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REVIEW PAPER

Chemical Composition, Health Benefits and Applications of Chia seeds: A Review

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Abstract

Consumers have adjusted their dietary preferences toward better food options as public health awareness has grown, and demand for functional food with many health advantages has increased. Chia, a plant native to Mexico and Guatemala, is commonly consumed for its health advantages related to chronic disorders like obesity, diabetes, and cancer. The high content of essential fatty acids, fibre, and antioxidants in this food contributes to its health benefits. It can be eaten on its own or mixed into yoghurt, salads, fruits, pastries, and beverages. Chia seeds have both a preventative and therapeutic effect on health, since their antioxidant capabilities protect the cardiovascular system from disease, while unsaturated omega-3 fatty acids assist lower serum cholesterol levels. Chia seed gum can be used as an alternative in food as an emulsifier, additive and foam stabilizer. Therefore, it is considered as a superfood.

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Introduction

Chia (*Salvia hispanica* L.) is a Lamiaceae family plant that is endemic to central Mexico and northern Guatemala. Carl Von Linneo, a Swedish botanist, identified Chia in 1753 and named it Salvia, which means "to rescue or cure" (in Latin). Chia was consumed as a source of energy by the pre-Columbian people in the 16th century, and it was included into numerous dishes in the indigenous Aztec civilization's diet. Chia seeds were utilized in religious rites as offerings to the Gods, and the oil derived from the seeds was used to make cosmetics. (Ferreira et al., 2015).

Being a biannually cultivated plant, Chia is categorized under the mint family (Lamiaceae), superdivision of Spermatophyta, and kingdom of Plantae (Mohd Ali et al., 2012). Its taxonomic description is as follows:

Kingdom: *Plantae*

Subkingdom: *Tracheobionta - Planta vascular*

Superdivision: *Spermatophyta - Planta de semillas*

Division: *Magnoloiphyta - Planta con flores*

Class: *Magnoliopsida – Dicotiledónea*

Subclass: *Asteridae*

Order: *Lamiales*

Family: *Lamiaceae*

Genera: *Salvia*

Species: *Hispanica* (Sharma and Mogra, 2019)

The optimal environmental conditions for the favourable growth of the plant include warm

climate, high rainfall and temperature of 15-30°C. Chia plant is about 1 m tall and has oval-elliptical leaves (4-8 cm long and 3-5 cm wide). The flowers are 3-4 mm in size with purple or white coloration. They are gathered in whorls or top of shoots. The fruits (schizocarp) contain several oval seeds which are about 2 mm long with a diameter of 0.8-1.3 mm and a width of 0.8-1.4 mm (Marcinek and Krejpcio, 2017). The seed has a smooth and shiny peel that can be black, brown, grey, black-spotted or white colored. Slimy mucilage is present inside the epidermal cells that expand when the seeds come in contact with water. This mucilage imparts a characteristic gel appearance to chia (Grancieri et al., 2019). Chia is a plant that grows in mountainous areas and is tolerant to high temperatures and dryness, although it cannot grow below 0°C. In valley locations, the growing time is about 125-135 days, with yields of up to 1325 kg/ha (Munoz et al., 2013).

Consumption of chia seeds has been increasing over the years, given its health benefits in accordance to chronic conditions such as obesity, diabetes, cancer, and heart diseases. The high amounts of essential fatty acids, dietary fibres, proteins, antioxidants, vitamins, and minerals in this food contribute to its health advantages. Chia seeds can be eaten whole or ground into flour and added to dishes like yoghurt, salads, fruits, and baked goods like bread, cakes, and beverages, among other things. In 2000, the United States Dietary Guidelines recommended that chia seeds be consumed as a primary diet in amounts of no more than 48 g per day (Mohd Ali et al., 2012). Chia incorporation in food improves its physicochemical, sensory, and nutritional properties. The mucilaginous gum present in chia seed possesses a good water and oil holding properties as well as has excellent emulsifying and stabilizing potential. In the same way, chia protein also possesses excellent emulsifying and interfacial characteristics. It also forms a good gel. Such gel forming fractions of chia proteins are promising additives for food processing as they provide consistency and thickening which helps in improving the food quality as well as extend the shelf life of foods (Grancieri et al., 2019).

