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Chia Seeds (SALVIA HISPANICA L.) and Food Supplementation: An Analysis of its Properties and Benefits

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Abstract

This is a narrative review study that aims to analyze the properties of chia and associate it with dietary supplements. A bibliographic survey of articles available in the Scopus database was carried out from January 2004 to April 2024, produced in Brazil and abroad, using the descriptor terms "Food Supplement" and "Chia (Salvia hispânica L.)". The sample consisted of a total of 69 articles, 22 of which were review articles that were excluded. The others were read and critically analyzed, thus excluding three more articles that escaped the theme. Most papers show the main components of chia and their benefits. Chia seed has Mexican origins and belongs to the Lamiaceae family. It has several properties that can be used in food preparation or pharmaceutical formulations. It can also be used to aid in the treatment and prevention of diseases. Chia is a seed rich in nutrients, including protein, fiber, antioxidants, and omega-3 fatty acids. It has been recognized for its ability to aid in weight loss, improve heart health, and strengthen bones. Additionally, chia is versatile and can be easily incorporated into a variety of dishes, making it a valuable addition to the daily diet.

Keywords: Chia Seeds; Food Supplementation; Dietary Supplements; Weight Loss; Strengthen Bones

Abbreviations

ADA: American Dietetic Association; AE: Emulsifying Activity; AGPF: Advanced glycation of the final product; HA: Anti-hypertensive; ALA: Alpha-linolenic acid; ANVISA: National Health Surveillance Agency; CRA: Water Holding Capacity; CRO: Oil Holding Capacity; DM: Malonic Dialdehyde; DNA: Deoxyribonucleic acid; DPA: Docosahexaenoic acid; EA: Emulsion Stability; ECA: Angiotensin Conversora Enzyme; EPA: Eicosapentaenoic acid; FDA: Food and Drug Administration; FE: Foaming; FOSHU: Foods for specified health use; GABA: ɤ- aminobutyric acid; GSC:Goma de semente de chia; IN: Normative Instruction; IPSC: Chia Seed Protein Isolate; ME: Keep Foam; The: Noradrenalina; n-3: Omega 3; n-6: Omega 6; OCED: Chia Oil in a Double Emulsion; pH: Hydrogen Potential; PUFAs: Polyunsaturated Omega 3 Long Chain Fatty Acid; RDC: Resolution of the Collegiate Board of Directors

Introduction

Since the time of Hippocrates, about 2500 years ago, the idea that food can be used as medicine has permeated society. However, it was in Japan in the 90s that the term "functional foods" gained prominence, marking the beginning of an era where food began to be strategically designed to promote health and prevent diseases. The industrialization of food in the 20th century brought with it public health challenges, driving governments and industries to seek innovative solutions. Thus, the market for healthy products, free of sugars and fats, emerged, and later, functional foods, which offer specific benefits to the body, such as reducing the risk of chronic diseases.

At the same time, food supplementation has emerged as a way to supplement the daily diet with essential nutrients, especially in cases where regular feeding is not enough. In the United States, the term "nutraceutical" is often associated with this practice, referring to the use of isolated components to enhance health. The increasing prevalence of diseases such as hypertension and diabetes has increased the demand for a healthier lifestyle, where dietary supplementation plays a crucial role. However, it is important to highlight the need for professional follow-up to avoid the indiscriminate use of supplements, which can interact with medications and adversely affect health.

Chia seed, a rediscovered superfood, has its roots in pre--Columbian civilizations, where it was prized for its medicinal and nutritional properties. After centuries of oblivion, chia has re-emerged as a rich source of essential fatty acids, antioxidants, fiber, protein, and other vital nutrients. Its inclusion in the modern diet is supported by scientific evidence highlighting its health benefits, although there is still a need for more studies to establish specific use claims.

This comprehensive text highlights the historical and contemporary importance of functional foods and dietary supplementation, as well as the exceptional nutritional value of chia seed, emphasizing the need for regulation and professional guidance in the use of these products to ensure health and well-being.

Methodology

In order to meet the objective of this work, an exploratory, descriptive and documentary study was carried out, based on a bibliographic survey of articles available in the Scopus database, in the period from January 2004 to April 2024, produced in Brazil and abroad and the Brazilian legislation, RDC 243/2018 and IN nº 28, of 26 July 2018. For this purpose, the descriptor terms "Food Supplement" and "Chia (*Salvia hispânica L.*)" were used, thus selecting original articles, available in full, considering title, keywords and abstract. Data collection was carried out in April 2024, obtaining a total of 69 articles (review articles, book chapters and books), these were read and critically analyzed. A total of 22 review articles were excluded, resulting in a total of 47 used articles.

Functional Foods, A Brief History

The use of food to prevent disease began about 2500 years ago with an emphasis on Hippocrates who said: "make food your medicine". The term "functional foods" was adopted only in the 90s in Japan, where it began its production and commercialization using the acronym FOSHU (Foods for specified health use). Functional foods were the third to arrive on the market, preceded by light and enriched products (Moraes and Colla, 2006).

In the second half of the 20th century, several health problems arose due to the industrialization of food, probably due to the artificial components used (Bianco *et al.*, 2008). In the 1970s, discussions between governments arose around this situation, and with that the food industry invested in research and created a new market, the "healthy market" that offered sugar-free and low-fat products. Also around this time, health professionals along with committees created by governments and academics created recommendations to change the diet of the population, once again forcing the food industry to seek innovations. (Bianco *et al.*, 2008).

In that same decade, another new market was created with value-added products. The concept of functional foods, however, emerged in the 1920s, due to the addition of iodine to salt in order to combat goiter, but only gained strength in Japan in the 90s (Bianco *et al*., 2008).

The FDA (Food and Drug Administration) has established regulations classifying foods into categories such as: food, food-medicated, dietary supplements, and foods for special dietary uses or drugs (Vidal *et al*., 2012). The United States differentiates the terms functional foods from nutraceuticals, and the term nutraceutical is used for products with a particular isolated component, in the form of capsules, powders, bars, among others (Moraes and Colla, 2006).

Foods with functional properties have been confused with drugs that prevent and treat diseases and their symptoms, so regulation is necessary. In Brazil, the responsible body is ANVISA (National Health Surveillance Agency), which published its first resolutions on functional foods in 1999, Resolutions No. 18/99 and 19/99 (Brazil, 1999a; Brazil, 1999b).

