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Chia seeds for nutritional security

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Abstract
A lot of attention is on impact of climate change on food security which is one dimensional. The increase in food production alone does not mean that there is adequate access and utilisation of food and it has received little scholarly attention in recent times.
Cereals and pseudocereals are the foods that human race has sustained itself from times immemorial. They are good sources of starch and fibres, proteins with good quality of amino acids, lipids, B complex vitamins and minerals like calcium, potassium, magnesium, iron, zinc and phosphorus. They are usually consumed as bread, breakfast cereals or cereal bars in developed countries.
Chia (*Salvia hispanica* L.) is a pseudo cereal that has been consumed by the world population due to its protective, functional and antioxidant properties attributed to the presence of lipids, dietary fibre, protein, phenolic compounds, vitamins and minerals. Studies have shown that chia has hypoglycemic, anti-inflammatory, antioxidant, anti-hypersensitive and cardio protective actions.
Consumption of chia has increased due to its beneficial effects related to obesity, cardiovascular disease, diabetes and some types of cancer. These benefits result primarily of the high concentration of essential fatty acids, dietary fibre, antioxidants, flavonoids, anthocyanins, vitamins, carotenoids and minerals present in this seed.

Keywords: Food security, pseudocereals, chia seeds, breakfast cereals, antioxidant properties of chia

Introduction
Food security exists when all people, at all times, have sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life for better physical, social and economic life. A changing climate, growing world population, rising food price and environmental stresses have significant yet highly uncertain impact on food security (Gibson, 2012) [18].
Globalization of agriculture and consequently its industrialization seem inexorable with negative side effects being felt throughout India resulting in biased technological development of some high demanding plant species and monoculture production with reduced genetic diversity in agriculture. As a consequence, Indian food security has become increasingly dependent on only a handful of crops. Over the time more than 10000 edible species were used by human but now only 150 plant species are commercialized on significant global scale, 12 of which provide approximately 80% dietary energy from plants and over 60% of the global requirement for proteins and calories are met from rice, wheat, maize and potato (Izdajatelj, 2010) [22].
The narrowing of the number of crops upon which global food security and economic growth depend has placed the future supply of food and rural incomes at risk. The facts have profound environmental consequences and concern for loss of crop varieties leading to various organizations and scientists worldwide in retrieving, researching and disseminating the knowledge in production and utilization of neglected, disregarded, underexploited and new plant species, or so-called alternative crops (Hafele and Sassin 1979) [19].
'*Salvia hispanica'* commonly called as chia seeds is a pseudocereal packed with nutrients like omega-3 fatty acids, dietary fibre, polyunsaturated fatty acids, protein, all essential amino acids, calcium and several other minerals. Chia is one of the highest sources for omega – 3 fatty acids and has anti-inflammatory effect. Chia seeds produces gel with good water binding capacity, oil holding capacity, viscosity and emulsion activity which easily can be extracted for potential use in frozen foods as a thickener, emulsifier and stabilizer (Ixtaina *et al*., 2008) [20].
Chia seeds with omega – 3 fatty acids play a key role in preventing the formation of clots and plaques in the arteries and also helps to prevent cardiovascular diseases. As a rich source of dietary fibre, it is useful for proper functioning of the intestine and contains highly nutritious proteins, more than traditional cereals (Reyes-Caudillo *et al*., 2008) [35].

Chia can be considered as a super food as it is an excellent source of essential fatty acids, protein, dietary fibre, vitamins and antioxidants along with essential minerals like phosphorus, manganese, calcium, potassium and sodium. The protein content in chia was higher than that of other traditional crops such as wheat, corn, rice, oat, barley and amaranth along with good amino acid profile (Weber *et al*., 1991) [42]. Ayerza and Coates (2000) [2] reported the antimicrobial action of chia seeds probably due to its oil composition (30%) of which 17-26% is linoleic acid and 50-57% is linolenic acid

Chia plant and seeds

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Chia seeds are small in size, oval-shaped and flat measuring between 2.0 to 2.5 mm in length, 1.2 to 1.5 mm width and 0.8 to 1.0 mm thickness. This seed available in different shades of colours from dark brown to black, and sometimes grey or white. It is an annual herb, bearing flower in summer with a height of about one meter with reverse petiolate and serrated leaves (4-8 cm long and 3-5 cm wide) with hermaphrodite flowers. Plant can grow in a wide range of well drained clay and sandy soils with reasonable salt and acid tolerance (USDA 2011) [40].

