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Introduction of Chia (*Salvia hispanica* L.) as an Important Oil-Medicinal Plant

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ABSTRACT

Chia (*Salvia hispanica* L.), an annual herbaceous plant, is one member of the Lamiaceae family. Its center of origin is between Mexico and Guatemala. It is a wonderful pool of omega-3 fatty acids, protein, antioxidants and dietary fiber for healthful diets. The United States Department of Agriculture (USDA) has encouraged the cultivation of chia as an industrial crop. The genetic basis of the chia cultivars is narrow due to self-pollination and the selection of pure lines. Therefore, further genetic improvement through molecular breeding is necessary for the profitability and sustainability of chia production. Unfortunately, little is known about the basic genetic characteristics of this species, such as karyotype, nuclear genome size, and diversity of molecular markers. According to scientific proof, dietary phytochemicals are very important and useful for treating and preventing many diseases in the human diet. People request functional foods with countless health advantages by growing the universal health consciousness. In addition to the traditional use of seeds, innovative uses of its seeds and leaves have been started due to its high protein content and mucilage production that have various applications. Chia seed is used as a functional food or a nutritional supplement. It also uses for medicinal purposes.

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1. Introduction

Chia (*Salvia hispanica* L.), which has been cultivated since ancient times (Cahill and Ehdaie, 2005), is an annual herbaceous plant of the Lamiaceae family (Thaboran *et al.*, 2020; Cahill, 2004). Salvia is the most major genus of this family and has about 1000 species that are widely scattered in different areas of the world, including South Africa, Central America, North America, South America and Southeast Asia (Segura-Campos *et al.*, 2014; Takano, 2017). According to the latest classification, this genus is part of the subfamily *Nepetoideae*, tribe *Mentheae*, subtribes *Salviinae* (Segura-Campos *et al.*, 2014). Its main source is between Mexico and Guatemala (Cahill, 2004).

The common name of *S. hispanica* L. is chia (Cahill and Provance, 2002). It is an expensive plant used by natives since the past for medicine, food, and oil (Cahill and Ehdaie, 2005), but its cultivation ceased and was unknown species for hundred years beyond the confines of Mexico and Central America because of its habituation to short days, high sensitivity to changes in photoperiods and poor tolerance to cold (Jamboonsri *et al.*, 2012).

During the last two decades, after the introduction of chia seeds by various scientists, the interest in chia consumption and research on it has increased (Gentry *et al.*, 1990; Coates and Ayerza, 1996).

Nowadays, there is a revitalized fondness for chia and a lot of work is to be done about it as a wonderful source of ω3, protein, antioxidants and dietary fiber for healthful diets (Bochicchio *et al.*, 2015a). In 2009, it was authorized as a novel food (EFSA NDA Panel, 2009). Chia seeds are considered as a healthy food with numerous nutritional value (Super food) (Marineli *et al.*, 2015) and there is not any proof that shows consuming whole or ground chia seeds is harmful (EFSA, 2005; 2009; Bresson *et al.*, 2009). Therefore, chia seeds and their derivatives are promising food sources.

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The United States Department of Agriculture (USDA) has encouraged the cultivation of chia as an industrial crop (Valdivia-Lopez and Tecante, 2015). Chia seeds are becoming more and more admired and are a key ingredient among consumers and producers (Iglesias-Puig and Haros, 2013; Kuznetcova *et al.*, 2020; Ribes *et al.*, 2021; Zettel and Hitzmann, 2018). Chia seed production has enhanced in late years (Grancieri *et al.*, 2019; Jamshidi *et al.*, 2019).

Nowadays, chia is commercially cultivated in several low-latitude agricultural regions in the world, mainly in Bolivia, Paraguay, Argentina, Mexico, Australia, Central America, Peru, Ecuador and Colombia, and the total acreage in 2014 was 370,000 hectares (Sosa, 2016; Orona-Tamayo *et al.*, 2016). Also, chia seeds are accessible in hypermarkets and health food stores (Dincoglu and Yesildemir, 2019).