These were intended to regulate the production, packaging, investment in technologies and commercialization of these foods (Amorim and Grisotti, 2010). Finally, functional foods are those with substances capable of reducing the risk of diseases and altering the functions of the human body (Bianco, 2008).

Functional foods have a value beyond ordinary foods that offer nutrients. They hold great potential to prevent chronic diseases and improve well-being. They can be classified according to the source, animal or vegetable, and the types of benefits they offer, which can be: cardiovascular system, growth, gastrointestinal system, cell development and differentiation, metabolism of substrates, antioxidants and the behavior of physiological functions (Moraes and Colla, 2006).

As an example, seeds and grains like chia, flaxseeds, oats, and quinoa are considered functional foods due to their high content of essential nutrients such as proteins, fibers, and healthy fats. Table 1 presents a detailed comparison of the nutritional composition of these foods, highlighting their contribution to a balanced and health-promoting diet.

Table 1: Nutritional Comparison of Chia, Flaxseeds, Quinoa, and Oats

Nutrient	Chia seeds(28 g)	Flaxseeds (28 g)	Quinoa (28 g)	Oats (28 g)
Calories	138	151	104	110
Protein (g)	4.7	5.1	4.0	4.0
Total Fats(g)	8.7	12	1.8	2.0
Saturated fats(g)	0.9	1.0	0.2	0.4
Total Carbohydrates(g)	12	8	19	19
Fibre (g)	10.6	7.7	2.6	3.0
Calcium (mg)	177	71	17	14
Iron (mg)	2.2	1.6	1.5	1.3
Magnésio (mg)	95	110	60	27
Omega-3(g)	5.0	6.3	-	-

Dietary supplementation

Food supplementation is intended to complement the daily diet with nutrients, if the diet is not fulfilling this function. The vitamins and minerals present in a supplement should be a minimum of 25% and a maximum of 100% of the recommended daily intake. They can be in the following forms: solid, semi-solid, liquid or aerosol (Pereira and Bajo, 2012).

Food supplementation is associated with a concept previously discussed, the term nutraceutical, more commonly used in the United States, which characterizes the use of isolated components in different forms in order to, like functional foods, complement the individual's diet (Moraes and colla, 2006).

The increase in the number of people suffering from cardiovascular diseases, hypertension, diabetes, obesity and other correlated diseases has caused the population to increase interest in a healthier lifestyle. What triggers these diseases is usually related to poor eating habits, with diets rich in saturated fatty acids, among other factors, and for this reason food supplementation has gained great attention worldwide (Ali *et al.*, 2012).

Food supplementation aims to complement the individual's diet with nutrients and calories to meet daily needs, in addition to being used to improve the performance and performance of athletes, increase body temperature for better caloric expenditure, reduce appetite, among others. The use of supplements is often not monitored by a health professional and with that there is indiscriminate use with the idea that supplements only generate benefits to the body. (Ferreira *et al.*, 2016).

The nutrients present in supplements can interact with medications, an interaction known as a drug-nutrient, impairing the kinetics of the drug and/or nutrient. An example of this is the complexation mechanism that decreases the availability of the drug and nutrient. Di- and trivalent minerals such as calcium (Ca^{2+}), magnesium (Mg^2+) and iron (Fe^2+ Fe^3+), when interacting with tetracyclines, can form non-absorbable chelates and thus be eliminated in the feces (Pereira and Bajo, 2012).

In Brazil, food supplementation was only resolved in 2018 and products have a period of 60 months to be regularized with the National Health Surveillance System. The purpose of this resolution is to provide requirements for the composition, quality, safety and labeling of these products. The chia seed is found in Annex I of Normative Instruction No. 28 of July 26, 2018, which complements RDC 243/2018 (Brazil, 2018a; Brazil, 2018b).

The inclusion of chia seed in Annex I of IN No. 28 was very important, especially (Brazil, 2018b), due to the scientific evidence that shows how rich it is in essential components for human health. Despite this, chia still has no claims of use, it is not known if there has been a demand from the industry or if more studies are needed to prove its effectiveness and thus establish criteria for use.

Chia seed

The chia seed began to be used around 3500 B.C. and gained importance between 1500 to 900 years B.C. It was used by the Mayans and Aztecs in medicinal preparations, food, and paints, being one of the main crops of pre-Columbian society. The word "chia" is a Spanish adaptation of *chian* or *chien* (plural), which means oily (Muñoz *et al.*, 2013).

The seed became extinct for centuries because it was used in rituals as an offering to the gods and was frowned upon by Catholic Spaniards, disappearing in the 16th century. They can grow up to two meters tall and their average yield is 250 g of seed per plant (Coelho and Salas-Mellado, 2014).

Chia belongs to the Lamiaceae family, of the class of dicots, genus Salvia and Hispanic species (Álvares-Chavez *et al.*, 2008). The pericardium is grayish brown with dark brown dots with irregular contours (García-Salcedo *et al.*, 2018). They are rich in antioxidants and therefore can be stored for a long period without deteriorating. They have a considerable amount of oil and much of it has linolenic acid, a fatty acid called omega 3, associated with several health benefits (Vásquez-Ovando *et al.*, 2009; Caruso *et al.*, 2018). Chia seed is also a great source of soluble and insoluble fiber, mucilaginous gum, and protein, containing all nine essential amino acids (Álvares-Chavez *et al.*, 2008; Costantini *et al.*, 2014; Timilsena *et al.*, 2016a; Bustamante *et al.*, 2017; Crespo *et al.*, 2018).

They have great nutritional value with high concentrations of essential fatty acids, especially alpha-linolenic acid (ALA - 60%), natural antioxidants such as chlorogenic acid, caffeic acid, myricetin, quercetin and kaempferol. It is a natural source of omega-3 that represents 75% of the total content of its oil (Muñoz *et al.*, 2013).

It also has a significant amount of dietary fiber, protein, mucilage that aids in digestion and has no gluten or toxic components. The levels of heavy metals do not exceed the maximum safe level. Finally, it is an important source of vitamins and minerals (Ali *et al.*, 2012).