History of chia seeds

Chia is an ancestral crop that was domesticated some 5,500 years ago, yet it has a fascinating and little-known history. Chia was one of the most important crops in the Aztec diet, along with maize, bean, and amaranth, which fed around 11 million people. Chia production was outlawed in Mexico during Spanish colonization because the Aztecs revered the crop and employed it in sacred rites, as well as because of the rivalry it had with plant species acquired from Spain. Because its traditional use as food and medicine was not passed down to at least six generations, chia production became extinct after nearly 260 years of limitations. The crop thrived after Mexico's independence in 1821 because diverse Nahua groups continued to produce it clandestinely in the mountains of Puebla, Guerrero, Morelos, and Jalisco (Sosa et al., 2016).

The first scientific evidence of the high content of polyunsaturated fatty acids (PUFA) in chia seeds grown in Mexico was published in 1940s; however, its importance was not realized because the essentiality of PUFA on humans was not known at that time. Instead, the harvest was utilized to manufacture beverages and paints for crafts (Small, 2011). This changed in 1975, when Greenlandic researchers discovered that PUFAs are vital for humans and that consuming less than 2 g per day can lead to coronary arteriosclerosis (Bang et al., 1980). This was the crucial step in demonstrating the importance of chia as a food for human nutrition. The chia plant was not imported to other countries and was only grown in the locations where it was used before to the Spanish invasion. As a result, chia is not a common ingredient in modern diets because it did not migrate as far as its ancient counterparts, corn and tomato. In 1990, study of chia as a vegetal source of PUFA, protein and fibre were started thus changing its status as a crop and food source for humans (Sosa et al., 2016).

Chemical composition

The nutritional value of chia seeds is presented in Table 1. Chia seeds are ascribed high nutritional value particularly because of their high contents of polyunsaturated fats, good quality protein, minerals and dietary fibre (Timilsena et al., 2016). Chia seeds have 30-34 g of dietary fibre, with the insoluble fraction

accounting for 85-93% and the soluble fraction for 7-15%. Chia seeds provide more dietary fibre than dried fruits and nuts. It has a high concentration of polyunsaturated fatty acids, particularly α-linolenic acid, in its fatty acid composition. It also contains a lot of plant protein.

Table 1
Nutritional value of chia seeds

Nutrient	*Value (per 100 g)*
Energy	486 Kcal
Moisture	7.14 g
Protein	18.18 g
Fat	32.16 g
Ash	4.1 g
Carbohydrate	4.59 g
Dietary fibre	33.37 g

(Grancieri et al., 2019)

Table 2
Amino acid composition of chia seeds

Essential amino acids	*Content (g/100 g)*	*Non-essential amino acids*	*Content (g/100 g)*
Arginine	2.14	***Cystine***	0.41
Histidine	0.53	***Tyrosine***	0.56
Isoleucine	0.80	***Alanine***	1.04
Leucine	1.37	***Aspartic acid***	1.69
Lysine	0.97	***Glutamic acid***	3.50
Methionine	0.59	***Glycine***	0.94
Phenylalanine	1.02	***Proline***	0.78
Threonine	0.71	***Serine***	1.05
Tryptophan	0.44		
Valine	0.95		

(Grancieri et al., 2019)

The amino acid composition analysis reveals the presence of eleven exogenous amino acids, with the highest concentrations of arginine, leucine, phenylalanine, valine, and lysine. Table 2 shows the amino acid makeup of chia seeds. Celiac patients can eat chia seeds because they are gluten-free.

Chia seeds are also high in polyphenols such gallic, caffeic, chlorogenic, cinnamic, and ferulic acids, as well as quercetin, kaempferol, and p-coumaric acid, which have high biological activity. Small levels of isoflavones like daidzein and genistin can be discovered. Moreover, they also contain tocopherols which include α-tocopherol (8 mg/kg lipids), γ-tocopherol (422 mg/kg lipids) and δ-tocopherol (15 mg/kg of lipids) (Kulczynski et al., 2019). Many vitamins and minerals are contained in chia seeds, with phosphorus, calcium, and potassium being the most abundant, as indicated in Table 3.