History of chia seeds: *Salvia hispanica* commonly called as chia seeds is an annual herbaceous plant, native of southern Mexico and northern Guatemala. The genus salvia consists of 900 species. Chia name was coming from the latin word 'salvere' meaning curative properties of the well- known culinary and medicinal herb *Salvia officinalis* (Dweck, 2005) [17].

Segura-Campos (2014) [37] reported chia produces numerous dry fruits which are commonly called seeds. These are small in size, white and dark seeds in pre-Columbian times eaten along with staple foods such as corn, beans and amaranth and were one of the basic foods in the diet of several Central American civilizations including Mayan and Aztec populations. Chia seed was used as an offering to the Aztec gods because of its religious use and has disappeared from usage for 500 years.

Production and consumption of chia seed: Cahill (2002) [8] reported production of chia seed in the Mexico after its independence. The annual production of chia was 15,000 ton and 500 Kg of yield seed per hectare. Chia crop was also be able to survive on the mountain zones of Jalisco, Michoacan, Puebla and Jalisco. The average production of chia seed is 500- 600 Kg/acre and under appropriate agronomic conditions the yield of 2500 kg/acre chia seed.

Lema *et al.* (2010) [26] reported chia seed has antioxidant properties with healthy fatty acid profile. Chia seed production is a major contributor to the Argentine economy being responsible for 24% of its agricultural economy. In 2008, Argentina contributed approximately 4% of the world grain production.

Ayerza and Coates (2009) [3] reported factors effecting the production of chia seed oil were climatic conditions and the technique used for its extraction. Results indicated that chia seed oil content tends to increase with altitude in which seeds are grown, and the environment also modifies oil composition. The temperature affects the type of fatty acids present in the oil and increased temperature during grain development reduced polyunsaturated fatty acids. The yield of chia seed oil normally ranges from 29.4 to 33.5%.

Borneo *et al.* (2010) [7] reported chia approved as a novel food in the year 2009 by the European Parliament and Council of Europe as chia does not cause any adverse allergenic, anti-nutritional or toxic effects. The versatile properties of chia helps it to be used different purposes in several countries like Mexico, Argentina, Chile, New Zealand, Japan, USA, Canada and Australia. Chia mostly used as a nutritional supplement and as an ingredient in cereal bars, biscuits, pasta, bread, snacks and yogurt.

Nutritional composition of chia seed: Ixtaina *et al*. (2008) [20] reported chia seed is underutilized pseudocereal with high amount of nutrients like protein (15-25%), carbohydrates (26-41%), dietary fiber (18-30%), ash (4-5%) and lipids (40%) of which 60% is omega-3 fatty acids that helps to improve high-density lipoprotein (HDL) in humans and protects from heart attack and stroke. Ixtaina *et al*. (2010) [21] reported that the quality of edible oils is important for their acceptance as food and its formulation. The lower content of saturated fatty acids (palmitic and stearic acids), adequate concentration of linoleic acids (18-20%) and higher content of α-linolenic fatty acids (55-60%) makes chia oil as a preferred and appealing choice for health foods and cosmetics.

Sapio *et al.* (2012) [36] reported that the insoluble dietary fibre of chia seeds ranged between 23 to 50% and this helps in retaining water several times its weight during hydration thereby providing bulk and prolonging gastro intestinal transit time.