Consumption of 25 g of chia seed per day over a seven-week period showed elevated plasma levels of ALA (138%) and eicosapentaenoic acid (30%) in postmenopausal women (Coelho and Salas-Mollado, 2014).

A study conducted on rats fed a diet rich in sucrose (62.5%) for a period of 3 weeks showed that the use of chia prevented dyslipidemia and insulin resistance, without altering the glycemia of rats. In addition, these animals on this diet prolonged for two months showed a reduction in visceral adiposity (Chicco *et al.*, 2009).

The substitution of ingredients in foods aims to increase the nutritional value without affecting the sensory aspects. Chia seed is an excellent candidate for this function because, in addition to adding nutritional value, it has the ability to retain water and oil, and can be used in baked goods and as a food emulsion (COELHO and Salas-Mollado, 2014).

Omega-3

The largest source of omega-3 comes from fish, but high intake of fish is associated with the ingestion of mercury and possibly other pollutants, posing a health risk (Cooper, 2015). In addition, chia seed can be used as a source of omega-3 by people allergic to fish or by vegetarians (Zettel and Hitzmann, 2018).

Salvia hispanica L. it is rich in omega 3, mainly ALA, a precursor to a long-chain fatty acid omega 3 polyunsaturated acid (PUFAs), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DPA). EPA and DPA are considered essential fatty acids since they are not produced by the human body (Álvarez-Chávez *et al.*, 2008; Marilneli *et al.*, 2014; Souza *et al.*, 2017). PUFAs help decrease triglycerides, cholesterol and blood pressure levels, have anti-inflammatory, cardioprotective, hepatoprotective and antidiabetic activity. In addition, they protect against autoimmune diseases, cancer, and arrhythmias (Costantini *et al.*, 2014).

Unlike omega 3, omega 6, also found in chia seeds, but to a lesser extent, has inflammatory, hypertensive and thrombotic activity, being important as a way to balance omega 3 activities (Caruso *et al.*, 2018).

There is much discussion about the omega 6/omega 3 (n6/n-3) ratio recommended by Pizzarro et al. of 4:1 or less. A high n-6/n-3 ratio is detrimental to health and can lead to the development of chronic diseases (Pizarro *et al.*, 2015; Costantini *et al.*, 2014). The eicosanoid derivative of omega-6, arachidonic acid is considered pro-inflammatory, and the eicosanoid derivative of omega-3, eicosapentaenoic acid, is anti-inflammatory (GIARETTA *et al.*, 2018). Therefore, to improve this relationship, it is ideal to increase omega 3, thus improving neural functions and helping in cases of heart disease, arthritis and cancer (Costantini *et al.*, 2014; Pizarro *et al.*, 2015).

Several studies, shown in Table 2, have shown that chia has a considerably low n6/n3 ratio, i.e., the amount of omega 3 is significantly higher than the amount of omega 6. These studies were based on different origins of chia, showing that regardless of the form in which chia is found, the values of the omega 6/omega 3 ratio will be approximate.

Pizarro et al. (2015) developed a study using chia flour in the preparation of bread in order to verify the benefits of this recipe optimization in the nutritional composition of the food. The breads without added chia had an amount of omega 6 of 19.26 ± 0.02 g/100g and omega 3 of 0.45 ± 0.03 g/100g, so their omega 6/omega 3 ratio was 42.68 ± 0.41. On the other hand, the breads prepared with the addition of chia flour presented a value of n6 of 18.72 ± 0.07 g/100g and of n3 of 12.94 ± 0.13 g/100g. Its n6/n3 ratio was 1.45 ± 0.01, showing that the use of chia in food preparation considerably decreases this ratio, making the food healthier for consumption.

Table 2: Comparison of Omega-6/Omega-3 Ratio in Different Varieties of Chia

Origin	C18:3 n-3 (g/100g)	C18:2 n-6 (g/100g)	Relação n-6/n-3	References
Chilean chia oil	62,80	18,23	0,29	MARINELI *et al.*, 2014
Chia flour	18,782 ± 0,836	6,110 ± 0,304	0,32	COSTANTINI *et al.*, 2014
Chia seeds	0,06341 ± 0,0003	0,01954 ± 0,0004	0,31	GIARETTA *et al.*, 2018
Peruvian chia seeds	57,71	18,82	0,33	AMATO *et al.*, 2015
Chia seed oil	61,4 ± 1,3 – 60,5 ± 0,0	20,8 ± 0,4 – 21,7 ± 0,1	0,34 – 0,36	DABROWSKI *et al.*, 2018
Australian chia seeds	58,39	20,74	0,35	AMATO *et al.*, 2015
Chia seed with organic + mineral fertilizers	62,80	20,11	0,32	AMATO *et al.*, 2015

The intake of this fatty acid is very important, as it has several health benefits for humans, and can lower triglyceride and cholesterol levels, which can lead to a decrease in blood pressure and protection against heart disease. It has anti-inflammatory, cardioprotective and hepatoprotective activity due to lipid redistribution of visceral fat and liver. Antidiabetic action and protection against arrhythmias, autoimmune diseases, and cancer (Ali *et al.*, 2012; Muñoz *et al.*, 2013; Cooper, 2015).

In addition, a study reports that omega-3 inhibits blood clotting, promotes tissue regeneration, reduces carbohydrate digestion time, helps control blood glucose levels, decreases the risk of brain diseases, depression, and epilepsy; improves the immune system and aids in the development of the retina and brain in fetuses, being beneficial for the health of children up to two years of age (Muñoz *et al.*, 2013).

Antioxidants

Myricetin, quercetin, kaempferol, tocopherol, chlorogenic acid and caffeic acid are phenolic acids that are present in chia seeds and have as their main activity as an antioxidant. However, other activities are attributed to them as anti-inflammatory, anticancer, and antithrombotic (Ali *et al.*, 2012).

The most important vitamin is tocopherol, which varies its amount between 238-427 mg/kg in chia seed and has antioxidant properties. Caffeic and chlorogenic acids are also present and protect the body against free radicals and inhibit the peroxidation of fats, proteins, and DNA. The quercetin present has antioxidant action with a cardioprotective effect (Muñoz *et al.*, 2013).