1.1. Morphology

Depending on the latitude in which chia seeds are grown, their life cycle from growth to harvest takes 90 to 180 days; 90 days in the latitude 06° 43' N and longitude 01° 36' W in Ghana (Yeboah *et al.*, 2014), 150 days in RIO GRANDE DO SUL whit 27° 54' South latitude and 54° 29' West longitude (Wojahn *et al.*, 2018) and 180 days in Italy whit Latitude 40° 51' 37.59" N, Longitude 15° 38' 49.43" E (Bochicchio *et al.*, 2015b). Its growth depends on the sea level, temperature and light (Cahill, 2004). Also, in Kermanshah with Latitude 34° 32' N, Longitude 47° 10' E is about 120 days. Chia height can be from 60 to about 180 cm in different mentioned altitudes (Fig. 1) (Capitani *et al.*, 2013; Wojahn *et al.*, 2018; Yeboah *et al.*, 2014). *Salvia hispanica* L. is a self-pollinating plant (Bochicchio *et al.*, 2015a). However, some scientists reported some degrees of outcrossing in domesticated and wild chia in their field studies (Hernandez-Gomez *et al.*, 2008; Cahill, 2004). Since plenty of insects are absorbed into chia flowers and low outcrossing is found in greenhouse conditions, it appears that insects are more likely to be responsible for transporting pollen instead of wind (Buchichio *et al.*, 2015a). Chia is a drought-resistant product, so it can grow in semiarid (Ayerza and Coates, 2009 a,b) and arid environments (Peiretti and Gai, 2009). Also, based on some researchers, this plant is sensitive to salt stress, and salinity can considerably diminish the yield of seed oil (Heuer *et al.*, 2002). Chia is semi-tolerant to acidic soils (Munoz *et al.*, 2013; Baginsky *et al.*, 2014; Pozo and Anabel, 2010). But it cannot stand frost and freeze in all development stages (Baginsky *et al.*, 2014; Jimenez, 2010). Chia needs a lot of sunlight and does not bear fruit in the shade (Cahill, 2004).

Since 1917, it has been stated that the maximum achievable yield of chia seeds is near 3.0 t/ha (Lomanitz, 1917). However, the seed yield commonly achieved by the farmers is lower, and on average, it is only 0.36 t/ha (Peperkamp, 2015). Chia presents low requirements of water and fertilizer (Orozco *et al.*, 2014), and it is also resistant to pests and diseases (Munoz *et al.*, 2013).

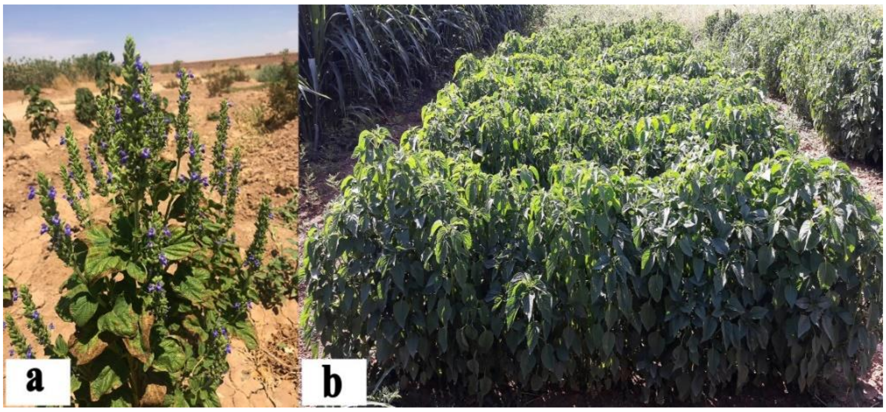

Figure 1. a) Chia (*Salvia hispanica* L.) single plant, b) Chia research farm of Razi University of Kermanshah, Iran, 2020.

1.1.1. Stems

Chia stems height is about 1-2 m and it presents a quadrate branching stem (Jamboonsri, 2010; Capitani *et al.*, 2013).

