



## **Medicinal and Nutraceutical Benefits of Chia Seed (*Salvia hispanica*)**

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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### **ABSTRACT**

Chia seeds (*Salvia hispanica* L.) are small seeds that develop on an annual herbaceous plant. Recently, there has been tremendous growth in the use of chia seeds because of their associated medicinal as well as high nutritional values. Initially, chia cultivation took place in Mesopotamian cultures, eventually disappearing for some centuries before being rediscovered in the mid-20<sup>th</sup> Century. In this paper, the main aim has been to provide an overview of chia seed in relation to its perceived medicinal properties. From the majority of scholarly affirmations, it has been established that some of the compounds that chia seeds contain, explain its associated healthful effects include minerals, vitamins, proteins, dietary fiber, polyunsaturated fatty acids, and  $\omega$ -3 fatty acids. Also, the literature contends that chia seeds are excellent sources of antioxidants and polyphenols, which include quercetin, myricetin, rosmarinic acid, and caffeic acid. Around the world, therefore, more and more scholarly investigations have focused on some of the beneficial effects of chia seeds, including the food, pharmaceutical, and medicinal industries. In this paper, it has been established that chia seeds have their medicinal properties gained in terms of pharmacological activities that

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include steatohepatitis and acute dyslipidemia improvement, sensory attributes, bioactive peptide and protein source, metabolic profile, and antioxidant and appetite suppressing properties. Important to note is that while most studies concur regarding these medicinal properties, in a few investigations, findings suggest that chia seeds do not pose significant beneficial effects, especially concerning health improvements in human subjects. As such, there is a need for future research to examine some of the parameters that could explain this variation, upon which more valid and informed conclusions and inferences might be made.

**Keywords:** *Salvia hispanica*; chia seed; antioxidant activity; nutritional properties; nutraceutical.

## 1. INTRODUCTION

Also referred to as Chia, *Salvia hispanica* L. exists as an ancient food, providing balanced amounts of minerals, high content of antioxidants, proteins with amino acids in excellent quantity, high omega-3/-6 fatty acids, and insoluble fiber [1]. For the chia seed coat, it comes with mucilage, which aids in the protection of the seed nutrients in the entirety, as well as participate in the foods' water retention process. Thus, this seed forms a crucial source of  $\alpha$ -linoleic, which is among the most beneficial  $\omega$ -3 fatty acids. For the chia seed storage proteins, in most cases, they constitute glutelin fractions, prolamin, albumin, and globulin. For the seed's main phenolic compounds, they include gallic, caffeic, and rosmarinic acids. Thus, due to its outstanding benefits, chia seed has attracted the attention and scholarly interest of industry, researchers, and nutritionists [1]. In the 21<sup>st</sup> century, this seed continues to be recognized due to the provision of invaluable nutraceutical benefits, examples being antioxidant and antihypertensive functions.

Originally from Northern Guatemala and Southern Mexico, Chia has been documented to exist as an annual herbaceous plant, whereby it belongs to the genus *Salvia*, subfamily Nepetoideae, mint family Labiate, and the order Lamiales. With about 900 species making up the genus *Salvia*, it has been distributed widely for many years and in the world's various zones, including South East Asia, South and North America, Central America, and Southern Africa [2-4]. From the literature, currently, Chia's cultivation is not just limited to Guatemala and Mexico. Rather, it has extended to Europe, America, Argentina, Peru, Columbia, Bolivia, and Australia, coming at a time when Mexico is still recognized as the largest producer of Chia in the world [3]. From historical records, Chia was used by ancient cultures in Mesopotamia (beside amaranth, bean, and corn), especially the Mayas

and Aztecs. Particularly, the seed would be used for food and folk medicine preparation. For societies in pre-Columbia, Chia existed as the second main crop, coming after beans. From the contexts of Aztecs communities, some of the functions that Chia played included religious rituals, making cosmetics, and consumption as food [4].

