated with a large number of physiological functions in human body. Chia seed is a potential source of antioxidants with the presence of chlorogenic acid, caffeic acid, myricetin, quercetin, and kaempferol which are believed to have cardiac, hepatic protective effects, anti-ageing and anti-carcinogenic characteristics. It is also a great source of dietary fibre which is beneficial for the digestive system and controlling diabetes mellitus with higher concentration of beneficial unsaturated fatty acids, gluten free protein, vitamin, minerals and phenolic compounds. Therapeutic effects of chia in the control of diabetes, dyslipidaemia, hypertension, as anti-inflammatory, antioxidant, anti-blood clotting, laxative, antidepressant, antianxiety, analgesic, vision and immune improver is scientifically established.

Keywords Chia · Omega-3 fatty acids · Protein · Fibre · Nutritional and therapeutic properties

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Introduction

Chia (*Salvia hispanica* L.) was originated from Mexico and Guatemala; it has been the part of human food for about 5500 years. Traditionally, the seeds were used by Aztecs and Mayas people in the preparation of folk medicines, food and canvases. In pre-historic times in Columbian societies, it was the second main crop after beans (Armstrong 2004). Whole and ground versions of chia along with its oil was the part of food, ancient cosmetics and the part of religious rituals in prehistoric times in Aztecs communities (Beltran-Orozco and Romero 2003). The word chia is derived from a Spanish word chian which means oily, it is oilseed, with a power house of omega-3 fatty acids, superior quality protein, higher extent of dietary fibre, vitamins, minerals and wide range of polyphenolic antioxidants which act as antioxidant and safeguard the seeds from chemical and microbial breakdown (Cahill 2003). Existence of chia as an integral part of the pre-Columbian diet had made their diets even superior to today's diet (Hentry et al. 1990) which is also admitted by the modern science. The massive nutritional and therapeutic potential of chia is little known, chia offers a great future perspective for feed, food, medical, pharmaceutical and neutraceutical sectors. Information contained in this review can be useful for health conscious people who want to be healthy through natural foods. This paper describes the huge nutritional and therapeutic potential of chia seed to make it the part of an average diet for better health and longevity.

Chia seed history

Chia (*Salvia hispanica* L.) belongs to the family Labiatae, originated from Mexico and northern and Gualtemala. The seeds have been the part of human nutrition since 1500 BC (Cahill 2003; Ayerza and Coates 2005). Traditionally seeds have been used as a food, in a wide range of folk medicines, primary cosmetics and a part of religious rituals in pre-Columbian societies (Craig 2004). The diets in pre-Columbian regimes were as nutritious as today (Hentry et al. 1990). The chia seed is widely used in many countries since thousands of years due to its massive nutritional and therapeutic potential (Fernandez et al. 2006a).

Botanical description

Chia belong to the family Lamiaceae; Genera Salvia Specie; hispanica, commonly known as chia, Spanish sage, Mexican chia and black chia (Hentry et al. 1990). Plant is an annual herb bears flower in summer, with a height of about one meter with reverse petiolate and serrated leaves (4–8 cm long; 3–5 cm wide) with hermaphrodite flowers (USDA 2011). Plant can grow in a wide range of well drained clay and sandy soils with reasonable salt and acid tolerance. It can produce 500–600 kg seed/acre but under appropriate agronomic conditions the yield of 2500 kg/acre has also been reported (Cahill 2003).

Nutritional composition of seed

The protein, fat, carbohydrate, dietary fibre, ash and dry matter contents of chia seeds ranged from 15 to 25 %, 30–33 %, 41 %, 18–30 %, 4–5 % and 90–93 % with a wide range of polyphenols (Ixtaina et al. 2008). The heavy metal content of seeds was within the safe limits with no potentially toxic mycotoxins and gluten (Peiretti and Gai 2009). Currently chia seed is widely used for the extraction of bio-active compounds for the development of functional foods (Bresson et al. 2009). The protein content of chia seed grown in different habitats ranged from 18.8 % to 21.5 %, the variation in protein content was probably be due to agronomic, climatic and soil conditions (Ting et al. 1990). In another study regarding the nutritional characterization of chia seed; medicinal characteristics of chia seed] reported that seed exhibited 20 % protein, 25 % fibre and 34 % oil. The high fibre content of chia seed as health perspective, fibre increases stool volume, prevent from diverticulosis and cancer. Comparison of nutritional characteristics chia with some other foods, mineral and vitamin content is presented in Table 1. The declaration chia a functional food by the European Parliament had a great deal of effect on its popularity, chia seed is now extensively used as a part of foods in Mexico, Argentina, Chile, New Zealand, Japan, USA, Canada and Australia for different purposes. Chia is considered as a safe food with no potentially harmful effects and widely used in baked goods, nutritional supplements, cereal bars, cookies, bread, snacks etc. (Beltran-Orozco and Romero 2003). Chia seed contains appreciable amount of fibre, which can absorb up 15 times water the weight of seed. The presence of higher extents of fibre help in diabetes mellitus by slowing down the digestion process and release of glucose, it also improves the peristaltic movement of intestine and reducing plasma cholesterol. The biological value of chia is superior to cereals and higher content of calcium, magnesium and potassium than milk (De Tucci 2006). US dietary guidelines recommend consuming chia as a primary source of food, chia sprouts are used in salads, chia seed is used in beverages and cereals based foods and it can be consumed in raw form (Ali et al. 2012).