1.1.2. Leaves

Its leaves are arranged alternately or opposite (Ixtaina *et al.*, 2008). The leaves are oval, with a sharp point and jagged edge. It grows on the point and branches (Cahill and Ehdaie, 2005). The leaves have different degrees of pubescence (Capitani *et al*., 2013). The leaves' length are 4-8 cm and their width is 3-5 cm (Baginsky *et al*., 2014). Different types of leaves of chia are shown in Fig. 2.

Figure 2. Different types of chia leaves from plants in chia research farm of Razi University of Kermanshah, Iran, 2021.

1.1.3. Flower

Chia has a perfect flower (hermaphrodite flower) (Cahill and Ehdaie, 2005). Its flowers are small and usually purple, blue or white, Fig. 3 (Capitani *et al*., 2013) and their small size reflect an extremely self-pollinating breeding system (Haque and Ghoshal, 1980). The corolla is bilabiate monopetalous (Ramamoorthy, 1985). It has 4 ovaries and 4 stamens. There will be 1-4 seeds in one flower (Cahill and Ehdaie, 2005).

The flowers are arranged in groups of six or more on the axis of the inflorescence (Baginsky *et al*., 2016).

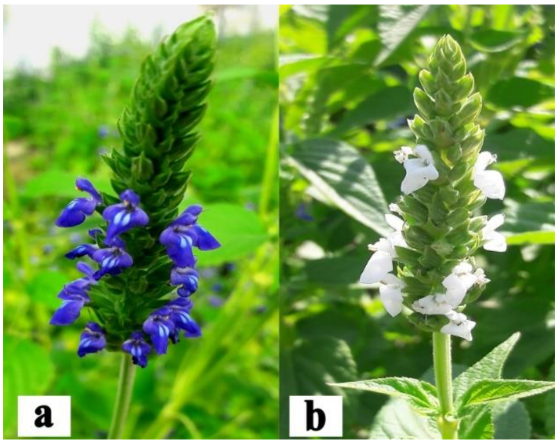

Figure 3. Chia flowers; a) Purple, b) White from plants of Chia research farm of Razi University of Kermanshah, Iran, 2021.

1.1.4. Seeds

Chia fruit is a type of schizocarp that separates and forms four fruits, which are called mericarps or nutlets (Segura-Campos *et al*., 2014). Its shape is oval and its size of it varies from 1-2 mm long by 1.5 mm wide (Hernandez Gomez *et al*., 2008; Ixtaina *et al*., 2008). The seeds coat color is different and changes from black, grey and black spotted to white, although today, most commercial plants are black-spotted, Fig. 4 (Ixtaina *et al*., 2008). The seed is wealthy in mucilage, starch and oil (Hernandez Gomez *et al*., 2008). Generally, the weight of 100 seeds is about 15 mg (Cahill and Ehdaie, 2005). The mature seeds mucilage, when it comes in contact with water, instantly expands and the seed size increases, so it gives a characteristic gel appearance to chia (Jamboonsri *et al*., 2012).

2. Agronomic management

Recent reports on chia crop management, mostly conducted in America, are mainly about the response of genotypes to growing environments in terms of morphology, yield and seed quality (Ayerza, 1995, 2010, 2011, 2013; Lobo Zavalia *et al*., 2011).

Rainfall in the amount of 300 to 1000 ml is very beneficial for the growth and development of chia, although it can grow in dry climates. Optimal rainfall distribution is beneficial for chia because it will provide adequate rainfall in the first phenological stages of vegetative growth and drier conditions in the later stages, particularly seed maturity (Yeboah *et al*., 2014). Although this plant can be grown in irrigated in addition to rainfed conditions (Coates and Ayerza, 1996), the exact amount of evapotranspiration cannot be calculated for it because there are limited scientific literatures on irrigation experiments. In South America, the chia seed for sowing is about 5-6 kg per hectare. The distance between its cultivation rows is variable, but the maximum frequency is 70-80 cm. Some studies have shown that the yield of chia can be affected by planting date, planting method and planting density. For example, Coates (2011) stated that an earlier planting date leads to higher yield, which is maybe due to a longer vegetative growth period.