Mainly, the growing of Chia is for seeds. The plant also produces purple and white flowers. Important to note is that it remains sensitive to daylight, and its growth can extend to 1 meter high, with the leaves being serrated and reverse petiole, extending to three to 5 cm wide and four to 8 cm centimeters long. For Chia seeds, generally, they are small because they are less than 1 mm thick, one to 1-1.5 mm wide, and 2 mm long [5,6]. Also, there are marked variations in the color of Chia seeds, ranging from white to black-spotted, grey, and black. From scholarly reports [6], marginal variations exist between white and black Chia seeds, with most considering them as equal. Regarding their nutritional values, they are similar, with white Chia seeds having 16.5% protein content and 32.4% fiber content, while black Chia seeds are documented to exhibit 16.9% protein content and 32.6% fiber content. Hence, it is only in their morphology that the black Chia seeds and white Chia seeds exhibit a marked variation or difference. Particularly, when compared to black seeds, white seeds tend to be broader, thicker, and larger [6]. Fig. (1) illustrates the Chia plant and its seeds.

From recent statistical outcomes, Chia seeds have been the most recognized foods around the world, a trend attributed to their medicinal values, as well as nutritional properties [8,9]. In the study by Coory et al. [10]. It was established that Chia forms a promising ingredient because of  $\alpha$ -linolenic acid that exists in the highest amount, making it easier to add to commercial food [10]. In other studies, it has been observed



**Fig. 1. Chia plant and its seeds [7]**

that because of fatty acids that exist in a high percentage in Chia seeds, they are crucial for antimicrobial activity, antioxidants, and health. When used as a nutritional element, Chia seeds have yielded enormous positive benefits in terms of reducing the risk of diabetes and heart disease, promoting stronger muscles and bones and healthy skin, and supporting the digestive system [11-14]. In this study, the central purpose is to provide an overview of Chia seeds, with a particular emphasis on their medicinal properties.

## **2. CLIMATIC CONDITIONS AND CHIA OIL PRODUCTION, GRAIN YIELD, AND GROWTH**

Chia's seeds have been documented to exhibit high contents of essential fatty acids, and the composition explains increasing crop production around the world. However, the crop's expansion faces challenges because the plant is photoperiod-sensitive, implying that it does well in regions without cold. Thus, the impact of various climatic conditions on oil production, crop yield, and the growth of Chia have been studied. In Chile, some of the areas that have been studied include Las Cruces, Canchones, and Valle de Azapa. In the findings, it has been documented that in Canchones and Valle de Azapa, which exhibit desert conditions, the regions have offered better conditions that have, in turn, promoted oil production ( $> 550 \text{ L ha}^{-1}$ ), the highest yield ( $> 2900 \text{ kg ha}^{-1}$ ), and plant growth. However, at a higher altitude, such as the context of Las Cruces, the yield has been

found to be adversely affected by low temperatures that coincide with the reproductive stage in April, making the yield to be less than  $129 \text{ kg ha}^{-1}$ . It has been documented further that the exposure of Chia plants to shorter days translates into precocious flower initiation, with inadequate day lengths implying that it is after the plants' accumulation of  $600\text{-}700^\circ\text{C d}$ . that they begin to flower [15]. Overall, therefore, it is worth inferring that Chia exhibits quantitative type day length sensitivities.

## **3. PHYSICO-CHEMICAL PROPERTIES OF CHIA OIL**

For Chia seed oil, studies have also focused on its phenolic content, tocopherols, unsaponifiable matter, fatty acid composition, and physico-chemical properties. From the affirmations, Chia oil has shown better saponification, iodine, and peroxide values, as well as better overall quality. For sterol fractions, they have been observed to be rich in 5-avenasterol (3.55%), campesterol (3.77%), and stigmasterol (4.83%). Also, omega-6 fatty acid (60.93%) has been found to be the main fatty acid in Chia seed oil. However, upon measuring the serum contents (for low and high-density lipoproteins, total cholesterol, and total lipids) and conducting kidney and liver tests (for alkaline phosphatase activities, alanine amino transferase, and aspartate amino transferase), it has been established that Chia oil does not yield significant effects on serum contents and kidney and liver function [16]. Hence, Chia oil is only rich in essential fatty acids.

#### 4. CHIA SEED TERAPEUTIC VALUE

Some studies have concentrated on the therapeutic value with which Chia seeds could be associated. From the study by Munoz et al. [17], the main aim was to analyze the cardioprotective effects of the seed. Due to the presence of  $\alpha$ -linolenic acid, Chia seeds are crucial for certain biochemical compounds' formation, including thromboxanes, and leukotrienes – that are linked to the human body's vital physiological functions. Also, Chia seeds' fatty acid has been observed to be capable of blocking sodium and calcium channel dysfunctions, averting possible hypertension. Similarly, the fatty acids are seen to aid in protecting ventricular arrhythmia and steering marked improvements in the parasympathetic tone. During pregnancy, Chia seed consumption has been found to help in the fetus' brain and retina development [4].