The high composition of fatty acids in foods can leave them susceptible to lipid oxidation, thus losing functional properties. However, chia oil was stable up to 60ºC for ten hours, in oxidative atmosphere and under high pressure (1400kPa). Only at temperatures above 80ºC for five hours did the oxidation process begin, indicating that chia oil cannot be heated above 80ºC (Souza *et al.*, 2017).

Caffeic acid, myricetin, kaempferol and quercetin are primary and natural antioxidants present in chia seeds, with caffeic acid being a phenolic compound and the others considered as flavonoids and procyanidins (Rahman *et al.*, 2017). They have antioxidant, anti-inflammatory, anticancer and antithrombotic activity (Vásquez-Ovando *et al.*, 2009).

A study carried out by Caruso and his collaborators (2018), with samples of chia seed from southern Italy, aimed to evaluate the nutritional characteristics of seeds stored in three different periods, 0.5 and 10 months, in glass packaging, room temperature and dark environment. 18.71% of linoleic acid was obtained and after 10 months 0.10% was lost. For the fatty acid ALA was found 65.42% and there was an increase of 0.25%. Caffeic acid was 0.482mg/g of the seed and 0.233% was lost. Myricetin was 0.076mg/g of the seed, losing 0.014%. Finally, Kaempferol obtained 0.054 mg/g from the seed and lost 0.006%. In this study, quercetin was not quantifiable.

All compounds showed an insignificant amount of loss and with this, the study showed the ability of the seeds to retain their compounds with functional properties, showing that they can be stored for up to 10 months without significant changes in their components (Caruso *et al.*, 2018).

The antioxidant activity of chia seed is high (Vásquez-Ovando *et al.*, 2009; Marineli *et al.*, 2014; Caruso *et al.*, 2018; Fernández-López *et al.*, 2018) due to the large amount of polyphenolic compounds (GÓMEZ-FAVELA *et al.*, 2017) tocopherol, polyphenol, carotenoids and phospholipids (Marineli *et al.*, 2014).

This activity can also be enhanced through the process of enzymatic hydrolysis, increasing the exposure of chia proteins with antioxidant amino acids (Segura-Campos *et al.*, 2013).

According to Oliveira-Alves et al. (2017), fourteen phenolic acid derivatives were detected in a sample of raw chia extract and 21 in a hydrolyzed extract, some of these compounds are electrochemically active and may be associated with the antioxidant activity of the extracts. This suggests that chia-based products when consumed by humans can increase antioxidant activity in the body.

However, Meineri et al. (2010) studied the quality of rabbit meat after receiving supplementation with chia seed for a period of thirty-five days and it was observed that it was ineffective in preventing oxidation by chia antioxidant compounds. It is speculated that the large amount of unsaturated lipids present in the seed may be responsible for the decrease in oxidative stability.

Proteins

Proteins are a set of several amino acids and chia seeds have between 15 and 23% proteins, with the nine essential amino acids being present in them: leucine, isoleucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine and histidine. It is a potential source of bioactive peptides, and can be used for specific vital functions, such as: growth, injured tissues and as a replacement for metabolic losses, reproduction, lactation and well-being in general (MUÑOZ *et al.*, 2013).

Proteins are of great importance to the human body, having as main functional characteristics: hydration, binding with water and fat, gelling behaviour, emulsifying, foamy and rheological. Chia seed contains about 19 – 23% (w/w) proteins, which contain the nine essential amino acids in considerable concentrations (COSTANTINI *et al.*, 2014).

A study by Vásquez-Ovando et al. (2013) dry extracted a portion of chia flour, yielding 180.55 ± 3.8 g/kg of protein-rich fraction (FRP) that contained 446.2 g/kg of protein and 114.8 g/kg of crude fiber. Marinelli (2014) studied Chilean chia seeds and found a protein amount of 25.32g/100g of the seed. Several studies have analyzed the amount of protein present in different forms of chia and, for the most part, have shown considerable levels of proteins, as shown in Table 3.

Table 3: Protein Content in Different Forms and Varieties of Chia

SAMPLE	AMOUNT OF PROTEIN(g/100g)	REFERENCES
Protein-rich fraction	44,62	VÁZQUEZ-OVANDO, 2012
Protein-rich fraction	44,62	SEGURA-CAMPOS *et al.*, 2013
Protein-rich fraction	28,14 ± 0,36	VÁSQUEZ-OVANDO *et al.*, 2009
Defatted chia flour	34,01	SEGURA-CAMPOS *et al.*, 2013
Defatted chia flour	32,24	VÁZQUEZ-OVANDO *et al.*, 2012

Defatted chia flour	32,24 ± 0,17	VÁSQUEZ-OVANDO *et al.*,2009
Chia seeds	28,56 ± 0,23	GARCÍA-SALCEDO *et al.*, 2018
Chia seeds	25,32 ± 0,21	MARINELI *et al.*, 2014
Chia seeds	23,5	MEINERI *et al.*, 2010
Chia seeds	20,58 ± 0,24	FERNÁNDEZ-LÓPEZ *et al.*, 2018
Chia flour	23,99	SEGURA-CAMPOS *et al.*, 2013
Chia flour	18,48 ± 0,76	GÓMEZ-FAVELA *et al.*, 2017

Mucilage

Mucilage is formed by chains of polysaccharides (Reyes--Caudillo *et al.*, 2008) and is present in chia seed between 5 and 6% (Campos *et al.*, 2015). It helps in increasing satiety and the production of fiber-enriched foods. It also helps in reducing the digestion time of carbohydrates. It can be used in the preparation of food by increasing its viscosity and can replace about 25% of oil or eggs in the preparation of cakes, reducing the consumption of these ingredients for the benefit of health (Muñoz *et al.*, 2013).

Fibers

Total dietary fibers include polysaccharides, oligosaccharides, lignin, and other associated substances and are in high concentration in chia, which is mostly composed of insoluble fibers (Zettel and Hitzmann, 2018). When consumed regularly, they decrease the risks of coronary heart disease, type II diabetes mellitus and several types of cancer. Its consumption is also associated with an increase in postprandial satiety and a subsequent decrease in hunger. The American Dietary Association (ADA) recommends daily intake for adults of dietary fiber between 20-35 g/day. (Muñoz *et al.*, 2013).

Fiber is also an abundant component found in chia, which is very important for health. The extraction of fibers from grains and seeds exhibits physiological and functional properties that are promising for use in food or for health benefits (Vásquez-Ovando *et al.*, 2009).