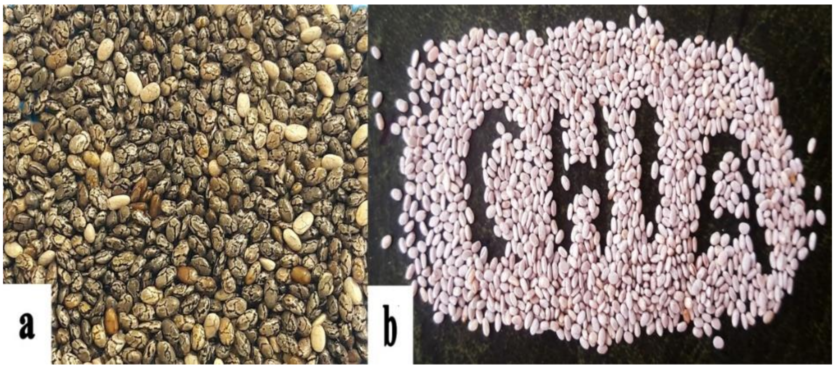

Figure 4. Different colors of chia seeds; a) Black spotted, b) White.

From another research, it has been determined that direct cultivation of chia is more effective than transplanting (Yeboah *et al.*, 2014). Also, the result of this study showed crop density has a positive effect on grain yield, so higher planting density leads to higher grain yield. Yeboah et al. (2014) reported that forty thousand plants per hectare with a small row distance (0.5 m × 0.5 m) had the highest yield. Another sowing densities experiment that used 4–125 plants/m^2 determined that the seed yield increases with the increase in cultivation density (Bochicchio *et al.*, 2015b). Researches in the USA find that sowing two to three kg/ha provides better yields with less lodging. Harvesting of chia is mechanical. The average yield of it in poor soils is around 600–1200 kilogram per hectare (Coates, 2011), while in high input conditions with suitable irrigation and fertilization, yields as high as 2500 kg/ha have been achieved in Argentina (Coates, 2011). Asymmetric flowering and non-uniformity of maturity are a major problems during harvest (Jamboonsri, 2010).

According to the results of our experiments in the research farm of Razi University of Kermanshah (data not shown), the suitable sowing time is the beginning of May. Also, the results of our preliminary evaluation of yield showed that the highest chia seed yield is about 3000 kg/ha in Kermanshah conditions.

3. Genetical characterization

The genetic diversity of chia has been investigated by some researchers (Cahill, 2004; Echeverrigaray and Agostini, 2006; Wang *et al.*, 2007; Farkas *et al.*, 2008; Boszormenyi *et al.*, 2009; Song *et al.*, 2010; Javan *et al.*, 2012; Zhang *et al.*, 2013). The genetic structure of modern *S. hispanica* genotypes has influenced by two major factors: having a high self-pollinating level (92-98.5%), (Haque and Ghoshal, 1980; Hernandez Gomez *et al.*, 2008) and genetic improvement (Cahill, 2004).

Through the centuries, like other crops, chia has been modified via selection breeding by humans. However, although classical breeding has been performed, chia yield is low (Grimes *et al.*, 2018). To make chia production beneficial and sustainable, more genetic advancement through molecular breeding is needed. Unfortunately, little is known about the basic genetic traits of this species, such as karyotype, nuclear genome size, and diversity of molecular markers. This species is estimated to have the greatest genetic diversity in Mexico. But we have a small amount of chia germplasm in the gene banks, and what is available is more than the domestic populations (Bochicchio *et al.*, 2015a). The genetic base is narrow and only suitable for planting in some areas (Coates and Ayerza, 1996). Polymorphic DNA markers are necessary tools for molecular breeding programs and genetic diversity studies and to speed up genetic improvement (Nadeem *et al.*, 2018; Tanksley, 1983; Yue *et al.*, 2021). But there are very few genetic studies of chia using molecular markers (Cahill, 2004).