When  $\alpha$ -linolenic fatty acids and dietary fiber are incorporated into diets, they make Salba-chia the key contenders in body weight regulation, as well as other comorbidities with which diabetes tends to be associated. From the investigation by Vuksan et al. [18], it was established that upon having 37 g/day supplementation of Salba-chia to isocaloric diets, there tends to be an

improvement in emerging and major risk factors for type-2 diabetes. The insights, thus, demonstrate that apart from weight maintenance, Chia seed exhibits a cardioprotective potential. The authors also conducted a related investigation and found that for Salba-chia, its use leads to the acute reduction of postprandial glycemia, especially after adding it to meals, aiding further in the reduction of prolonged satiety. Given calorie-restricted diets, also, upon adding Salba-chia for 6 months, scholarly insights have demonstrated that, along with standard medical care, there tend to be minor yet crucial weight losses among obese and overweight individuals with type 2 diabetes [4,18].

#### 5. ECOLOGY AND HABITAT

So far, Chia has been observed to be dominant in gravel riverbeds. However, other investigations suggest that the plant is located on soil and waste heaps. An additional habitat where Chia plant is commonly found is along traffic routes, cemeteries, parking lots, and the vicinity of ports. In new regions, the main features of Chia involve gravelly or sandy soils, as well as highly distributed habitats, whether natural or anthropogenic. Hence, Chia tends to occur along plant invasions' corridors [25].

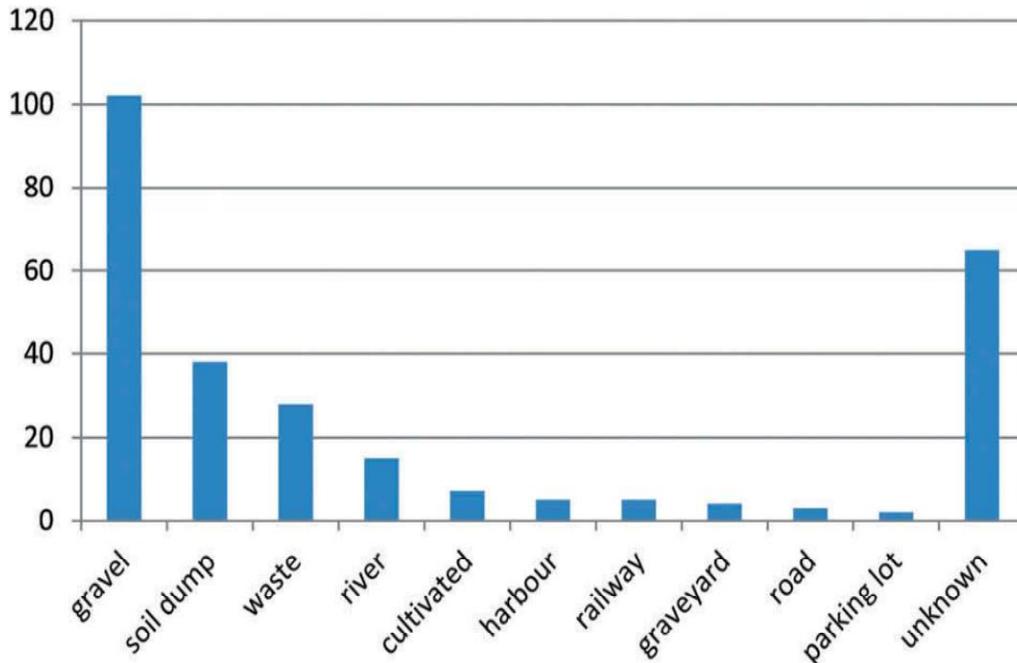


Fig. 2. An illustration of the habitat-based grouping of European localities with Chia

Source: [25]