Table 1 Nutrient value of chia seed

Nutrient	USDA	Comparison of fibre content of some foods Reference: Fernández et al. 2006b.	
Energy (100 g)	486	Chia	37.7
Protein %	16.54	Walnuts	5.2
Fat %	30.47	Fava Beans	19.0
Vitamin C mg	1.6	Figs and Plums	17.0
Thiamine mg	0.62	Dried Peas	4.4
Riboflavin mg	0.17	Breakfast Cereals	4.0
Niacin mg	883	Banana	4.0
Folate µg	49	Lentils	12–15
Calcium mg	631	Almond	14.0
Potassium mg	407	Carrots	2.9
Magnesium mg	335	White Bread	2.2
Phosphorus mg	860	Cauliflower	2.1
Selenium (µg)	55.2	Peanut	8.1
Iron mg	7.72	Quince	6.4
Zinc 4,58		Kiwi	1.6

USDA National Nutrient Database for Standard Reference, Release 24 (2011)

Protein content

With 20 % protein content, chia possesses a massive potential to correct and prevent protein energy malnutrition. Protein content of the seed greatly depends upon environmental and agronomic factors. The protein content of chia seed is greater than protein content of all the cereals. The absence of gluten in chia is another unique feature of chia that it can be digested by the patients suffering from celiac disease. The literature revealed the presence of 9 essential amino acids in chia in appreciable amount. Foods rich in protein had a great deal of effect on weight loss due to the loss of fats in the body. The

results of a study revealed that intake of 25 % protein of the total energy, consequence in a significant fat loss (Skov et al. 1999). Consumption of high protein diet may also help to maintain body weight. The effect of high protein (18 % of the total energy intake) and low protein diet (5 % of the total energy intake) on 113 overweight male and females was investigated for 4 weeks. It was concluded that the group which was fed over high protein diet lost more weight than the other group which was kept over low protein diet (Lejeune et al. 2005a). The regular intake of chia may help the overweight men and women to lose weight; however, this aspect needs detailed investigation. The major protein in chia seed is globulin which constitutes about 52 % of the total protein with mostly 11S and 7S proteins and molecular size ranged from 15 to 50 kDa. Albumins and globulins revealed a better thermal stability, albumins, globulins, prolamins and glutenins denatured at 103, 105, 85.6 and 91 °C. Seed revealed a good balance of essential and non-essential amino acids (Sandoval-Oliveros and Paredes-Lopez 2013).

Fibre content

The dietary fibre contained in foods and especially in whole grains is an important biocomponent due to its potential health benefit. A large number of research studies have shown the effect of fibre consume such as the decrease of risk for coronary heart disease, risk for diabetes mellitus type 2, and several types of cancer (Reyes-Caudillo et al. 2008) On other hand, the consumption of dietary fibre has been associated with the increases of post meal satiety and decreases subsequent hunger. According to the American Dietetic Association dietary fibre has demonstrated benefits for health maintenance and disease prevention (USDA 2000). Chia seed contains between 34 and 40 g of dietary fibre per 100 g, equivalent to 100 % of the daily recommendations for the adult population; the defatted flour possesses 40 % fibre, 5–10 % of which is soluble and forms part of the mucilage. (Mohd et al. 2012) This fibre content is higher than quinoa, flaxseed, and amaranth, even grater compared with other dried products (Table 2). Therefore, chia seed can be used in the prevention of many cardiovascular diseases and diabetes, among others, as demonstrated by a number of epidemiological studies (Tables 3 and 4).

Minerals

The huge nutritional potential is evident from the fact that it contains 6, 11 and 4 times higher calcium, phosphorous and magnesium. The calcium, phosphorous and potassium content of chia is many folds greater than wheat, rice, oats and corn with 6 and 2.4 times greater iron spinach and liver (Beltran-Orozco and Romero 2003). The concentration of macronutrients in chia is as; calcium 631, potassium 407, magnesium 335, phosphorus 860 mg/100 g. Microelements; selenium 55.2, copper 0.924, iron 7.72, manganese 2.72, molybdenum 0.2, sodium 16 and zinc 4.58 μg/100 g.

Table 2 Fibre content of some foods

Food	Fibre g/100 g	Food	Fibre g/100 g
Chia	**34.4**	Dried Plums	7.1
Flax Seed	27.3	Dried Fig	9.8
Amaranth	6.7	Dried Apple	8.7
Quiona	7.0	Dried Banana	9.9
Amond	12.2	Dried Peaches	8.2
Peanuts	8.5	Dried Pears	7.5
Soybean	9.6		

U.S. Department of Agriculture (2011)

Chemical characteristics of chia seed oil (CSO)

Iodine value, saponification value, tocopherol content of chia oil was 207, 193.3 and 480 mg/kg, with 0.1 and 0.3 ppm Cu and Fe, respectively. The oil revealed a lower peroxide and anisidine value 1.0 ($meqO_2/kg$) and 0.3 the induction period of oil as measured on Rancimat was 2.3 h. Contradictory findings regarding oil yield has been reported in literature, Coates and Ayerza (1996) reported that yield of CSO was 32.2 to 36.8 as compared to 35.6 to 38.6 reported from Chia seeds grown in Argentina. The difference in oil yield could be connected to the difference in climatic conditions, agronomic practices, fertilization regimes, irrigation practices etc. (Chapman 2001). The higher values of tocoperols can have a positive impact on the storage stability of chia oil. The lower induction period in the investigation was correlated to the higher extent of unsaturated fatty acids present in chia oil. However, detailed investigation is required on the processing performance and storage stability of chia oil as this aspect of this marvellous oil has not been studied so far. The comparison of chemical characteristics of chia oil of various sources and protein content of chia seed is given in Fig. 1. Chia produces light coloured essential oil in higher