Due to the low genetic diversity of chia germplasm, other methods can be used to create and find genetic diversity, such as mutation breeding (Bochicchio *et al.*, 2015a). Based on the study using the RAPD marker to analyze the genetic diversity of chia populations, it has been found that there is almost no diversity in commercial varieties of chia (Cahill, 2004). Yue et al. (2021) identified 15 polymorphic microsatellites from chia DNA sequences and used them to evaluate genetic diversity and population relationships of 6 chia genotypes native to Mexico, Australia and Bolivia. They have low allelic (2.79 to 3.64) and gene diversity (0.27 to 0.38). The 6 cultivars were highly identical (> 0.893) and closely related to each other. Overall, these cultivars have low genetic diversity. So, they said to start a breeding plan to improve traits. It is necessary to use seeds of multiple chia cultivars to increase genetic diversity in the initiator population. Also, the results of research conducted using ISSR markers to assess the genetic diversity of chia provenances showed low genetic diversity for them (Palma-Rojas *et al.*, 2017).

4. Cytological characteristics

Despite the high nutritional value of chia, there is little information about its molecular bases. To begin understanding the genetic and molecular base of this plant, we need to determine the genome content as well as the genetic relationship between some provenances to determine whether they are similar or different (Palma-Rojas *et al.*, 2017). Chia is a diploid plant with 12 chromosomes (Haque and Ghoshal, 1980; Haque, 1981; Estilai and Hashemi, 1990; Harley and Heywood, 1992); its chromosomes have the same size and shape (Palma-Rojas *et al.*, 2017), but its genome size (C-value) is unknown. However, the average C-value is 0.62 pg based on previous research on other species of this genus (Bennett and Leitch, 2011).

The shape of all chia chromosomes is the rod and their size varies from 5.0µ to 3.0µ. So it is not feasible to find any clear primary or secondary constriction in each pair (Haque and Ghoshal, 1980). Palma-Rojas et al. (2017) reported they have no satellites, and the chromosomes of the provenances are identical in terms of size and centromere position. The haploid set of salvia chromosomes has a mean length of 19.32 ± 0.48 mm. They showed *S. hispanica* has one metacentric pair, one sub-metacentric pair, three sub-telocentric pairs and one telocentric pair in karyotype analysis. However, these researchers say no quantitative explanation for the karyotype. Also, Estilai and Hashemi (1990) from the salvia karyo-idiogram showed that chromosome pairs five and six are nearly between sub-metacentric and sub-telocentric types. The chromosome morphology for the other 4 pairs is not clearly defined according to Levan et al. (1964) chromosome nomenclature. The genus of salvia has highly variable chromosome numbers due to polyploidy and a wide diversity of basic numbers (x) of chromosomes (Zhiyun *et al.*, 2004). Salvia polyploidy species have been shown to have 7, 8, 10, 11, 12 and 13 basic chromosome numbers (Alberto *et al.*, 2003).

5. Chia nutritional values

There is scientific proof that dietary phytochemicals can play a critical role in the therapy and prevention of many diseases. By growing the universal health consciousness, people request functional foods with countless health advantages. As all foods supply various amounts of nutrients that are important to grow or support vital processes, it can be said that all foods are functional. Functional foods are common foods that contain different kinds of benefits that may improve optimal health or reduce disease hazards (Hasler *et al.*, 2000). Over the years, people have turned to unhealthy foods and become addicted to artificial and carbonated beverages. Therefore, they suffered from various heart diseases at a young age. Many texts and literatures emphasize the health benefits of chia seeds and their nutritional value (Coates and Ayerza, 1996).

5.1. Oil

Chia has the highest content of ω3 among all-natural sources, so its fatty acids have been highly regarded by researchers (Palma *et al.*, 1947; Ayerza, 1995; Ayerza and Coates, 2011; Segura-Campos *et al.*, 2014). In general, the mature seeds have 25–40% oil, of which omega (ω)-3 alpha-linolenic acid makes up 60% of it and 20% of it is omega (ω)-6 linoleic acid (Ayerza and Coates, 2004; 2009a,b; Rocha Uribe *et al.*, 2011; Silveira Coelho and de las Mercedes Salas-Mellado, 2014). Ecosystem effects, various climatic conditions, different geographical areas (Ayerza, 1995; Coates and Ayerza, 1996, 1998; Ayerza and Coates, 2004), extraction methods (Ixtaina *et al.*, 2011), genotype and environmental factors (Bochicchio *et al.*, 2015a), date of sowing (Coates and Ayerza, 1996; Baginsky, 2016) and salinity of irrigation water (Heuer *et al.*, 2002) can affect the oil percentage and fatty acids composition.