Chia flour has a high amount of fiber, according to the study by Vásquez-Ovando et al., 2009, a total fiber of 56.46 g/100 g of chia flour. Of this value, the highest amount found was 53.45 g/100 g of insoluble fibers and 3.01 g/100 g of soluble fibers. Despite the low amount of soluble fiber present in chia flour, its ability to retain water can be 15.4 times greater than its weight.

This ability is important for regulating bowel function and controlling blood pressure levels. In addition, a high percentage of insoluble fibers helps in the feeling of satiety, due to the space occupied in the stomach, and increases the volume and weight of the fecal bolus, improving intestinal function, preventing constipation and colon cancer (Vásquez-Ovando *et al.*, 2009; Ramos et al., 2017; Caetité *et al.*, 2017; Nduko *et al.*, 2018).

Vitamin & Minerais

Vitamins are naturally present in foods, have enzymatic activities and are classified as micronutrients (Ferreira *et al.*, 2016). Chia is a good source of B vitamins, containing niacin (B3) in higher concentrations than corn, soybeans or rice; thiamine (B1), riboflavin (B2) and folate (B9). It also has vitamin C, A and E (Muñoz *et al.*, 2013).

Chia seed is also an excellent source of minerals, namely: calcium, potassium, magnesium, phosphorus, selenium, copper, iron, manganese, molybdenum, sodium and zinc. It has a higher amount of minerals than milk, wheat, rice, oats and corn (Muñoz *et al.*, 2013).

Chia seed is a good source of minerals considered micronutrients necessary for the structure and proper functioning of the human body, the main ones being: potassium (K), calcium (Ca), sulfur (S), magnesium (Mg) and phosphorus (P). They are rich in Mg, P and Ca. These are mainly found in chia mucilage (Amato *et al.*, 2015; García-Salcedo *et al.*, 2018; Nduko *et al.*, 2018).

The use of chia in food

Chia seed is an important raw material for functional foods due to its special characteristics that offer advantages over other existing sources. Baby food, baked foods, cereal bars, yogurts, salads, beverages or mixed cereals and sauces are some of the ideal foods for chia enrichment (Coelho and Salas-Mollado, 2014; López *et al.*, 2019).

Not only benefiting from its nutritional values, but also in its preparation as hydrocolloids or as a substitute for eggs, fats or gluten. It increases the stability of the oil and the viscosity of the food, and is widely exploited in this aspect (zettel and Hitzmann, 2018).

With the increase in life expectancy and dietary changes came the concept of functional foods, these are products with healthy components, products altered, fortified, enriched and improved for health (Cotabarren *et al.*, 2019).

A study conducted in Germany with 503 participants showed the acceptability of breads with functional ingredients, one of them being chia. Participants were divided into categories according to age, gender, and educational level. As a result, they were grouped into: group 1 of traditional consumers with 12.7%; group 2: consumers who care about the quality of the product, 35.1%; group 3 consumers who care more about health (28.0%) and group 4 consumers who care more about price 24.2% (Meyerding *et al.*, 2018).

The highest acceptability of chia bread was in group 1, followed by groups 4, 3 and 2. Chia and flaxseed, as functional ingredients, were one of the main consumer preferences in relation to the other ingredients present in the study, namely quinoa and amaranth. This showed the potential of chia in food preparation (Meyerding *et al.*, 2018).

Nduko *et* al. (2018) used chia seed in different amounts to add nutritional value to pineapple jelly. His first observation was the significant increase in the total protein content, with the jelly having 0.53% protein and after the addition of chia seeds it varied between 1.60 – 8.60% according to the amount added.

However, the use of the seed directly in the preparation generated sensory alterations, causing a negative impact on acceptability. The addition of 6.25% of chia, the lowest amount added in the study, was the most acceptable amount, as it did not significantly alter the color and texture of the jam, altering the flavor, but with moderate acceptability (Nduko *et al.,* 2018).

Using chia oil to cook food was tested by Teng et al. (2018) and showed the production of malonic dialdehyde (MD) and advanced glycation of the final product (AGPF) probably due to the high abundance of polyunsaturated fatty acids. DM is an indicator of lipid peroxidation of fatty acids that are involved in the process of carcinogenesis and leads to mutations of tumor suppressor genes. AGPF, on the other hand, accelerates the process of several diseases such as retinopathies, cataracts and Alzheimer's. To reduce these effects, there was an enrichment with flavonoids in order to increase the antioxidant capacity. Dihydromyricetin was the flavonoid that showed the best results, promoting an increase in antioxidant capacity and strongly inhibiting the formation of toxic agents.

The use of chia seed alone as a food ingredient can be difficult due to its high oil content and low cohesion, and combinations are suggested to make better use of the properties of the seed. The combination of chia with oats and barley improved the water retention capacity, texture and viscoelastic quality of biscuits (Inglett *et al.*, 2013b; Inglett *et al.*, 2014b). In addition, chia hydrocolloids can be used in beverages mixed with fruit juices and smoothies, and can also be used in the preparation of puddings and pancakes (Inglett and Chen, 2013a).

Pizarro *et al.* (2015) added chia flour with a small amount of gluten in the preparation of breads. With this, there was an improvement in the nutritional value of the food, increasing the amount of protein by 7%, decreasing the amount of saturated fatty acids by 14% and mono and unsaturated acids by 16%, with an increase in polyunsaturated fatty acids to 60%. This increase in polyunsaturated fatty acids was mainly due to the increase in alpha-linoleic acid.

The n-6/n-3 ratio can be improved with the use of chia, as previously discussed. It can be used as a substitute for ingredients in a recipe. For example, the change of 75% of eggs in the preparation of the cake reduced the value of this ratio from 215.7 to 28.9 and when it replaced 75% of the oil, it reduced the ratio to 13.2. This change is important because with the replacement of eggs, for example, it decreases the cholesterol content of the food (Borneo *et al.*, 2010).

However, this high substitution influenced the acceptability, color, texture and taste of the final product, with an ideal change of up to 25% of each ingredient for greater acceptance. Even if used in smaller quantities, it will still contribute to the reduction of the ratio and, consequently, improve the nutritional value of the food (BORNEO *et al.*, 2010).