**Table 1. Insights from clinical studies and chia seed therapeutic value outcomes**

<b>S/No.</b>	<b>Purpose</b>	<b>Research context</b>	<b>Description of study</b>	<b>Findings</b>	<b>Ref.</b>
1	The main purpose of this investigation lay in the evaluation of the impact posed by Salba-Chia on obesity-related risk factors, visceral obesity, and body weight among obese and overweight adults experiencing type 2 diabetes.	The study involved or targeted obesity-related satiety hormones and C-reactive protein levels. Also, the focus was on glycemic control, body composition, and alterations in waist circumference and body weight.	Participants were selected in two groups, with 77 individuals on the focus.	There was an increase in plasma adiponectin, reduced C-reactive protein and waist circumference, and significant loss in weight.	[18]
2	The study strived to compare the behavior of Salba-chia with flax as two seed types in relation to their impact on satiety scores and postprandial glycemia.	The study involved the collection of satiety ratings and blood glucose samples during fasting, as well as more than two hours postprandially.	There was the randomization of 15 healthy individuals, who received a 50-gram glucose challenge, both when supplemented with 31.5 grams of flax or 25 grams of ground Salba-Chia or alone.	In the results, it was indicated that Salba-chia exhibited a marked ability to convert glucose into slow-release carbohydrates. Also, Salba-Chia was found to affect satiety significantly, outperforming flax. A factor that explained this state of superiority for Salba-chia was its associated higher fiber viscosity.	[19]
3	The motivation of this study was to find out how Chia seed oil ingestion affects running performance in humans.	The study was randomized, with a crossover approach seeing individuals run to exhaustion, following acute Chia-seed oil-flavored water ingestion. Also, there was acute ingestion of flavored water alone, followed by a washout period of at least two weeks.	With 8:00 am selected as the time at which blood samples were offered, the participants ingested 0.5 liters of flavored water with 7 kcal kg <sup>-1</sup> Chia seed oil or flavored water alone, with the order being random. At 8:30 am, there was the provision of another sample before participating in running until exhaustion. At an	In the results, it was noted that Chia seed oil ingestion about half an hour prior to running increases the levels of plasma ALA. However, in the study, discernible benefits were observed for the athletes.	[20]

S/No.	Purpose	Research context	Description of study	Findings	Ref.
			hour post-exercise, blood samples were collected. Other samples had been collected immediately post-exercise.		
4	This study sought to find out how the supplementation of Chia affects blood pressure, as well as the impact on related cardiometabolic factors.	The study focused on males and females experiencing hypertension. Also, the focus was on the implementation of a placebo-controlled, experimental, double-blind, and randomized research.	There was the clinical measurement of blood pressure, the assessment of the nutritional status, blood sample collection, and the monitoring of ambulatory blood pressure.	In the findings, with the placebo or Chia consumption, no renal disorders, hepatic disorders, or gastrointestinal disorders were reported. Also, given the selected hypertensive individuals, there was a marked reduction in blood pressure.	[21]
5	This study sought to find out how whole and milled Chia seeds could be effective relative to the alteration of risk factors. The study population constituted postmenopausal and overweight women.	With gas chromatography on the focus, the study employed a metabolomics technique in which, alongside multivariate statistics, there was mass spectrometry. Also, the partial least-square discriminant and principal component analytical approaches were implemented.	The selected individuals ingested 25 grams of placebo or Chia seed supplements on daily basis, stretching to ten weeks. Measurements that were taken included metabolic profiling, plasma fatty acids, and fasting blood samples (relative to inflammation markers), as well as the serum lipid profile, the augmentation index, blood pressure, and body mass and composition.	Results demonstrated that upon ingesting milled Chia seed, 25 grams per day, in this case, a comparison of the ten-week outcome relative to the use of placebo or whole Chia seed indicated a marked increase in plasma EPA and ALA in overweight women. Thus, milled Chia seed ingestion proved more beneficial than placebo or whole Chia seed ingestion. However, the ingestion of milled Chia seed did not pose a statistically significant impact on disease risk factors or inflammation, regardless of whether metabolomics-based or traditional measures were employed.	[22]