ALA content of chia is higher than the other ALA-rich oilseeds such as flax (57%) (Ayerza and Coates, 2004), camelina (48.4%) (Peiretti and Meineri, 2007), and similar or slightly lower than perilla (Ciftci *et al.*, 2012).

Both of the essential fatty acids are crucial for the human body health, but humans and animal bodies can not synthesize them, so they must obtain them through food. The highly unsaturated metabolites can be constructed from these fatty acids; arachidonic acid and γ-linolenic acid (n-6 PUFA) from linoleic acid (LA) and the most important metabolites: eicosapentaenoic acid and docosahexaenoic acid (n-3 PUFA) from α-linolenic acid (ALA) (Gorjao *et al.*, 2009). Therefore, it is recommended to eat foods that are rich in α-linolenic acid. Marine fish are the best-known sources of n-3 PUFAs (Gorjao *et al.*, 2009), but flax seeds and chia seeds are also important plant sources with the highest ALA concentrations (Ayerza, 1995; Coates and Ayerza, 1998; Oomah *et al.*, 1995). Also, the omega-6/omega-3 fatty acid ratio in the human diet is an important ratio of unsaturated fats. The proper ratio of it varies from 1:1 to 3:1, but commonly it is much higher in the human diet. This ratio in chia seed oil is lower than 1 (Ixtaina *et al.*, 2011; Silveira Coelho and de las Mercedes Salas-Mellado, 2014); therefore, it can be used for balancing the unsaturated fatty acid in the diets.

5.2. Protein

Animal-derived proteins have good quality, but they are expensive and can cause allergies in some people. Plant proteins can be a good source of essential amino acids, supplementing or even substituting animal sources (Montoya-Rodrıguez *et al.*, 2015; Sandoval-Oliveros and Paredes-Lopez, 2013). Chia seeds have high levels of protein compared to cereal seeds or other oilseeds, 16-26% depending on the environment (Ayerza and Coates, 2004, 2009, 2001), though it does not plant as a protein crop commercially around the World.

The amount of seed protein strongly depends on environmental and agronomic factors. Ayerza and Coates (2009a, b, 2011) reported that the amounts of proteins change with the environment of production. For example, the protein content significantly decreases when elevation increases. Its protein content (20%) is higher than that reported for other crops, like *Triticum aestivum* (14%), *Hordum vulgare* (9.2%), *Avena sativa* (15.3%), *Zea mays* (14%), and *Oryza sativa* (8.5%) (Monroy-Torres *et al.*, 2008). Moreover, the digestibility of chia protein is good (78.9%) (Sandoval-Oliveros and Paredes-Lopez, 2013) and it is higher than beans (77.5%), corn (66.6%), *Oryza sativa* (59.4%), and *Triticum aestivum* (52.7%) proteins (Betancur-Ancona *et al.*, 2004). Chia seeds have all amino acids that are essential for human nutrition such as glutamine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, histidine and valine (Sandoval-Oliveros and Paredes- Lopez, 2013). Among them, glutamine has the highest quantity and histidine has the lowest amounts (FAO/WHO/UNU, 2008; Sandoval-Oliveros and Paredes-Lopez, 2013). The amino acid profile of chia is appropriate for the adult diet (Weber *et al.*, 1991). The seed is also free from mycotoxins (Jamboonsri *et al.*, 2012) and there is no proof of allergic reactions (EFSA, 2005, 2009) to chia seeds consumption.

5.3. Fiber

Another favorable characteristic of chia seeds for researchers is that it contains high fiber (5-6%), which can be used as dietary fiber (Ayerza and Coates, 2001; Reyes-Caudillo *et al.*, 2008) and is also very interesting for drug and industrial uses because this high content of soluble fiber can form a very hydrophilic mucilage. As well as chia meal has 33.9–39.9 % of dietary fiber (Capitani *et al.*, 2012). So it is a great crop for being consumed in human and animal nutrition (Ting *et al.*, 1990). In some studies, have been determined that chia seed total dietary fiber content ranges between 32.4 and 37.50 g/100 g, which most of them being insoluble (>93%) and the remainder (<7%) being soluble (Reyes-Caudillo, 2008). Some reports have determined that the consumption of chia seed fiber has a potential effect on the treatment of some diseases, such as coronary heart disease, the risk for type 2 diabetes, and cancer (Lattimer *et al.*, 2010; Kaczmarczyk *et al.*, 2012).