Table 3 Protein content

Cereal	Protein Content%
Chia	20.70
Oats	16.89
Barley	12.48
Corn	9.42
Rice	6.50

(Ayerza and Coates 2005)

Table 4 Amino acid profile of chia

Amino Acid	Chia (g/100 g)	Soybean (g/100 g)
Aspartic acid	1.69	5.11
Threonine	0.71	1.77
Serine	1.05	2.36
Glutamic acid	3.50	7.88
Glycine	0.95	1.88
Alanine	1.05	1.91
Valine	0.95	2.10
Cysteine	0.41	0.65
Methionine	0.59	0.54
Isoleucine	0.80	1.97
Leucine	1.37	3.31
Tryptophane	0.44	0.59
Tyrosine	0.56	1.54
Phenylalanine∗ 1.016	1.01	2.12
Lysine	0.97	2.71
Histidine	0.53	1.10
Arginine	2.14	3.15
Proline	0.77	2.38
Reference	U.S. Department of Agriculture (2011).	Seed Proteins; Shewry and Casey (2003).

concentration; the major part of oil is used in the formulation of omega-3 supplements. Chia leaf oil can also be used a condiment/flavour enhancer (Ahmed et al. 2006; Beltran-Orozco and Romero 2003). The higher concentration of omega-3 in chia oil can help to correct the dislipidemia i.e. increased LDL, triglyceride and lower HDL cholesterol.

Fatty acid composition

The trend of healthy life style has a high degree of effect on the utilization of functional foods. American Heart Association also directs the consumers to shift from saturated fats to unsaturated oils (USDA 2000). Foods with lower contents of saturated fatty acids are the order of day and in recent year's significant increase in the demand of such products have been observed. The great deal of shifting from saturated fats to unsaturated sources of oils is greatly attributed to the large number of incidences of cardio-vascular diseases, hypertension, obesity, diabetes other health related disorders (Hansel et al. 2007). The situation has led to the increased consumption of functional foods containing higher content of polyunsaturated fatty acids. The hypercholesterolemic effect of saturated acids and health benefits of polyunsaturated fatty acids has been well recognized (Lokuruka 2007). Omega-3

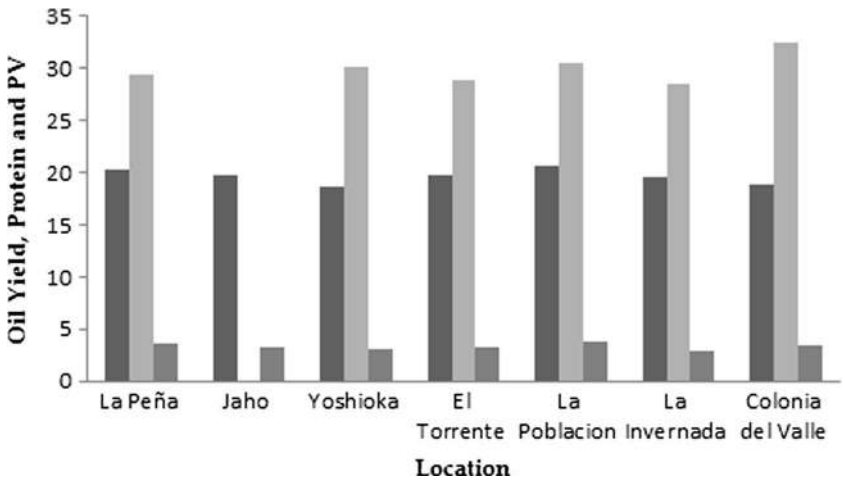

Fig. 1 Chemical characteristics of chia from various sources. Reference: Ayerza and Coates (2004). PV: Peroxide Value ($meqO_2/kg$)

fatty acids have three carbon atoms between last double bond methyl group, whereas omega-6 has six carbon atoms in between the methyl group and last double bond (Pawlosky et al. 2003). The presence of higher concentration of polyunsaturated fatty acids in chia oil has increased its popularity and cultivation many folds. Omega-3 fatty acids are comprised of three essential fatty acids; alpha-linolenic acid, eicosapentaenoic acid, and docosahexaenoic acid whereas omega-6 is comprised of linoleic acid and arachidonic acid (Pawlosky et al. 2003). Chia seed with appreciable amounts of ω-3 alpha-linolenic acid (ALA) and ω-6 linoleic acid. Of all the known food sources chia contains the highest concentration of these fatty acids. On an average it contains about 64 % ω-3 and 19 % ω-6 fatty acids (Ali et al. 2012). The seed is appropriately known as power house of omega fatty acids. Eicosapentaenoic acid, and docosahexaenoic acid have cardio-protective effects (Manzella and Paolisso 2005) (Tables 5).