Coelho and Salas-Mellado (2015) in a study demonstrated that the use of chia is important to improve the n-6/n-3 ratio with the addition of chia flour and chia seed in the preparation of bread. The breads without added chia (control) showed a value of 0.86 ± 0.02 g/100g of omega 6 and 0.03 ± 0.02 g/100g of omega 3, with an omega 6/omega 3 ratio of 28.67. With the addition of chia flour, the values changed to 1.02 ± 0.02 g/100g (n6), 1.21 ± 0.02 g/100g (n3) and 0.84 (n6/n3).

The addition of chia seed led to the following values: 1.10 ± 0.02 (n6), 1.85 ± 0.02 g/100g (n3) and 0.59 (n6/n3). Both chia flour and chia seed generated a significant decrease in the n6/n3 ratio, and this decrease was even greater when added to the whole chia seed (COELHO and SALAS-MOLLADO, 2015).

Chia can reduce the glycemic index of foods, so it can be used in the treatment of people with diabetes. Zhu and Chan (2018) partially substituted wheat flour used in the preparation of baked bread and analyzed its impact on glycemic response. Bread without the addition of chia had a glycemic index of 117 and with the addition of chia of 300 g/kg it reduced this index by 25%.

It is believed that this reduction in the glycemic index was due to the mucilage of the chia seed, which increased the viscosity of the baked bread, reducing the physical association and interaction between wheat and hydrolytic enzymes. The glycemic load was also reduced, being 50 in bread that does not contain chia and decreasing to 26 with the addition of 300 g/kg of it (Zhu and Chan, 2018).

Contrary to this study, Salgado-Cruz *et* al. (2017) added chia mucilage to pita bread and observed a higher glycemic index in the bread crumb compared to the control bread, which may be related to the level of gelatinization of the starch present in the preparation with chia mucilage. Cruz, like Zhu and Chan, stated that fibers and proteins play a barrier role for enzymatic action, but in the last study, gelatinization had a greater effect than protective action (Zhu and Chan, 2018; Salgado-Cruz *et al.*, 2017).

Chia in pharmaceutical preparations

The use of chia in pharmaceutical preparations has been investigated not only as a compound with functional properties, but as a structural part of compositions. The use of chia in oil-in-water (O/A) emulsion, for example, was investigated by Julio *et* al. (2016).

The mucilage and protein-carbohydrate combination of the seed affect the physicochemical properties and especially the rheological characteristics of the emulsion. Chia mucilage mainly affected the rheological characteristics of the emulsion, increasing the viscosity and consequently decreasing the movement of the oil droplets, thus increasing the stability of the emulsion (Julio *et al.*, 2016).

Timilsena *et* al. (2016c) produced microcapsules based on chia seed protein isolate (IPSC) combined with chia seed gum (GSC), in order to increase the oxidative stability of capsules that obtained chia seed oil (CSO).

The study showed that iPSC and GSC-based microcapsules alone have already significantly increased OSC storage time, when combined they were even more efficient. It was calculated using the Totox values, which indicate the oxidation state during storage, the period of time that the OSC could be stored without microencapsulation and microencapsulated (Timilsena *et al.*, 2016c).

Totox values above 30 are considered unsuitable for human consumption, in 20 days of storage the oil without microencapsulation reached a value of 38.1, being unfit for human consumption. The 30-day storage of the IPSC-GSC combination obtained a value of 19.8, approximately, showing that this combination extracted from the chia seed itself is ideal for the protection of chia seed oil. This study showed another possibility of using chia in pharmaceutical preparations (timilsena *et al.*, 2016c).

Hypercholesterolemia or high cholesterol is a health condition that must be taken care of. Often, in order to avoid the use of medications, supplementation is used as an alternative. Chia seed was studied by Sierra *et* al. (2015) to verify the efficacy of its use in the treatment of this pathology.

Animals were divided into four groups, the first received a controlled diet, the second a high-cholesterol diet, the third a controlled diet associated with chia seed, and the last group a high-cholesterol diet associated with chia. Groups one and four showed no change in total cholesterol levels in their plasma after six weeks, showing that the addition of chia did not change this parameter (Julio *et al.*, 2016).

It was observed in this study that the groups that received the chia seed during the six weeks had a greater response to acetylcholine, a neurotransmitter responsible for endothelium-dependent vascular relaxation and decreased response to the contraction of angiotensin II and noradrenaline (NA). This shows the protective effect on vascular function played by regular consumption of the seed (Julio *et al.*, 2016).

A property that is still little studied is the ability of chia seed to help in the treatment of hypertension. The article by Segura-Campos *et al.* (2013) showed a protein-rich portion of hydrolyzed chia in a sequential treatment with Alcalase and Flavourzyme, in different periods of time, with 150 minutes being the one that produced the greatest hydrolysis, followed by 120 and 90 minutes.

These products were administered to spontaneously hypertensive rats and these showed antihypertensive effect. The probable explanation is that angiotensin-converting enzyme I (ACE) has a greater affinity for hydrophobic amino acid residues, present in chia. (Field Insurance *et al.* 2013).

In an analysis of chia flour was found to be 9.51 mg/100g from the GABA (ɣ- aminobutyric acid) sample. GABA is a non-protein amino acid with four carbons and is one of the major inhibitory neurotransmitters of the central nervous system. It has biological activities against diabetes, hypercholesterolemia, hypertension, inflammation, depression and anti-proliferative activity of cancer cells (Gómez-Favela *et al.*, 2017).

Treatment and/or prevention of diseases

Components present in chia seed are important in treatments and prevention of diseases as shown above. Chia has no evidence of adverse effects or allergic reactions (Muñoz *et al.*, 2013).

Zettel and Hitzmann (2018) cited in their review article studies that showed an effect on the treatment of overweight patients and on the treatment of obese patients with type II diabetes. Jin et al. (2012) studied ten postmenopausal women, between 52 and 60 years old, who used 25g/day of ground chia seed for seven weeks. Six plasma samples were collected from each woman to measure the levels of ALA, EPA, DPA and DHA. A significant increase in plasma levels of ALA and EPA was observed.

Another study with a total of 67 participants used a supplementation containing chia seed, soy protein, oats and prickly pear for two months. Participants experienced weight loss, reduced triglyceride levels, and reduced blood glucose levels (Guevara-Cruz *et al.*, 2012).