Table 3
Mineral and vitamin composition of chia seeds

Minerals	*Content (mg/100 g)*	*Vitamins*	*Content (mg/100 g)*
Calcium	631.0	***Ascorbic acid***	1.6
Iron	7.7	***Thiamine***	0.6
Magnesium	335.0	***Riboflavin***	0.2
Phosphorous	860.0	***Niacin***	8.8
Potassium	407.0	***Vitamin E***	0.5
Sodium	16.0	***Folate***	0.049
Zinc	4.6		

(Kulczynski et al., 2019)

Bioactive compounds in chia seeds

The extra-nutritional constituents that provide health benefits beyond basic nutrition are commonly known as bioactive compounds (Hamzalioglu and Gokmen, 2016). Presence of caffeic acid, chlorogenic acid and quercetin can be correlated with higher content of phenolics in chia (0.99 mg GAE) which is known to protect from oxidative deterioration. Chia seeds are known to contain high amount of protocatechuic acid (0.747 mg/g), chlorogenic acid (0.222 mg/g), and caffeic acid (0.144 mg/g) among phenols. Caffeic acid dimers are also frequent in chia samples and the most abundant among them is rosmarinic acid (0.927 mg/g) which is known to be anti-inflammatory, antioxidative, antithrombotic, antimutagen, anti-bacterial and antiviral (Grancieri et al., 2019). Caffeic acid in chia seeds were found to be greater than that reported for mango, papaya and blueberry (Balasundram et al., 2006). Polyphenolic compounds such as quercetin, caffeic acid and chlorogenic acid found in chia seeds are believed to have anti-carcinogenic, antihypertensive, and neuron protective effects (Ullah et al., 2016).

Flavonoids are polyphenols with a 15-carbon structure made up of two benzene rings connected by a heterocyclic pyrene ring. They are responsible for the color and flavor of food, as well as preventing fat oxidation. (Yao et al., 2004). Flavonoids are widely distributed in chia seeds and their synthesis has been found to increase with microbial infection. They are

known to be hepatoprotective, antibacterial, anti-inflammatory, anti-cancer and anti-viral (Cushnie and Lamb, 2005). Among flavonoids, myrcetin, quercetin and kaempferol are found to be abundant in chia seeds (Taga et al., 1984). Other bioactive compounds found in chia seeds include tannins (14.93 mg GAE/g), phytates (1.16 g/100 g), carotenoids (57.0 µg/100 g), flavones (6.07 µg/100 g), and flavanones (4.39 µg/100 g) (Grancieri et al., 2019).

Fatty acid composition

Chia seed oil has been used in traditional medicine for treating stomach problems and eye infections since ancient times (Lu and Foo, 2002). Consumers are shifting away from saturated fats and toward unsaturated fats as part of the healthy lifestyle movement. This is due to the high prevalence of cardiovascular disease, obesity, and diabetes, all of which are linked to saturated fats. As a result, the intake of functional foods containing polyunsaturated fatty acids such as omega-3 and omega-6 fats has increased (Ullah et al., 2016). Alpha-linolenic acid, eicosapentaenoic acid, and docosahexaenoic acid are omega-3 fatty acids, whereas linoleic acid and arachidonic acid are omega-6 fatty acids. Chia seed is renowned as an omega fatty acid powerhouse because it contains significant amounts of omega-3 [alpha-linolenic acid (ALA)] and omega-6 [linoleic acid (LA)]. It has been observed that consuming 7.3 g of chia seed per day is sufficient to meet the necessary dietary intake of omega-3 fatty acids (de Falco et al., 2017).

Several phenolic components included in chia seed oil, such as tocopherols, phytosterols, and carotenoids, are known to protect against lipid oxidation (Matthaus, 2002). It was reported that chia seed oil contains 62.8% α-linolenic acid and 18.23% linoleic acid (da Silva Marineli et al., 2014). Chia seeds can thus be regarded a natural supply of polyunsaturated fatty acids, which have anti-inflammatory, antiarrhythmic, and antithrombotic properties and hence play a significant role in human health. The fatty acid content of chia seeds is seen in Table 4.