Phytochemicals in chia seed

Unrestrained free radicals in human body leads to oxidative damage of animated organs and biochemical compounds, oxidative stresses can consequence in diabetes, arteriosclerosis, thrombosis, inflammation, various types of cancers (Kris-etherton et al. 2002). The increased knowledge of benefits of consuming natural antioxidants has led to a considerable increase in their consumption (Jeong et al. 2004). Free radicals can protect from the bad consequences by neutralizing the free radicals (Nadeem et al. 2014). The total phenolic content in chia seed extract was 8.8 % on dry matter basis (Reyes-Caudillo et al. 2008). The presence of caffeic acid, chlorogenic acid and quercetin can be correlated with higher extents of phenolics in chia. Uribe et al. (2011) described that chia seed is potentially a great source of antioxidants, the massive antioxidant potential can be utilized for better health and preservation of food lipid systems. Ayerza and Coates 2001 isolated polyphenolics from chia seed viz. chlorogenic acid, caffeic acid, myricetin, quercetin and kaempferol. Hernandez (2012) has also reported a higher concentration of phenolic compounds in chia seed. The strong in vitro antioxidant activity of chia seed has been studied in detail (Serpen et al. 2012). Tepe et al. (2006) studied the antioxidant activity of ethanolic chia seed extract and reported that polyphenols of chia seed considerably inhibited the free radicals in beta carotene linoleic acid system. The free radical scavenging activity of chia seed was even greater than many potentially strong natural antioxidant sources; antioxidant activity of chia seed was greater than *Moringa oleifera*, sesame cake extract as described by Nadeem et al. (2013); Nadeem et al. (2014). Craig (2004) reported that the existence of polyphenols in chia seed protect it from oxidative deterioration. Crosby (2005) characterized the phenolics of chia seed through HPLC and reported that chia seed contained chlorogenic acid, caffeic acid, quercetin, phenolic glycoside k and glycoside Q in appreciable amounts. The antioxidant activity of these phenolic compounds has been well documented. Reyes-Caudillo et al. (2008) also reported that chia seed with a wide range of antioxidant compound can be regarded as a great source of antioxidants. Tepe et al. (2006) reported that phenolics of chia seed can appreciably inhibit the lipid peroxidation phenomenon. Quercetin, chlorogenic acid, caffeic acid are believed to have anti-carcinogenic, antihypertensive, neuron protective effects (Shahidi and Naczk 1995). Ayerza and Coates (2002) demonstrated that chia seed possessed the following polyphenolic compounds; Myricetin, quercetin, kaemferol, Caffeic acid, Flavonol glycosides and Chlorogenic acid. The results of a recent investigation regarding the stabilization of winterized cottonseed oil revealed that supplementation of winterized cottonseed oil added with 750 ppm chia seed extract significantly prolonged the shelf stability of cottonseed oil at ambient temperature (Nadeem et al. 2015a).

Table 5 Fatty acid composition of chia (*salvia hispanica* l.) oil

Fatty Acid	Ricardo Ayerza	R Ayerza and W Coates	Luz Magali Álvarez-Chávez	Ixtaina et al. (2011)
C16:0	9.66	3.40	6.30	7.2
C18:0	4.34	3.40	3.10	3.8
C18:1	6.84	18.00	7.50	15.2
C18:2	17.65	63.20	19.9	19.1
C18:3	64.08	7.63	63.4	64.7

Therapeutic perspectives of chia

Cardio-protective effects

Alpha-linolenic acid, eicosapentaenoic acids play a vital role in the formation of vital biochemical compounds such as prostaglandins, leukotrienes, and thromboxanes which are encountered in numerous physiological functions (Pawlosky et al. 2003). Omega-3 fatty has the capability of blocking calcium and sodium channel dysfunctions, which otherwise can consequences in hypertension (Leaf and Kang 1998). Omega-3 fatty acids improve the parasympathetic tone, heart rate variability and protect ventricular arrhythmia. Fatty acid composition of chia has been reported in literature (Ricardo Ayerza; R Ayerza and W Coates), the concentration of omega-3 and omega-6 fatty acids in all the studies were consistent with minor variations (Table 2). Alpha-linolenic acid content of the seed greatly depends upon the developmental stage, a declining trend (23 %) in the concentration of alpha-linoenic acid has been reported in the fully matured seed, and the similar fashion of decline has also been reported in lignin content (Norlaily Mohd Ali,). Ingeborg et al. (2004) performed a meta-analysis to

determine the quantitative correlation between the ingestion of alpha-linoenic acid and mortalities from heart failures, increased intake of alpha-linoenic acid decreased the risk of heart failures (combined relative risk 0.79). The results of a scientific investigation conducted in St. Michael Hospital in Toronto Canada revealed some key benefits of chia, which are (1) best source of omega-3 fatty acids, (2) higher iron and fibre content gluten free, more calcium and magnesium than milk, (3) 37 g seed on daily basis stabilized blood glucose level in diabetic patients, (4) prevent myocardial infraction and strokes by inhibiting platelets aggregation, (5) lower systolic blood pressure up to 6 mmHg (Vuksan et al. 2007; Vuksan et al. 2010). Fernandez et al. 2008 have also reported some medicinal properties of chia which include the reduction of cholesterol, inhibition of blood clotting, prevent stresses and epilepsy, improvement of the immune system, eating chia in pregnancy helps in the development of retina and brain of foetus. The findings of a study performed over male Wistar rats disclosed that feeding chia seed had a great declining effect on triglycerides and enhanced the beneficial HDL cholesterol. The other benefit of feeding chia seed was the reduction of omega-6 in plasma, consequences in a lower omega-6: omega-3 ratio which has a cardio-protective effect (Ayerza and Coates 2007). In another investigation, the impact of feeding chia seed to a group of rats in which dyslipidemia was introduced. The results of this study revealed that feeding chia seed greatly decreased the visceral adiposity, decreased triglycerides and decreased LDL cholesterol. The effect of feeding chia seed (50 g/day) to 12 healthy individuals for 30 days was investigated. The diastolic blood pressure decreased from 66.1 to 61.5 mmHg with significant decline in serum triglycerides and no side effect was reported (Vertommen et al. 2005) (Tables 6 and 7).