Toscano et al. (2014) conducted a study with a group of 26 people between 35 and 65 years of age, clinically diagnosed with stage I hypertension. Of this group, 17 were using antihypertensive drugs (HA) and the other 9 had not adhered to pharmacological treatment (unds/HA). Thus, they were separated into three groups, two with people who used antihypertensive drugs and one who did not. They were given 35 g/-day of chia flour or placebo for 12 weeks.

There was a decrease in mean arterial pressure in the groups that received chia, and the s/HA group that received chia did not show a decrease in mean arterial pressure, only in systolic pressure. In addition, the groups that received chia flour showed a reduction in lipid peroxidation when compared to the group that used HA with placebo and showed a reduction in nitrite levels, leading to the conclusion that chia flour has the ability to promote a decrease in blood pressure in individuals who use HA or not (Toscano *et al.*, 2014).

However, some studies have not been able to prove its effectiveness in individuals who used chia daily for a period of time. Nieman *et* al. (2009) conducted a study with 76 overweight or obese people, 28 males and 48 females, who received supplementation twice a day. 14 men and 25 women received 25g of chia seed, while 14 men and 23 women received placebo for a period of 12 weeks. twice a day. No effect on waist circumference, blood pressure, oxidative stress, or inflammation was observed.

Miranda *et* al. (2019) studied obese mice in order to investigate the effects of chia administration on their metabolism. The animals were divided into four groups: group 1 with a controlled diet, group 2 with a controlled diet plus 3% of chia flour, group 3 with a high-fat and high-calorie diet, group 4 with the same diet as group 3 plus 3% of chia flour. The study lasted 16 weeks and, despite showing an increase in the amount of ALA, it was ineffective in reducing the deleterious effect on the body composition of animals on a diet rich in lipids, glucose intolerance and the activity of antioxidant enzymes in the liver.

Bilgic *et* al. (2018) investigated the cognitive and behavioral effects of mice fed chia seed and experimentally induced Alzheimer's disease through aluminum hydrochloride. High levels of aluminum are found in the brain and cerebrospinal fluid of patients suffering from Alzheimer's disease and so it has been used to induce the disease. The animals received supplementation before or after treatment with aluminum. The seeds were ground and mixed with rat food at 36.2% w/w.

Supplementation was ineffective in both moments against Alzheimer's-related anxiety and also attenuated depressive behavior, however, the treatment did not show improvement in learning and memory. The cognitive performance of rats pretreated with chia was worse than that of those not treated with chia, including those with the disease. In this case, chia not only proved to be ineffective but exacerbated the disease (Bilgic *et al.*, 2018).

The chia seed does not yet have health claims and/or functional properties in Brazil by ANVISA, but it is known that it has bioactive components and studies that enable its use for this purpose, and it is important to have even more studies to elucidate which benefits would be more appropriate and the best ways to use it for better use of its content.

Based on the importance of chia seeds, the relevance of their components and their possible applicability as a food supplement, here is the wording of the article that correlates chia seeds with the new Brazilian legislations, entitled: Chia seeds (*Salvia hispanica L.*) and food supplementation: establishing a correlation with the new 2018 legislation of ANVISA.

Dietary supplementation has been used in Brazil for several years and achieved its first resolution only in mid-2018. The new RDC 243/2018 was created by Anvisa in order to ensure better quality and safety of these products. Dietary supplement, according to the RDC, is defined as: "a product for oral ingestion, presented in pharmaceutical forms, intended to supplement the diet of healthy individuals with nutrients, bioactive substances, enzymes or probiotics, isolated or combined" (Brazil, 2018a).

Salvia *hispanica L.* better known as chia, a seed with nutritional values used in food and supplementation, is on the list of constituents authorized for use in food supplements of Normative Instruction (IN) No. 28, of July 26, 2018. This NI has the role of establishing the constituents of supplements, their limits of use, claims, and complementary labeling (Brazil, 2018b).

Chia seed is rich in fatty acids such as omega-3s, with the main one being alpha linolenic acid (ALA). ALA is commonly used for prevention and treatment of heart disease and vascular disease. In addition, chia is an excellent source of soluble and insoluble fiber, antioxidants, protein, vitamins and minerals (Marineli *et al.*, 2014; Souza et al., 2017; García-Salcedo *et al.*, 2018).

The use of chia supplementation is intended to reduce risk factors for diabetes, reduce blood pressure, inflammation, and cardiovascular risks. It also plays a role in intestinal regulation (Sierra et al., 2015; Zhu and Chan, 2018; Lazaro *et al.*, 2018).

The objective of this study was to carry out a literature review in order to evaluate the use of chia seed in its broad aspect and associate it with food supplementation according to the new RDC 243/2018.

Functional properties of chia seed

According to Vázquez-Ovando *et* al. (2009 and 2012), *Salvia hispânica L.* has a considerable emulsifying activity, between 50.5 and 56 %, and is not significantly influenced by the pH of the medium. In addition, the emulsion formed has good stability between pH values 2 to 10, with better values being observed in alkaline pH. This property of chia seed can be used in the production of foods that require an emulsion stabilizer such as ice cream, thus maintaining consistency and texture.

The foaming capacity (FE) of chia was low (22 - 29 %) and pH dependent, but its ability to maintain foam (ME) is quite efficient, especially at pH values between 8 and 10, although it regresses over time. The EF capacity may be low due to the lack of balance between hydrophobicity and hydrophilicity, generating a high energy at this interface (Vásquez-Ovando *et al.*, 2013).

Viscosity is another property that is very present in chia, it is measured by the texture of its fluid, and is defined as the resistance of the fluid caused by internal friction (Coorey *et al.*, 2014; Agrahar-Murugkar *et al.*, 2016). A value ranging from 2000 to 12000 cP was found with shear rates between 5 and 100 rpm, being inversely proportional between 10 and 50 rpm (Vásquez-Ovando *et al.*, 2013).

This property is directly linked to the mucilage trait strongly associated with *Salvia hispanica L.* The expansion capacity of chia flour is around 11.82 ± 1.12 mL/g, due to the high concentration of fibers and proteins that retain water, forming a network, due to the hydrophilic characteristic of these components (García-Salcedo *et al.*, 2018).