Dietary fiber: Lin *et al.* (1994) [28] reported chia seed is a good source of dietary fiber with 5% soluble fiber which appears as clear mucilage when it is placed in water. Hence chia is useful as a source of dietary fiber and possesses huge potential for application in food industry.

Mohid *et al.* (2013) [30] reported that chia seeds contained 34 to 40% of dietary fibre and is equivalent to 100% of the daily recommendations for adults. The defatted chia seed flour

contained 40% dietary fibre of which 5–10 % was soluble fiber and forms part of the mucilage helping to slow the digestion, prevent cardiovascular diseases and manage diabetes.

Yuan *et al*. (2014) [43] reported that chia seeds accelerated intestinal movement due to high quantity of insoluble fiber that increased volume of faecal mass and provided satiety, thus preventing obesity and colon cancer in humans.

Jeong *et al*. (2010) [23] reported that insoluble dietary fibre content in chia seeds increased gastro intestinal time and was directly related to gradual increased post-prandial glucose levels and decreased insulin resistance over a period of time.

Fatty acids: Bhatty *et al.* (1993) [6] reported chia oil is highly unsaturated with 83% polyunsaturated fatty acids (PUFA) of which 18% is linoleic acid and 64% of α-linolenic acid. Chia oil is also qualitatively different from the less commonly used vegetable oils with a high content of PUFA such as flax with the content of 53.3% ALA.

Lin *et al*. (1994) [28] reported that *chia* seed have high fat content of about 25-40%, out of which 68% was ω-3 fatty acids and 20% of ω-6 fatty acids and rich in all essential amino acids particularly lysine, leucine, isoleucine and valine. These ω-3 fatty acids are helpful in the prevention and management of hyperlipidaemia, hyperglycaemia and hypertension (Sapio *et al.*, 2012) [36].

Powlosky *et al.* (2003) [33] reported that chia seeds contained ω-3, α-linolenic acid (ALA) and ω-6 linoleic acid. On an average it contains about 64% ω-3 and 19% ω-6 fatty acids. Due to their excellent fatty acid concentration of chia seed is known as power house of omega fatty acids. Eicosapentaenoic acid and docosahexaenoic acid have cardio-protective effects. The ω-3 fatty acids improve the parasympathetic tone, heart rate variability and protect ventricular arrhythmia.

Antioxidants: Taga *et al.* (1984) [38] reported chia contained antioxidants like chlorogenic acid and caffeic acid in large quantity and myricetin, quercetin, kaempferol and flavanols in traces. These compounds are both primary and synergistic antioxidants and make chia a very stable source of ω-3 fatty acids. These antioxidant compounds such as quercetin are capable of preventing oxidation of fats, proteins and DNA. Caffeic acid and chlorogenic acid play a key role in protect against free radicals and inhibit the peroxidation of fats. These compounds present in the seed have much stronger antioxidant properties than those of ferulic acid, vitamin C and vitamin E.

Reyes-Caudillo *et al.* (2008) [35] reported phenolic compounds present in chia seeds are rosmarinic acid and daidzein along with thepresence of myricetin, quercetin, kaemferol, caffeic acid, flavanol glycosides and chlorogenic acid. Phenolic compounds were quercetin, chlorogenic acid, caffeic acid have anticarcinogenic, antihypertensive and neuron protective effect.

Okuyama *et al.* (1997) [32] reported the chia seed help in prevention and management of cardiovascular diseases, cancer, diabetes and depression because chia exhibited high antioxidant activity which is associated with the polyphenolic compounds and presence of tocopherols.

Jeong *et al.* (2004) [24] reported that increased chia seed consumption was observed due to its natural antioxidants that influence oxidation of free radicals there by providing better health and preservation of food lipid systems in the body.

Micronutrients: Kon *et al*. 2013 [25] reported mineral content of 100g chia seed as calcium (536 mg), magnesium (350 mg), potassium (564 mg), phosphorus (751 mg), iron (6.3 mg), copper (1.4 mg), and zinc (4.4 mg). Mineral deficiency decreases enzyme activity affecting the human body and resulting in functional disorders of individual organs and the immune system thereby leading to frequent depressions.