Health promoting properties of chia seeds

Nowadays consumers shift their dietary habits towards healthier food options, particularly those which present therapeutic effects and convey an adequate amount of nutrients (Melo and Oliveira, 2018). Chia seeds are high in fibre, which turns into a gel when exposed to water. This helps with bowel motions and hence relieves constipation. Fibre has also been shown to aid digestion. Chia's ability to inhibit digestion has been related to the prevention of diabetes. Chia seeds' gelatinous coating can also help to reduce blood sugar rises. The seeds are one of the foods that has been discovered to be beneficial in the treatment of diabetes and to lower blood pressure in diabetics (Cifti et al., 2012).

Weight management depends on our food habits and lifestyle. Although no single food can help or hinder weight reduction, chia seeds are regarded an alternative that aids weight loss due to their high fibre content. The seeds absorb water in the stomach and expand, which reduces hunger. Fibre promotes satiety and makes us feel full for longer periods of time. Several antioxidant chemicals found in chia seeds suppress NF-B transcription factor activation in vitro, lowering inflammatory and carcinogenic processes. Chia seeds have a higher antioxidant concentration than other seeds, making them more shelf durable. Neurological illnesses, immunodeficiency, ischemic heart disease, strokes, Alzheimer's and Parkinson's disease, and cancer are all protected by antioxidants (Grancieri et al., 2019).

Chia seeds contain omega-3 fatty acids, which have been shown to improve skin dryness and inflammation. Moreover, anti-inflammatory properties of chia seeds help protect the skin from UV radiation, reduce wrinkles and skin sagging. The biological effects of chia seed PUFAs in the skin have been extensively studied, including inhibition of trans epidermal water loss, maintenance of the stratum corneum epidermal barrier, and interruption of melanogenesis in melanocytes. Chia seeds have been discovered to help prevent diverticular disease, which is characterized by the presence of tube-like structures in the intestine with no indications of inflammation

and is frequently associated to a lack of fibre (Cifti et al., 2012).

Therapeutic properties of chia seeds

Chia seed consumption has been shown to reduce serum cholesterol level due to high concentrations of dietary fibre and unsaturated omega-3 fatty acids. Chia seeds have been reported to be effective in the treatment of dyslipidemia, a metabolic disease characterized by an abnormally high level of cholesterol in the blood. The ability of chia bioactive peptides to prevent critical indicators of cholesterol production, such as 3-hydroxy-3-methylglutaryl coenzyme A reductase, has recently been established (Coelho et al., 2018). Chia seeds are rich in tryptophan which produces the sleep hormones serotonin and melatonin. So, chia seeds aid good sleep and relaxation. They are also used for treating sleep disorders. Chia seeds contain 30% of the recommended daily allowance (RDA) of magnesium, making them beneficial in the treatment of hypertension, osteoporosis, and type II diabetes (Cifti et al., 2012).

Therapeutic properties such as analgesic, laxative, hypotensive and antineoplastic properties are also attributed to chia seeds (Ayerza and Coates, 2005). They are recognized for their anti-oxidant and anti-inflammatory effects, which help to protect the cardiovascular system (Brenna et al., 2009). Chia seeds' anti-coagulant properties may also aid in the prevention of strokes and heart attacks in Type II diabetics. Chia seed eating has been demonstrated in studies to lower postprandial glycemia in healthy people (Ho et al., 2013). Chia seed and oil are known to have a protective effect on blood vessels as they reduce the concentration of triacylglycerol (Sierra et al., 2015) and were reported to increase the concentration of α-linolenic acid and eicosapentaenoic acid in blood serum of overweight women (Neiman et al., 2012). Calcium and sodium channel dysfunctions, which can lead to hypertension, can be blocked by omega-3 fatty acids. They boost parasympathetic tone, heart rate variability, and ventricular arrhythmia protection (Ullah et al., 2016).