The high viscosity values of chia seeds suggest that even in small amounts they can promote consistency in some products such as soups, sauces, baby food and pasta (Vázquez-Ovando, 2013).

Water holding capacity (ACC) is the ability of a wetted material to retain water when subjected to an external centrifugal force of gravity or compression. This property is high in the chia seed, and can be 15 times greater than its weight. CRA is bound to mucilage and proteins present in the seed, and can be used in preparations that require hydration, viscosity and conservation (Vázquez-Ovando, 2009; Inglett *et al.*, 2014b; Timilsena *et al.*, 2016b).

Upon contact with water, chia mucilage appears as a transparent "capsule" around the seed (Vásquez-Ovando *et al.*, 2009; Inglett *et al.*, 2013b; Inglett *et al.*, 2014a; Inglett *et al.*, 2014b; Segura-Campos et al., 2014; Timilsena *et al.*, 2016b; Agrahar--Murugkar *et al.*, 2016; López *et al.*, 2018).

One study showed a CRA of 98.97 ± 3.69 g/g of chia mucilage extracted at 85ºC for two hours, a very considerable value (Orifici *et al.*, 2018). When the chia seed is immersed in water, its outer layer swells, forming a layer of gel, firmly binding the seeds. This mucilage is formed due to the partial expulsion of soluble fibers from the seed that come into contact with water (Ramos et al., 2017).

On the other hand, chia has a low oil retention capacity (CRO), and can be used in frozen products, since it will not add oiliness (Vásquez-Ovando *et al.*, 2009). CRO is important for the preservation of aromas, to improve palatability and to increase the shelf life of confectionery products (García-Salcedo *et al.*, 2018).

García-Salcedo *et* al. (2018) analyzed chia flour and chia seed mucilage isolate through an X-ray diffraction equipment and observed that only in the chia mucilage sample did it produce a visible peak corresponding to -OH at the wavelength of 1101 $^{cm-1}$, attributed to the carbohydrate. Due to the similarity between the compositions of both samples, it was concluded that chia mucilage is basically composed of soluble fibers, soluble proteins, and fats.

Another study evaluated the efficiency of chia oil in a double emulsion (OCED), in this case water-in-oil-in-water, over a period of eight days. OCED showed the highest viscosity compared to the other vegetable oils analyzed, presenting the best efficiency in initial encapsulation. This high viscosity can be explained by the presence of mucilage that binds to the water of the double emulsion which, when undergoing heat treatment, further increases the viscosity (Bou *et al.*, 2014).

For the formation of chia mucilage, different exudation times (1 hour, 2 hours and 3 hours) at 60 ºC were analyzed with a seed:water ratio of 1:40. A significant increase of 26.3% was observed from the first hour to the second hour and a significant decrease of 11.9% from the second hour to the third.

In conclusion, two hours is the ideal time to maximize the exudation of chia seed mucilage. To maximize mucilage extraction, the importance of temperature was observed. At 85ºC for two hours, with the ratio 1:31 (seed: water) 116 g/kg of mucilage was obtained, in addition to better functional properties such as water retention capacity (ACC) of 98.97 g/g, emulsifying activity (AE) of 54.67 g/g and emulsion stability (EA) of 57.56 g/g. This shows the great possibility of using chia mucilage as a thickening and stabilizing agent (Orifici *et al.*, 2018).

Brazilian Legislations

The chia seed is present in the attached list of Normative Instruction No. 28/2018, which complements Collegiate Board Resolution (RDC) 243/2018 and establishes the constituents, their limits of use, claims and supplementary labeling. It is mentioned four times in Annex I, where the constituents authorised in studies for food supplements are listed, except for food supplements indicated for infants (0 to 12 months) or young children (1 to 3 years).

It is present in IN 28 as: chia seed (*Salvia hispânica L*), defatted ground chia seed (*Salvia hispânica L.*), ground chia and chia seed oil (Salvia hispânica L.). The first three are in the dietary fiber group and the last in the lipid group. According to RDC 243, the constituents present in Annex I, in which chia falls, are authorized for use in the composition of food supplements (Brazil, 2018a; Brazil, 2018b).

RDC 243 (Brazil, 2018a) was created with the aim of providing the requirements for the composition, quality, safety and labeling of food supplements. The constituents of chia seeds such as vitamins, minerals, fatty acids, fibers, among others, have the purpose of providing nutrients in a complementary way to the individual's diet, with the aim of maintaining health, as recommended by the resolution.

It defines nutrients as: "a chemical substance normally consumed as a component of a food, which provides energy, which is necessary for the growth, development and maintenance of health and life, or the lack of which results in characteristic chemical or physiological changes." (Brazil, 2018a).

In addition, chia seeds have bioactive substances that have a metabolic or physiological function in the human body, and omega 3, dietary fiber, proteins, antioxidants, vitamins and minerals can be considered bioactive substances. However, even though chia presents constituents of great importance and that have their own allegations, it itself still does not have allegations (Brazil, 2018a).

The resolution was created as a way to ensure the quality of the final product sold, encompassing its composition, quality, safety and labeling. However, it only comes into force in 2023, since a period of 60 (sixty) months was stipulated for the adaptation of the products from the date of publication of the resolution, which was published on July 26, 2018. For new products, the resolution is already in force, and this period is 60 months only for products already on the market (Brazil, 2018a).

Conclusion

Salvia hispanica L. (chia seed) is included in the Normative Instruction (IN 28 of 2018) and RDC 243 of the same year as a supplementary constituent. According to the studies reviewed, chia seed has proven to be an excellent aid in the treatment and prevention of various diseases and holds potential for use in pharmaceutical preparations. However, further research on chia seed supplementation is necessary to better understand its full benefits and applications.

Additionally, its effectiveness as an additive or substitute for ingredients in foods has already been demonstrated, making it a viable option for individuals seeking preventive health benefits through their diet. Reconsidering dietary habits to incorporate healthier food choices can reduce the need for supplementation, provided people are committed to changing their habits and managing their time for better nutrition.

Food should not only be seen as fuel for the body but as a nourishing experience, combining essential nutrition with the pleasure of eating. In doing so, we can enhance well-being while enjoying the benefits of functional foods like chia.

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