Munoz *et al.* (2012) [31] analysed chia seeds and found them to be a good source of several vitamins and minerals particularly niacin, zinc, calcium, phosphorus and magnesium. Niacin content of chia was higher than other cereals (corn, soybeans and rice), whereas the riboflavin and thiamine content was similar to corn and rice. Chia contained six times more calcium, eleven times more phosphorus and four times more potassium than 100 ml of milk.

Beltran-Orozco and Romero (2003) [5] reported chia contained 13 to 354 times more calcium, 2 to 12 times more phosphorus and 1.6 to 9 times more potassium than 100g of wheat, rice, oats and corn. The iron content of chia was also quite high compared to most other seeds with six times more iron than spinach, 1.8 times more than lentils and 2.4 times more than liver.

Chia seed rich in micronutrient concentration mainly are vitamin E and complex B vitamins like riboflavin (0.17mg), niacin (8.82mg) ad thiamine (0.62mg) per 100g. In addition, chia has high calcium concentration (631mg), phosphorus (860mg), potassium (407mg), magnesium (335mg), iron (7.72 mg) and zinc (4.58 mg) per 100g chia (USDA, 2015) [40].

Health benefits of chia seed: Marineli *et al*. (2105) [29] investigated the antioxidant property of chia seed in obese rats. The dietary chia oil induced the expression of HSP70 and HSP25 in skeletal muscle and restored superoxide dismutase and glutathione peroxidase expression. In addition, extended treatment with chia seed and short treatment with chia oil restored peroxisome proliferator activated receptor-γ coactivator-1α (PGC-1α) expression. The antioxidant compounds present in chia were tocopherols, phytosterol, carotenoids and phenolic compounds also had a synergistic effect.

Coorey *et al*. (2014) [13] investigated on the feeding of chia seeds to Isa Brown hens and results showed high ω-3 fatty acid content in their egg yolks without compromising the flavour of eggs. Eggs with higher omega-3 fatty acid content may exhibit anti-hypercholesterolemia when consumed by humans. Jin *et al.* (2012) investigated in 10 post-menopausal women using 25g of milled chia per day over a seven-week period and found a significant increase in serum ALA and EPA concentrations.

Chicco *et al*. (2009) [11] reported role of chia maintaining the lipid and glucose homeostasis in the body. There was a significant reduction in waist circumference in healthy individuals after a month of chia supplementation with no change in body weight maybe due to specific loss of fat mass. In a chronic treatment, dietary chia seed reduced the visceral adiposity and insulin resistance among sucrose-induced diabetic rats.

Vertommen *et al*. (2005) [41] investigated the impact of feeding chia seeds to a group of rats with dyslipidaemia. Results revealed that feeding chia seeds greatly decreased the visceral adiposity, decreased triglycerides and LDL cholesterol levels. In the healthy individuals, ingestion of chia (50 g/day) for 30 days experiment, diastolic blood pressure decreased from 66.1 to 61.5 mmHg with significant decline in serum triglycerides and no side effects.

Ulbricht *et al*, (2009) [39] reported that chia seed were useful for prevention and management of allergies, angina, cancer, coronary heart disease, heart attack, hormonal/endocrine disorders, hyperlipidaemia, hypertension, stroke and vasodilatation.

Lemaitre *et al*. (2003) [27] studied the effect of chia supplementation on blood pressure. Results showed that a slight decrease in blood glucose, blood became less prone to coagulation, decreased levels of internal inflammation as measured by C-reactive protein (CRP). The systolic blood pressure decreased by an average of 6 mmHg, considering that systolic blood pressure desired and pre hypertension are 90-119 and 120-139 mmHg respectively.