5.4. Vitamin and antioxidants

Moreover, chia seeds and oil also possess a lot of useful compounds which are good for human health, like vitamin B (B6 and B1), A, C, K and E (Bushway *et al.*, 2006; Mehta *et al.*, 2020) and natural antioxidants (Reyes-Caudillo *et al.*, 2008; Amato *et al.*, 2015), carbohydrates, magnesium, zinc, iron, calcium and phosphorous (USDA, 2004) and it does not have any danger for human health (Bresson *et al.*, 2009).

6. Uses

Chia seeds are used as a functional food or nutritional supplement. The seeds can be eaten whole, after oil extraction (consumption of oil and meals) or ground as an additive to other foods. Chia seeds have some advantages, including the higher amount of ω-3 (Ayerza and Coates, 2004), the long shelf-life of whole seeds (Ahmed *et al.*, 1994; Amato *et al.*, 2015), and the lack of fishy flavors (Coates and Ayerza, 1998). Ayerza and Coates (2011) stated that an adult who needs 2,700 calories a day should consume 22.5 to 26.5 grams of chia seeds or 9.6 to 9.7 grams of oil per day to get the daily recommended amounts of omega-3 fatty acids. As chia has high amounts of protein compared to other grains, it can be included in the human diet alone or as a food ingredient to create a richer source of protein than other grains. Chia oil extracted may be used as a condiment or in beauty products (Munoz *et al.*, 2013). Also, it has been used for eye infections in racial medicine (Lu and Foo, 2002; Reyes-Caudillo *et al.*, 2008).

By adding chia seeds and oil as additives to food products, we can achieve functional foods as tested in bakery products (Pizarro *et al.*, 2013; Silveira Coelho and de las Mercedes Salas-Mellado, 2014). Chia seeds are gluten-free, so it is very suitable for celiac disease. Celiac disease has become one of the most important gastrointestinal diseases today, and a gluten-free diet is often prescribed for these patients (Steffolani *et al.*, 2014).

So, using chia seeds in the food industry for the production of bread, bars, cookies, and breakfast products has increased especially in the USA, Latin America, and Australia (Cerna *et al.*, 2014). According to studies on making bread, it is better to use whole or pre-soaked chia grains compared to ground grains because it has less specific volume, higher firmness of bread and better color (Steffolani *et al.*, 2014).

Cerna et al. (2014) found that using 3% chia seeds to make bread is very suitable and ideal, and they also concluded that the concentration and amount of seeds used in bread preparation only affect its texture and color and it has no effect on its taste. When chia fruits hydrated, they produced a gel surrounding the seeds. It absorbs water 27 times its weight (Munoz *et al.*, 2012a, b). Ahmed et al. (1994) stated hydrated chia seeds are traditionally used in beverages called “agua fresca” or “chia Fresca” in Mexico. Polysaccharides of chia can be used in many applications, from food to the pharmaceutical industry (de la Paz Salgado-Cruz *et al.*, 2013).

7. Animal feed

Because chia is rich in health-promoting compounds, it can be used in animal feed to enhance the concentration of linolenic acid and reduce cholesterol levels in meat and eggs (Mohd Ali *et al.*, 2012). The main purpose of using chia in the animal diet was to increase the omega-3 fatty acid content of animal products. So far, only chia seeds (raw or processed) and their oil, also other products such as seed meal, have been used in animal feed. There is no report on how whole chia plants can affect the diet of animals (Ahmed *et al.*, 1994; Peiretti and Gai, 2009; Peiretti, 2010; Amato *et al.*, 2015).