Angiotensin I-converting enzyme inhibitory peptides of chia

The perceived side effects of synthetic angiotensin I-converting enzymes (ACE-I) on human body has led to the discovery of natural bioactive peptides having ACE-I inhibitory effect. A peptide of chia was tested for ACE-I inhibitory effect in terms of hydrolysate and ultra-filtered fractions. The hydrolysate revealed 58.46 % inhibition, while the inhibition of ultra-filtered fraction was 69.31 %. Amino acid profile of this fraction was determined and it was further purified through gel filtration chromatography. The amino acid profile revealed a significant inhibition of ACE-I of chia seed by obstructing the angiotensin II generation. The results suggest the potential of harvesting the bioactive peptides to control ACE-I in a more natural way with decreased risk factors. Hydrolysed chia proteins was added into white bread and carrot cream, the hydrolysis generates peptides with potential ACE inhibitory activities with no significant effect on quality of these food products (Segura-Campos et al. 2013).

Table 6 Phytosterol in chia seed oil as compared to other oils

Source	β-Sitosterol	Stigmasterol	Stigmastanol
Chia Jalisco	7.96	1.83	2.27
Chia Sinaloa	4.59	1.38	2.17
Evening primrose	8.62	0.044	NR
Olive	1.33	0.009	NR
Peanut	0.99	0.134	NR
Rape Seed Oil	3.93	0.025	NR
Sesame	3.31	0.33	NR

Reference: (Phillips and Wiliams 2000)

Effect of chia on immune system

Fernandez et al. (2008) studied the effect of chia seed on the immune system of 23 days old Weanling male Wistar rats, the concentrations of thymus and serum IgE were used as an indicator of immunity. Trial was conducted for one month, rats were divided into three groups, one group was fed on chia seeds 150 (g/kg diet), second group was fed on chia oil 50 (g/kg diet), while the third group was kept control. Diets of both the groups were formulated in such a way that they had similar concentration of alpha-linoenic acid and energy. After the termination of feed phase, body weights of all the three groups were measured after 4 h of fasting and blood was analysed for serum IgE concentration (ng/ml). The results evidenced no difference in body weight and IgE, when chia was administered in seed or oil form. Concentration of IgE was considerably higher in both the groups as compared to the control. Inclusion of chia in any form did not induce any symptom of abnormal behaviour, diarrhoea, dermatitis, supplementation of diets with other sources of omega-3 fatty acids such as flaxseed or marine products usually results in allergy, fishy flavour, problems of gastrointestinal tract, diarrhoea (Ayerza and Coates 2005).

Chia oil as skin curative

A study was performed to determine the likely benefits of topical omega-3 fatty acids, topical products containing chia oil formulated. Five patients with pruritus affected by end stage renal disease and five health volunteers having xerotic pruritus were used in this investigation. A topical formulation was prepared by the addition of 4 % chia oil and applied for 8 weeks. Itching indications, trans-epidermal water loss and skin capacitance were measured on a 6 points scale. Application of topical formulation added with chia oil significantly improved the skin hydration, lichen simplex chronicus, and prurigo nodularis in all the patients. Healthy volunteers suffering from xerotic pruritus also revealed improvement in

Table 7 Therapeutic value of chia

Therapeutic value	Reference
Cardiac protective	Munoz et al. (2012b)
Helps to control diabetes	EFSA (2009)
Potential source of several bio-active peptides, Repair of damaged tissue and general well-being	Segura-Campos et al. (2013)
Control of dyslipidaemia	Chicco et al. (2009)
Potential to lower the bad LDL cholesterol and increase beneficial HDL cholesterol	Ayerza, and Coates (2005) Brenna et al. (2009)
Control of hypertension and triglycerides and Anti-inflammatory	Rodea-González et al. (2012)
Antioxidant activity for commercial uses	Nadeem et al. (2015a)
Chia is non-allergic (whole/ground)	EFSA 2005; EFSA 2009
Antiplatelet, Antiplatelet, anti-carcinogenic, laxative, hypotensive, cardiac tonic, cardiovascular protector, treatment of anaemia, improves dermatitis, analgesic	Ayerza and Coates, 2005 http://animales-campo.vivavisos.com.ar.
Antidepressant, antianxiety, vision and immune improver	
EPA and DHA improver in blood	Nieman et al. 2009
Antineoplastics	Adams et al. (2006)
Hypotensives	Vuksan et al. (2007)
Celiac disease, constipation and vasodilatation	Adams et al. (2005)
Joint pain, kidney disorders	Wojcikowski et al. (2006)
Antiviral	Jiang et al. (2005)

skin hydration followed by the *trans* epidermal water loss and capacitance of skin (Jeong et al. 2010).

Omega-3 neutraceutical from chia oil

Health benefits of omega fatty acid have been discussed in detail in the upper part of this review, in a recent investigation, chia oil was fractionated into olein and stearin fractions with the objective to produce high omega-3 neutraceutical. Fatty acid composition revealed that omega-3 fatty acids in olein fraction were more than 80 % HPLC determination revealed that neutraceutical fraction had higher concentration of anti-oxidant substances as compared to parent chia oil. (Rahman et al. 2015).

Uses of chia seed

The approval of chia seed as a Novel Food by the European Parliament has led to high degree of usage of chia seed in a wide range of foods. It is already well established that chia does not have anti-allergic, anti-nutritional and toxic effect on human health. Biscuits, pasta, cereal bars, snacks and yoghurt and cake are usually supplemented with chia seed (The Chia Company 2009; Borneo et al. 2010). Chia is one of the few medicinal plants that produce essential oil in a great concentration, which is used for the preparation of omega-3 capsules. Nutritional value of butter oil was enhanced by blending with chia oil from 6.5 % to 25 %, concentration of omega-3 fatty acids in chia fortified butter oil ranged from 4.17 % to 16.74 % (Nadeem et al. 2015b). These results evidenced the successful application of chia oil to butter oil, however, further study should be performed to study the suitability of chia oil in other dairy products. The oil extracted from the leaves of chia is utilized as scent and condiment (Ahmed et al. 2006). It is revealed from the studies that chia seed had a higher concentration of phytosterols which have and cancer and cardio-protective effect with antimicrobial activities (Alonso-Calderon et al. 2013). Recently, it is established that mucilage of chia seed can be utilized as a functional coating with improved functional properties (Munoz et al. 2012a).