Table 4
Fatty acid profile of chia seeds

Saturated Fats	*Content (g/100 g)*	*Unsaturated Fats*	*Content (g/100 g)*
Palmitic acid	7.1	***Oleic acid***	10.53
Stearic acid	3.24	***Linoleic acid***	20.37
Arachidic acid	0.24	***Linolenic acid***	59.76
Lignoceric acid	0.1	***Eicosenoic acid***	0.16

(Kulczynski et al., 2019)

Industrial uses of chia seeds

The technological functionality of dietary fibres found in abundance in chia seeds is determined by hydration qualities such as water holding capacity, absorption, solubility, swelling, viscosity, and gelling (Borderias et al., 2005). Treatment of chia seeds with water helps extract gum from the dietary fibre fraction and this extracted chia gum can be used as an additive to control texture, viscosity, stability and consistency in food systems (Capitani et al., 2015). Chia seed gum, which can resist temperatures as high as 244°C, is a promising ingredient in high-value food formulations (Timilsena et al., 2016). Rheological behavior of chia seed gum is shear thinning or pseudoplastic type. Moreover, it has an oil holding capacity of 11.67 g/g and water absorption capacity of 36.26 g/g (Segura-Campos et al., 2014).

Chia seed fibre can be a valid alternative in foods as foam stabilizer and emulsifier. Due to high protein content, it has the ability to facilitate solubilization of two immiscible liquids and to maintain an emulsion (Pearce and Kinsella, 1978). Chia mucilage has a water retention capacity of 27 times its own weight, according to studies (Munoz et al., 2012). Chia seeds are especially used in gluten free formulations of bread and pasta, for medicinal and cosmetic uses as a thickening agent, and as a component in biodegradable film (Capitani et al., 2016). Chia is also used for preparation of omega-3 capsules as it produces essential oil in great concentration. Essential oil extracted from leaves of chia is utilized as scent and condiment. It is also used for insect control as it contains insect repelling compounds such as β-caryophyllene, globulol, β-pinene, and widdrol. Chia seed mucilage has recently been discovered to be a functional coating with

better functional characteristics (Ullah et al., 2016).

Conclusion

Because of the recent surge of healthy lifestyle changes, functional foods have received a lot of attention. One reason for this is the rising number of people suffering from cardiovascular diseases, high blood pressure, obesity, and diabetes, all of which are caused by a sedentary lifestyle and a diet heavy in saturated fatty acids (SFA). There have been various studies that show a link between high SFA and low PUFA intake and cardiovascular disease. Chia has recently recovered its reputation as a high-PUFA oil source. It was once the primary food source for Mexico's indigenous peoples, but it is now widely cultivated and sold due to its omega-3 fatty acid and antioxidant benefits. Its cultivation has now spread to America, Australia and Southeast Asia.

Chia is mostly consumed by humans in the form of extracted oil, which is used in cooking oil, confections, and supplements. It is typically consumed as a salad made from chia seeds, as well as in beverages, cereals, and salad dressings. Chia seeds or oil have been widely employed in the food sector for a variety of uses, including breakfast cereals, bars, cookie snacks, fruit juice, cake, and yoghurt. Consumers were not aware of chia's health benefits until recently, despite its well-known fatty acid profile. Thus, according to current studies, chia is an excellent choice of oil for maintaining a balanced serum lipid profile, but more research is needed into the mechanisms of its hypolipidemic effects, as clinical bioactivity and safety evaluation of chia seeds is currently limited. Many studies are currently being carried out in order to improve their functionality as high-nutrient dietary supplements with bioactive components.

References

Ayerza, R., & Coates, W. (2005). *Chia: Rediscovering an Ancient Crop of the Aztecs*. University of Arizona Press.

Balasundram, N., Sundram, K., & Samman, S. (2006). Phenolic compounds in plants and agri-industrial by-products: Antioxidant activity, occurence, and potential uses. *Food Chemistry*, *99*(1), 191–203.

Bang, H. O., Dyerberg, J., & Sinclair, H. M. (1980). The composition of the Eskimo food in north western Greenland. *The American Journal of Clinical Nutrition*, *33*(12), 2657–2661. https://doi.org/10.1093/AJCN/33.12.2657

Borderias, A. J., Sanchez-Alonso, I., & Perez-Mateos, M. (2005). New applications of fibres in food: addition to fishery products. *Trends in Food Science and Technology*, *16*.