Ayerza and Coates (1999, 2000, 2001) and Ayerza et al. (2002) stated that chia seeds do not have some detriments, such as fishy flavor and digestive problems of other sources of polyunsaturated fatty acids in the animal diet. In the study of poultry diets with chia seeds, Ayerza and Coates (2000) found that their egg yolks are rich in polyunsaturated fatty acids and have a low level of cholesterol and saturated fats. In a study, In a study Ayerza and Coates (2006) feeding dairy cows with chia seeds, their outcomes showed that the percentage of omega-3 fatty acids increased without affecting the production or content of total fatty acids and cholesterol. Meineri and Peiretti (2007) used chia seeds for rabbit feed and reported that the regime containing 10 % of chia seeds enhances the digestibility of acid detergent fiber, dry matter, organic matter, crude protein, crude fiber and gross energy.

In another study, Peiretti and Meineri (2008) enhanced the chia seed ratio in the rabbit diet. Their results showed polyunsaturated fatty acids in the meat significantly increased. Peiretti and Gai (2009) with respect to chia leaves and whole plants, reported that the quality of chia forage depends on the time of harvest and is optimal before shooting. Peiretti (2010), in an experiment, showed that chia is a good plant for silage because by observing the deficiency of lactic acid and the presence of alcohols and volatile fatty acids, it was determined that it had been fermented.

8. Ethnobotanical and medical applications

Cahill (2003) stated that the leaves and vegetative parts of *S. hispanica* L. can be used for pharmaceutical goals. According to Ahmed et al. (1994), chia leaves can be used to extract flavors and aromas. Medical studies have shown that ω-3 fatty acids are essential nutrients and play an important role in human health for the prevention of various diseases, including cardiovascular disease, anti-thrombotic, anti-inflammatory, anti-arrhythmic and plaque stabilization (Galli and Marangoni, 2006).

In the point of nutritional value, vegetable oil composition is important. The n-3 fatty acids (FAs) have a very vital role in body physiology and development, particularly during fetal and infant growth (Bowen and Clandinin, 2005). Therefore, the health administration of many countries has independently encouraged people to consume foods having high amounts of n-3 FAs and a favorable n-3/n-6 fatty acid (FA) ratio. With respect to this specific FA composition, the food industry has to seek out peculiar fats and oils having these compounds to optimize the ‘‘fat profile’’ of the end products (Dubois *et al.*, 2007). Although traditionally, using oils with high amounts of n-3 is the limited cause of their inconsistency and flavor reversion, the availability of stabilized products allows manufacturers to provide different kinds of products (Shahidi, 2008).

Three out of every five people in the world die from diseases such as cardiovascular disease, cancer and diabetes (Wang *et al.*, 2016). These diseases are caused by high blood pressure, high cholesterol and ultimately, overweight and obesity (World Health Organization, 2017).

According to epidemiological studies, obesity is directly related to the consumption of sugar, fructose and products containing high amounts of saturated fats. This dietary pattern, in which people consume large amounts of fats, animal foods, refined carbohydrates and added sugars, is often referred to as the “western diet” (Popkin *et al.*, 2011; Popkin *et al.*, 2004).

This type of diet is remarked as an unbalanced diet due to insufficient distribution of macronutrients to meet human needs (Institute of Medicine, 2005). A steady and inactive lifestyle and an unbalanced diet have led to obesity (World Health Organization, 2017), which led to some events that are related to the development of some diseases like insulin resistance (IR), type 2 diabetes mellitus, and cardiovascular diseases (Pozza and Isidori, 2018). Plant foods contain bioactive compounds that can be used to prevent and treat disease (Borowska and Brzoska, 2016). Chia seed is one of the plant foods known for its high concentration of beneficial nutritional compositions (da Silva *et al.*, 2017).

Conflict of Interests

All authors declare no conflict of interest.

Ethics approval and consent to participate

No human or animals were used in the present research.

Consent for publications

All authors read and approved the final manuscript for publication.

Availability of data and material

All the data are embedded in the manuscript.

Authors' contributions

All authors had an equal role in study design, work, statistical analysis and manuscript writing.

Informed Consent

The authors declare not to use any patients in this research.

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