Insect control

The leaves of chia contain an essential oil that contains β-caryophyllene, globulol, γ-muroleno, β-pinene, α-humoleno, germacren-B, and widdrol. These compounds are believed to have strong repellent characteristics to a wide range of insects (Ahmed et al. 2006).

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References

Adams JD, Wall M, Garcia C (2005) *Salvia columbariae* contains tanshinones. Evid. Based. Complement Alternat Med 2:107–110

Adams JD, Wang R, Yang J, Lien EJ (2006) Preclinical and clinical examinations of Salvia miltiorrhiza and its tanshinones in ischemic conditions. Chin Med 1:3

Ahmed M, Hamed R, Ali M, Hassan A, Babiker E (2006) Proximate composition, antinutritional factors and protein fractions of guar gum seeds as influenced by processing treatments. Pak J Nutr 5(5):340–345

Ali NM, Yeap SK, Ho WY, Beh BK, Tan SW, Tan SG (2012) The Promising Future of Chia *Salvia hispanica* L. J Biom Biotechnol. doi:10.1155/2012/171956

Alonso-Calderon A, Chávez-Bravo E, Rivera A, Montalvo-Paquini C, Arroyo-Tapia L (2013) ABCDLKF'K;GL';LKG

Armstrong D (2004) Application for approval of whole chia (*Salvia hispanica* L.) seed and ground whole seed as novel food ingredient. Northern Ireland, R

Ayerza R, Coates W (2001) Chia seeds: new source of omega-3 fatty acids, natural antioxidants, and dietetic fiber. Southwest Center for Natural Products Research & Commercialization. Office of Arid Lands Studies, Tucson

Ayerza R, Coates W (2002) Dietary levels of chia: influence on hen weight, egg production and sensory quality, for two strains of hens. Br Poult Sci 43:283–290

Ayerza R, Coates W (2004) Composition of chia (Salvia hispanica) grown in six tropical and subtropical ecosystems of South America. Trop Sci 44(3):131–135

Ayerza R, Coates W (2005) Chia: Rediscovering an ancient crop of the Aztecs. University of Arizona, Tucson

Ayerza RJ, Coates W (2007) seeed yield oil content and fatty acid composition of three botanical sources of & ohgr: 3 fatty acid planted in the Yugas ecosystem of tropical Argentina. Trop Sci 47(4):183–187

Beltran-Orozco MC, Romero MR (2003) La Chia, Alimento Milenario, Departamento de Graduados e Investigacion en Alimentos. ENCB, IPN, Mexico

Borneo R, Aguirre A, León AE (2010) Chia (*Salvia hispanica* L) gel can be used as egg or oil replacer in cake formulations. J Am Diet Assoc 110:946–949

Brenna JT, Salem Jr N, Sinclair AJ, Cunnane SC (2009) α- Linolenic acid supplementation and conversion to n-3 long-chain polyunsaturated fatty acids in humans. Prostaglandins Leukotrienes Essent. Fatty Acids 80:85–91

Bresson JL, Flynn A, Heinonen M, et al (2009) Opinion on the safety of Chia seeds (*Salvia hispanica* L.) and ground whole Chia seeds, as a food ingredient. J Eur Food Safety Authority 996:1–26

Cahill J (2003) Ethnobotany of chia, Salvia hispanica L. (Lamiaceae). Econ Bot 57:604–618

Campos MRS, Gonzalez FP, Guerrero LC, Ancona DB (2013) Angiotensin I-Converting Enzyme Inhibitory Peptides of Chia (Salvia hispanica) Produced by Enzymatic Hydrolysis. Inter J Food Sci Article ID 158482 8 pages. doi:10.1155/2013/158482

Chicco AG, D'Alessandro ME, Hein GJ, Oliva ME, Lombardo YB (2009) Dietary chia seed (*Salvia hispanica* L.) rich in alpha-linolenic acid improves adiposity and normalises hypertriacylglycerolaemia and insulin resistance in dyslipaemic rats. Br J Nutr 101:41–50

Coates W, Ayerza R (1996) Production potential of chia in northwestern Argentina. Ind Crop Prod 5(3):229–233

Craig R (2004) Application for approval of whole chia (Salvia hispanica L.) seed and ground whole seed as novel food ingredient. Northern Ireland, Company Representative Mr D Amstrong. Craig & Sons, http://www. food.gov.uk/multimedia/pdfs/chiaapplication.pdf

Crosby G (2005) Lignans in food and nutrition. Food Technol 59:32–-36

De Tucci J (2006) Chia, la semilla que reduce el colesterol. Magazine Bayres Today 5.

EFSA (2005) Opinion of the Scientific Panel on Dietetic Products, Nutrition and Allergies on a request from the Commission related to the safety of chia (*Salvia hispanica* L.) seed and ground whole chia seed as a novel food ingredient intended for use in bread. EFSA J 278:1–12.