<b>S/No.</b>	<b>Purpose</b>	<b>Research context</b>	<b>Description of study</b>	<b>Findings</b>	<b>Ref.</b>
6	Here, the purpose lay in the evaluation of how dietary patterns of oat, Chia seed, nopal, and soy protein affects biochemical variables, which included Metabolic syndrome (MetS). Also, the study strived to unearth the response to dietary patterns, the aspect of glucose intolerance, and AUC for insulin and glucose.	The study was conducted in the form of a parallel-arm, double-blind, placebo-controlled, randomized, single-center investigation or research.	The initial stage constituted the instruction of participants to have them consume reduced energy diets. Also, the diets consumed contained low cholesterol and low-saturated fat, a process that extended for two weeks. As the second stage set in, there was a random assignment of the participants to have them consume either the placebo or dietary pattern, adding to the initial diet that constituted reduced energy. This second stage extended for two months.	In the results, the study demonstrated a decrease in WC, BMI, and BW. However, the percentage of the fat or lean mass did not change significantly in either group, results that were found to be consistent even after the final dietary treatment.	[23]
7	The main aim of the selected study was to assess the relationship between carbohydrate loading and omega-3 Chia seed loading.	The body weight of the study subjects determined CHO-loading treatments, implying that they remained isocaloric.	For the performance testing outcomes, there was a comparison between two forms of CHO-loading treatment.	In the results, this study indicated that there was no marked variation in CHO loading and omega-3 Chia loading.	[24]

In autumn 2018, Slovenia experienced a fast Chia outbreak. Mainly, the occurrence of these species was on gravel bars, stretching to about 2,000 square kilometers. For most of the observed sites, the majority existed along rivers of catchment basins. In the floristic composition, Chia's natural plant communities have been documented, and they form riverine gravel terraces' initial plant communities. The associations into which these plant communities have been classified include *Bidenti frondosae-Panicetum barbipulvinati*, *Chaerophyllo-Petasitetum officinalis*, and *Polygono lapathifoliae-Salicetum eleagni* [26].

#### **Steatohepatitis and Acute Dyslipidemia**

**Improvement:** Recognized for their richness in omega fatty acids, Chia seeds have been studied relative to their ability to improve steatohepatitis and dyslipidemia, especial in animal studies. Thus, the focus of the latter study was to determine the impact of using Chia on acute tyloxapol (TI)-induced dyslipidemia, as well as the impact on acute carbon tetrachloride (TC)-induced steatohepatitis. The study also focused on how Chia intake affects mixed damage combining the two conditions, with a particular emphasis on non-obese rats. With four experimental groups selected and put on a diet containing 15% added Chia and other four groups exposed to a diet with established rodent food, findings indicated that Chia intake prevented steatohepatitis totally or partially. Also, in the dyslipidemic groups, Chia intake led to a notable reduction in lipids. In the study, Chia's hepatoprotective and hypolipidemic effects were attributed to the high content of phenolics, as well as omega-3 [27]. Overall, it was inferred that upon including Chia in non-obese patients' diets, cirrhosis is likely to be prevented, with the individuals' health state also improved significantly.

**Sensory Attributes:** Chia seed has also been studied to determine how its incorporation towards optimized nutria bar development could yield beneficial outcomes if any. In the latter study, Chia seed formulations of 20%, 15%, 10%, and 5% were used. The resultant bar that was developed was evaluated relative to its storage quality, physiochemical properties, sensory attributes, and nutritional quality. In the findings, it was reported that for Chia seed, the 10% incorporation with antioxidant activity, carbohydrate, crude fat, ash, crude fiber, and protein content was the most acceptable and that for the nutria bars, their shelf proved stable [28]. Molecular mechanisms and effects of Chia seeds

on unbalanced diets have also been studied. In particular, the motivation has been to examine how the process of metabolic biomarker modulation is influenced. In the findings, Chia has been affirmed to exhibit the capacity of yielding AMPK modulation, coming in the form of improved inflammation, antioxidant activity, lipogenesis, and insulin and glucose tolerance [29]. Additional scholarly investigations and descriptions have focused on how long-chain consumptions of fatty acids intersect with human health. In type-2 diabetes mellitus, findings suggest that the anti-inflammatory and antioxidant properties of the fatty acids associated with Chia are confirmed, aiding further in cancer prevention, as well as the prevention of stroke and cardiovascular disease [30]. The findings are seen to concur with those reported in [31], whereby Chia was confirmed to be a disease remedy, especially because the constituents of the seeds make it to be a functional or nutraceutical food.

#### **Bioactive Peptide and Protein Source:**

for studies that have delved into this subject [32], the main aim has been to unearth how the high content of dietary fiber and omega-3 fatty acids with which Chia seeds are associated poses medicinal value if any. In the results, it has been reported that amino acid analysis depicts peptides containing antioxidant capacity, angiotensin-converting enzyme inhibitors, and dipeptidyl peptidase-IV inhibitors. Hence, similar to other studies [33-36], in humans, whole Chia seed is seen to exhibit anticholesterolemic, hypoglycemic, and hypotensive effects, as well as antioxidant capacity. However, in the study by de Miranda et al. [37], Chia seed supplementation failed to reduce some of the deleterious effects with which lipid-rich diets are associated, especially concerning aspects such as the activity of the liver's anti-oxidants enzymes, glucose intolerance, and body composition. Given such mixed results, it becomes imperative for future research to focus on some of the factors that could explain the variations in Chia seed effects when investigated in different research settings and under different experimental conditions [37].