Brenna, J. T., Salem, N. J., Sinclair, A. J., & Cunnane, S. C. (2009). Alpha-Linolenic acid supplementation and conversion to n-3 long chain polyunsaturated fatty acids in humans. *Prostaglandins, Leukotrienes and Essential Fatty Acids ISSFAL*, *80*.

Capitani, M. I., Corzo-Rios, L. J., Chel-Guerrero, L. A., Betancur-Ancona, D. A., Nolasco, S. M., & Tomas, M. C. (2015). Rheological properties of aqueous dispersions of chia (*Salvia hispanica* L.) mucilage. *Journal of Food Engineering*, *149*.

Capitani, M. I., Matus-Basto, A., Ruiz-Ruiz, J. C., Santiago-Garcia, J. L., Betancur-Ancona, D. A., Nolasco, S. M., Tomas, M. C., & Segura-Campos, M. R. (2016). Characterization of biodegradable films based on Salvia hispanica L. protein and mucilage. *Food and Bioprocess Technology*,*9*.

Cifti, O. N., Przybylski, R., & Rudzinska, M. (2012). Lipid components of flax, perilla and chia seeds. *European Journal of Lipid Science and Technology*, *114*(7), 794–800. https://doi.org/10.1002/ejlt.201100207

Coelho, M. S., Soares-Freitas, R. A., Areas, J. A., Gandra, E. a., & Salas-Mellado, M. (2018). Peptides from chia present antibacterial activity and inhibit cholesterol synthesis. *Plant Foods for Human Nutrition*, *73*(101–107).

Cushnie, T. P. T., & Lamb, A. J. (2005). Antimicrobial activity of flavonoids. *International Journal of Antimicrobial Agents*, *26*, 343–356.

da Silva Marineli, R., Moraes, E. A., Lenquiste, S. A., Godoy, A. T., Eberlin, M. N., & Marostica, M. R. (2014). Chemical characterization and antioxidant potential of Chilean chia seeds and oil (Salvia hispanica L.). *Journal of Food Science and Technology*, *59*.

de Falco, B., Amato, M., & Lanzotti, V. (2017). Chia seeds products: an overview. *Phytochemistry Reviews*, *16*(4), 745–760. https://doi.org/10.1007/s11101-017-9511-7

Ferreira, C., de Sousa Fomes, L. de F., da Silva, G. E. S., & Rosa, G. (2015). Effect of chia seed (*Salvia hispanica* l.) consumption on cardiovascular risk factors in humans: A systematic review. *Nutricion Hospitalaria*, *32*(5), 1909–1918. https://doi.org/10.3305/nh.2015.32.5.9394

Grancieri, M., Martino, H. S. D., & Gonzalez de Mejia, E. (2019). Chia Seed (*Salvia hispanica* L.) as a Source of Proteins and Bioactive Peptides with Health Benefits: A Review. *Comprehensive Reviews in Food Science and Food Safety*, *18*(2), 480–499. https://doi.org/10.1111/1541-4337.12423

Hamzalioglu, A., & Gokmen, V. (2016). Interaction between Bioactive Carbonyl Compounds and Asparagine and Impact on Acrylamide. In *Acrylamide in Food* (pp. 355–376).

Ho, H., Lee, A. S., Jovanovski, E., Jenkins, A. L., Desouza, R., & Vuksan, V. (2013). Effect of whole and grounded *Salba* seeds (*Salvia Hispanica* L.) on postprandial glycemia in healthy volunteers: a randomized controlled, dose-response trial. *European Journal of Clinical Nutrition*, *67*(2).

Kulczynski, B., Kobus-Cisowska, J., Taczanowskia, M., Kmeicik, D., & Gramza-Michalowska, A. (2019). The chemical composition and nutritional value of chia seeds – current state of knowledge. *Nutrients*, *11*. https://doi.org/10.3390/nu11061242

Lu, Y., & Foo, L. Y. (2002). Polyphenolics of Salvia - a Review. *Phytochemistry*, *59*, 117–140.