EFSA (2009) Scientific Opinion of the Panel on Dietetic Products Nutrition and Allergies on a request from the European Commission on the safety of Chia seed (Salvia hispanica) and ground whole Chia seed' as a food ingredient. EFSA J 996:1–2

Fernandez IR, Ayerza W, Coates SM, Vidueiros N, c, Pallaro AN (2006a) Nutritional characteristics of chia. Actualización en Nutrición. Tucson, Arizona 85706, USA. Office of Arid Lands Studies, The University of Arizona. 7: 23–25

Fernández I, Ayerza R, Coates W, Vidueiros SM, Slobodianik, Pallaro AN (2006b) Nutritional characteristics of chia. Actualización en Nutrición. Tucson, Arizona 85706, USA, Office of Arid Lands Studies, The University of Arizona. 7: 23–25.

Fernandez I,. Vidueiros SM, Ayerza R, Coates W, Pallaro A (2008) Impact of chia (*Salvia hispanica* L.) on the immune system: preliminary study Proceedings of the Nutrition Society, 67 (OCE), E12 doi: 10.1017/S0029665108006216

Hansel B, Nicolle C, Lalanne F, Tondu F, Lassel T, Donazzolo Y, Ferrières J, Krempf M, Schlienger JL, Verges B, Chapman MJ, Brucket E (2007) Effect of low-fat, fermented milk enriched with plant sterols on serum lipid profile and oxidative stress inmoderate hypercholesterolemia. Am J Clinical Nutr 86(3): 790–796

Hentry HS, Mittleman M, McCrohan PR (1990) Introduccion de la chia y la goma de tragacanto en los Estados Unidos. In: Janick OJ, Simon JE (eds) Avances en Cosechas Nuevas. Prensa de la Madera, Portland OH, pp. 252–256

Hernandez LM (2012) Mucilage from Chia Seeds (Salvia Hispanica): Microestructure, Physico-Chemical characterization and applications in Food Industry. PhD Thesis, Thesis submitted to the Office of Research and Graduate Studies in partial of the requirements for the Degree of Doctor in Engineering Sciences

Ingeborg AB, Katan MB, Zock PL (2004). The journal of Nutrition. Downloaded from Jnnutritionorg at Pakistan: ASNA Sponsored on June 15, 2015.

Ixtaina VY, Nolasco SM, Tomas MC (2008) Physical properties of chia (*Salvia hispanica* L.) seeds. Ind Crop Prod 28(3):286–293

Ixtaina VY, Martinez ML, Spotorno V, Mateo CM, Maestri DM, Diehl BWK, Nolasco SM, Tomas MC (2011) Characterization of chia seed oils obtained by pressing and solvent extraction. J Food Compos Anal 24:166–174

Jeong SM, Kim SY, Kim DR, Man KC, Ahn DU, Lee SC (2004) Effect of heat treatment on the antioxidant activity of extracts from citrus peals. J Agric Food Chem 52:3389–3393

Jeong SK, Park HJ, Park BD, Hwan Kim H (2010) Effectiveness of Topical Chia Seed Oil on Pruritus of End-stage Renal Disease (ESRD) Patients and Healthy Volunteers. Ann Dermatol 22(2): 2010. doi:10.5021/ad.2010.22.2.143

Jiang RW, Lau KM, Hon PM, Mak TC, Woo KS, Fung KP (2005) Chemistry and biological activities of caffeic acid derivatives from *Salvia miltiorrhiza*. Curr Med Chem 12:237–246

Kris-Etherton PM, hecker KD, Bonanome A, Coval SM, Binkoski AE, Hilpert KF, Griel AE, Etherton TD (2002) Bioactive compounds in foods: their role in prevention of cardiovascular disease and cancer. Am J Med 113:71–88

Leaf A, Kang JX (1998) Omega-3 fatty acids and cardiovascular disease. The re - turn of T-3 fatty acids into the food supply. I- Land-based animal food products and their health effects, edited by Simopoulos AP. Karger S, Basel AG, pp. 24–37

Lejeune MP, Kovacs EM, Westerterp-Plantenga MS (2005a) Additional protein intake limits weight regain after weight loss in humans. Br J Nutr 93:281–289

Lokuruka MNI (2007) Role of fatty acids of milk and dairy products in cardiovascular diseases: a review. AF J Food Agri Nutr and DEV 7(1). http://www.bioline.org.br

Manzella D, Paolisso G (2005) Cardiac autonomic activity and Type II diabetes mellitus. Clin Sci 108:93–97

Mohd AN, Yeap SK, Ho WY (2012) The promising future of Chia. Salvia Hispanica L J Biomed Biotechnol 171956(9 pages). doi:10.1155/2012/171956

Munoz LA, Aguilera JM, Rodriguez-Turienzo L, Cobos A, Diaz O (2012a) Characterization and microstructure of films made from mucilage of *salvia hispanica* and whey protein concentrate. J Food Eng 111:511–518

Munoz LA, Cobos A, Diaz O, Aguilera JM (2012b) Chia seeds: microstructure, mucilage extraction and hydration. J Food Eng 108:216–224

Nadeem M, Abdullah M, Mahumd A, Hussain I, Inayat S (2013) Stabilization of butter oil with modified fatty acid profile by using Moringa oleifera extract as antioxidant. J Agric Sci Technol 15:919–928

Nadeem M, Situ C, Mahmud A, Khalique A, Imran M, Rahman F, Khan S (2014) Antioxidant activity of sesame (*Sesamum indicum*) cake extract for the stabilization of olein based butter. J Am Oil Chem Soc. doi:10.1007/s11746-014-2432-3

Nadeem M, Azeem W, Ahmad S (2015a) Stabilization of winterized cottonseed oil with chia (S*alvia hispanica* L.) seed extract. J Food Sci Technol. doi:10.1007/s13197-015-18232