**Metabolic Profile:** Through ferric-reducing antioxidant power (FRAP) and 2, 2-diphenyl-1-picrylhydrazyl (DPPH) assays, Chia seed total antioxidant capacity was measured. Other parameters that were investigated included carotenoid concentrations, chlorophyll, cellulose content, ascorbic acid, and total phenolics. In the

outcome analysis, it was established that through dark-grown Chia microgreen illumination, there tends to be a marked or significant increase in the content of the bioactive compounds that were measured in the entirety. Also, illumination was found to increase Chia seed antioxidant capacity, with more pronounced effects felt about 48 hours after the illumination or exposure to the light process [38]. The results are, therefore, seen to concur with other studies, which avow that: cassava-chia seed blends have good functional and physical properties – due to nutritive extruded instant porridge flour production potential [39]. Chia supplementation reduces the incidence of celiac disease, pruritus, diabetes, cancer, hypertension, obesity, and cardiovascular disease [40], dietary chia offers pharmaceutical properties such as acting as an antioxidant and modulating antioxidant enzyme activities – besides alleviating diabetic severity and serum lipid profiles [41], and Chia seeds form a potential antioxidant source due to the presence of kaempferol, quercetin, myricetin, caffeic acid, and chlorogenic acid – that exhibit anti-carcinogenic and anti-ageing characteristics, as well as hepatic protective and cardiac effects [42].

**Antioxidant and Appetite Suppressing Properties:** Investigations on Chia seed as an appetite suppressant have been motivated by its remarkable binding and gelling capacities, as well as Chia seed flour's oil holding and water holding potential [43]. For such investigations, findings demonstrate that the plant's high healthful potential could be attributed to its innovative properties and concoction arrangement, pharmacologically beneficial features linked further to Chia seed-associated polyunsaturated fats that occur in the form of dissolvable dietary fiber and omega-6 and omega-3 [43]. Also, it has been established in the literature that when Chia seed's hydrolyzed and crude extracts are evaluated, the resulting phenolic compounds include derivatives of danshensu (that include alvianolic and rosmarinic) and caffeic acid, which reflect crucial dietary sources for establishing natural antioxidants responsible for disease prevention, especially conditions arising from oxidative stress [44]. Lastly, nutraceutical properties of Chia seeds have been investigated with the aim of determining their feasibility and potential for commercial production, especially in relation to the field of pharmacology. In the results, it has been avowed that due to several nutrients that they possess, Chia seeds exhibit great

potentiality for use as nutraceutical compounds hence, proving beneficial to human health. The seeds' crucial compounds that account for such scholarly inferences include phytochemicals (that come with high antioxidant activities such as isoflavones and phenolics), vitamins, minerals, and essential amino acids, oil (with high amounts of omega-6 and omega-3 fatty acids), and insoluble and soluble fiber [1].

## 6. CONCLUSION

In summary, this paper has provided an overview of Chia seeds in relation to their medicinal properties. From the literature, animal studies and those that have focused on human participants have investigated the seeds' main components by isolating and evaluating them to gain knowledge of their health and nutrition benefits, as well as functional properties. From the results, most of the studies concur that Chia seeds exhibit active compounds that explain their antioxidant and antihypertensive potential. In the future, these findings point to the need for advanced molecular technologies (in the form of novel technologies and DNA editing to pave the way for the development of new cultivars associated with superior attributes, allowing further for the rational and intelligent use of Chia seeds in an industry such as the pharmaceutical sector. Important to note is that even though most of the studies contend that Chia seeds come with promising medicinal properties, a few studies, as revealed in this paper, point to a less significant intersection between the use of Chia-seeds (or Chia seed supplementation) and improvements in human health. As such, future research needs to focus on some of the factors that could explain this variation in previous scholarly findings, upon which more valid conclusions and more informed and reliable inferences might be made.

## CONSENT

It is not applicable.

## ETHICAL APPROVAL

It is not applicable.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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