Comba *et al*. (2010) [12] reported chia seed oil was suggested for management of inflammatory problems like pain, redness and swelling which can cause severe problems. Prevention and management of these health-related problems was achieved by inclusion of chia seeds and its oil in daily diet as it contains PUFA, prostaglandins and eicosanoids which induce lesser extent of inflammation via reduced induction of COX-2.

Divyapriya *et al*. (2016) [15] investigated antibacterial effect of chia seeds extract against all the three main pathogens of periodontal disease by using disc diffusion method. Similarly, in micro dilution assay test, both the aqueous and ethanolic extract of *S. hispanica* exhibited antibacterial effect.

Applications of chia seeds in food industry: Ayerza and Coates, (2002) [4] reported functional foods have gained tremendous attention day by day worldwide due to the wave of healthy lifestyle changes. The most important reason for the interest to shift to a healthier lifestyle is the increasing number of people suffering from cardiovascular diseases (CVDs), high blood pressure, obesity, diabetes and other related diseases. These conditions are commonly due to inactive lifestyle and poor diet.

Capitani *et al*. (2015) [9] reported chia seed gum was used as food and industrial applications due to rich dietary fiber content present in it. It acts as not only physiological functionality for their beneficial effect on human health but also technological functionality which greatly depends on hydration properties. Chia gum was used in food industries to improve the products physical parameters like viscosity, stability, texture, and consistency due to its good functional properties like water-holding and absorption capacity, solubility, swelling, viscosity and gelling.

Ali *et al*. (2012) [1] reported chia seed is used as a healthy oil supplement for humans and animals. Human consumption of chia in diet is mainly used as incorporation into cooking oil, confections and supplements. In 2000, the US dietary guidelines recommend that chia seed can be used as a primary food not exceeding 48 g/day. Chia is commonly consumed in salads as sprouts, beverages and salad dressing.

Borneo *et al*. (2010) [7] reported that use of chia seed in bread products was limited to not more than 5%. Other than bread, the food industry of various countries around the world used chia seeds or its oil for different applications such as breakfast cereals, bars, cookie snacks, fruit juices, cake and yoghurt.

Chavan *et al*. (2017) [10] reported chia mucilage was potentially used in the food industries as it contains excellent stabilizing and thickening abilities. Chia seed mucilage has shown greater emulsion stability than commercially available guar gum and gelatine. Hence, it can used in bakery products, powdered beverages, yogurt, ice cream, sauces and creams.

Dubois *et al*. (2007) [16] reported chia seed has not been commercialized for a long time in Argentina due to the comparatively small-scale production, problems in its availability and sustainability as an edible oil source in the global market exist. The current planting and production of chia seed oil are yet to fully meet the world market demand.

Borneo *et al*. (2010) [7] reported that chia seed is used different purposes as nutritional supplement and as an ingredient in cereal bars, biscuits, pasta, bread, snacks and yogurt, among others that include their use even in cake formulations in various countries like Mexico, Argentina, Chile, New Zealand, Japan, the United States, Canada and Australia.

Munoz *et al*. (2012) [31] reported chia seed was extensively used in food industries due to their mucilage property in form of soluble fiber. Mucilage of chia was used to blends to produce films and coatings with improved properties.

Mohid *et al*. (2013) [30] reported chia plant and grains possess dark-coloured or black grains, like other plants and grains. This plant not attacked by insects because it contains compounds that offer protection. Chia plant contained essential oils and can be extracted from the leaves with main components like β-caryophyllene, globulol, γ-muroleno, β-pinene, α-humoleno and widdrol that act as a repellent against insects.

Conclusion

Food security is a serious problem faced by whole word. To combat nutritional security, improved use of underutilized grains like chia seeds can be good option due to extensive nutritional composition. Now a day's people showing interest at industrial level also because of their excellent physical and functions properties. Chia can help in the prevention of nutritional related disorders because it contains higher concentration of fatty acids, essential amino acids, good quality proteins and adequate amount of dietary fiber.

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