Nadeem M, Ajmal M, Rahman F, Ayaz M (2015b) Analytical characterization of butter oil enriched with omega-3 and 6 fatty acids through chia (*Salvia hispanica* L.) seed oil. Pak J of Anal Envi Chem (Accepted)

Nieman DC, Cayea EJ, Austin MD, Henson DA, McAnulty SR, Jin F (2009) Chia seed does not promote weight loss or alter disease risk factors in overweight adults. Nutr Res 29(6):414–418

Pawlosky R, Hibbeln J, Lin Y, Salem N (2003) N-3 fatty acid metabolism in women. Br J Nutr 90:993–994

Peiretti PG, Gai F (2009) Fatty acid and nutritive quality of chia (Salvia hispanica L.) seeds and plant during growth. Anim Feed Sci Technol 148(2–4):267–275

Phillips GO, Wiliams PA (2000) Introduction to food hydrocolloids. In: Go P, Williams PA (eds) Handbook of Hydrocolloids. Woodhead Publishing Limited, Cambridge England

Rahman Ullah., Nadeem M, Ahmad S, Azeem MW, Tayyab M (2015) Fractionation of Chia Oil to Enhance Omega 3 & 6 Fatty Acids: Oxidative Stability of Fractions. Food Sci Biotech (Accepted)

Reyes-Caudillo E, Tecante A, Valdivia-Lopez MA (2008) Dietary fibre content and antioxidant activity of phenolic compounds present in Mexican chia (*Salvia hispanica* L.) seeds. Food Chem 107(2):656–663

Rodea-González DA, Cruz-Olivares J, Roman-Guerrero A, Rodriguez-Huezo ME, Vernon-Carter EJ, Pérez-Alonso C (2012) Spray-dried encapsulation of chia essential oil (*Salvia hispanica* L.) in whey protein concentrate-polysaccharide matrices. J Food Eng 111:102–109

Sandoval-Oliveros MR, Paredes-Lopez O (2013) Isolation and characterization of proteins from chia seeds (*Salvia hispanica* L.). J Agric Food Chem 61:193−201. doi:10.1021/jf3034978

Segura-Campos MR, Salazar-Vega IM, Chel-Guerrero LA, Betancur-Ancona DA (2013) Biological potential of chia (*Salvia hispanica* L.) protein hydrolysates and their incorporation into functional foods. LWT Food Sci Technol 50:723–731

Serpen A, Gökmen V, Fogliano V (2012b2012a) Total antioxidant capacities of raw and cooked meats. Meat Sci. 90: 60–65. PMid: 21684086. doi:10.1016/j.meatsci.2011-05-027 http://dx.doi.org/10.1016/j.meatsci.2011.05.027

Shahidi F, Naczk M (1995) Phenolic compounds in grains. In: In food phenolics. Source, chemistry effects, applications. Technomic Publishing Company Inc, Lancaster PA, pp. 3–39

Shewry PR, Casey R (eds) (2003) Seed proteins. Kluwer Academic Publishers, Dordrecht

Skov AR, Toubro S, Ronn B, Holm L, Astrup A (1999) Randomized trial on protein vs carbohydrate in ad libitum fat reduced diet for the treatment of obesity. Int J Obes Relat Metab Disord 23:528–536

Tepe B, Sokmen M, Akpulat AH, Sokmen A (2006) Screening of the antioxidant activity of six salvia species from Turkey. Food Chem 95:200–204

The Chia Company (2009) Request for scientific evaluation of substantial equivalence application for the approval of chia seeds (*Salvia Hispanica* L.) from The Chia Company for use in bread. Food Standards Agency: London, UK.

Ting IP, Brown JH, Naqvi HH, Estilai A, Kummamoto J, Matsumura M (1990) Chia: a potential oil crop for arid zones. In: Naqvi HH, Estilai A, Ting IP (eds) New IND CROP PROD. University of Arizona, Tucson, AZ, pp. 197–200

Uribe JAR, Perez JIN, Kauil HC, Rubio GR, Alcocer CG (2011) Extraction of oil from chia seeds with supercritical CO2. J Supercrit Fluids 56(2):174–178

USDA (2000) Dietary guidelines for Americans. 5th edn. Home and Garden Bull. No. 232, 11

USDA (2011) National Nutrient Database for Standard Reference, Release 24. Nutrient Data Laboratory Home Page. US. Department of Agriculture, Agricultural Research Service

Vertommen J, Van de Sompel AM, Loenders M, Van der Velpen C, De Leeuw I. (2005) Efficacy and Safety of 1 Month Supplementation of SALBA (*Salvia Hispanica* Alba) Grain to Diet of Normal Adults on Body Parameters, Blood Pressure, Serum Lipids, Minerals Status and Haematological Parameters. Results of a Pilot Study. The 23th International Symposium on Diabetes and Nutiriton of the European Association for the Study of Diabetes

Vuksan V, Whitman D, Sievenpiper J, Jenkins A, Rogovik A, Bazinet R, Vidgen E, Hanna A (2007) Supplementation of conventional therapy with the novel grain Salba (*Salvia hispanica* L.) improves major and emerging cardiovascular risk factors in type 2 diabetes. Diabetes Care 30:2804–2810

Vuksan V, Jenkins AL, Dias AG, Lee AS, Jovanovski E, Rogovik AL, Hanna A (2010) Reduction in postprandial glucose excursion and prolongation of satiety: possible explanation of the long-term effects of whole grain Salba (*Salvia Hispanica* L.). Eur J Clin Nutr 64(4): 436–438

Wojcikowski K, Johnson DW, Gobe G (2006) Herbs or natural substances as complementary therapies for chronic kidney disease: ideas for future studies. J Lab Clin Med 147:160–166