Marcinek, K., & Krejpcio, Z. (2017). Chia seeds (*Salvia hispanica*): health promoting properties and therapeutic applications – a review. *Roczniki Panstwowego Zakladu Higieny*, *68*(2), 123–129.

Matthaus, B. (2002). Antioxidant activity of extracts obtained from residues of different oilseeds. *Journal of Agriculture and Food Chemistry*, *50*.

Melo, D., & Oliveira, M. B. (2018). Health Benefits of Chia Seeds' Dietary Consumption. *EC Nutrition*, *11*(13), 738–741.

Mohd Ali, N., Yeap, S. K., Ho, W. Y., Beh, B. K., Tan, S. W., & Tan, S. G. (2012). The promising future of chia, Salvia hispanica L. *Journal of Biomedicine and Biotechnology*, 9.

Munoz, L. A., Cobos, A., Diaz, O., & Aguilera, J. M. (2012). Chia seeds: Microstructure, mucilage extraction and hydration. *Journal of Food Engineering*, *108*.

Munoz, L. A., Cobos, A., Diaz, O., & Aguilera, J. M. (2013). Chia seed (Salvia hispanica): An Ancient Grain and a New Functional Food. *Food Reviews International*, *29*(4).

Neiman, D. C., Gillit, N., Jin, F., Henson, D. A., Kennerly, K., Shanely, R. A., Ore, B., Su, M., & Schwartz, S. (2012). Chia seed supplementation and disease risk factors in overweight women: a metabolomics investigation. *Journal of Alternative and Complementary Medicine*, *18*(7), 700–708.

Pearce, K. N., & Kinsella, J. E. (1978). Emulsifying properties of proteins: evaluation of a turbidimetric technique. *Journal of Agriculture and Food Chemistry*, *26*.

Segura-Campos, M. R., Solis, N. C., Rubio, G. R., Guerrero, L. C., & Ancona, D. B. (2014). Chemical and functional properties of chia seed (*Salvia hispanica* L.) gum. *International Journal of Food Science.*, 2014, 241053.

Sharma, V., & Mogra, R. (2019). A Comprehensive Review on Chia Seeds (*Salvia hispanica* L.). *International Journal of Chemical Studies*, *7*(5), 57–61.

Sierra, L., Roco, J., Alarcon, G., Medina, M., Nieuwenhove, C. V., Peral de Bruno, M., & Jerez, S. (2015). Dietary intervention with Salvia hispanica (chia) oil improves vascular function in rabbits under hypercholesterolaemic conditions. *Journal of Functional Foods*, *14*.

Small, E. (2011). 34. Chia – not just a pet. *Biodiversity*, *12*(1), 49–56. https://doi.org/10.1080/14888386.2011.575104

Sosa, A., Ruiz, G., Rana, J., Gordillo, G., West, H., Sharma, M., Liu, X., & Robles de la Torre, R. (2016). Chia Crop (*Salvia hispanica* L.): its history and importance as a source of polyunsaturated fatty acids omega-3 around the world: a review. *Journal of Cancer Research Forecast*, *1*(1), 1–4. https://doi.org/10.17303/jcrf.2016.104

Taga, M. S., Miller, E. E., & Pratt, D. E. (1984). Chia seeds as a source of natural lipid antioxidants. *Journal of the American Oil Chemists Society*, *61*, 928–932.

Timilsena, Y. P., Adhikari, R., Kasapis, S., & Adhikari, B. (2016). Molecular and functional characteristics of purified gum from Australian chia seeds. *Carbohydrate Polymers*, *136*.

Ullah, R., Nadeem, M., Khalique, A., Imran, M., Mehmood, S., & Javid, A. (2016). Nutritional and therapeutic perspectives of Chia (*Salvia hispanica* L): a review. *Journal of Food Science and Technology*, *53*(4), 1750–1758. https://doi.org/10.1007/s13197-015-1967-0

Yao, L. H., Jiang, Y. M., Shi, J., Tomas-Barberan, F. A., Datta, N., Singanusong, R., & Chen, S. S. (2004). Flavonoids in food and their health benefits. *Plant Food Human Nutrition*, *59*, 113–122.

