Chia seed mucilage: Extraction methods and potential application in food matrix

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ABSTRACT
Chia (Salvia hispanica L.) is a herbaceous plant native to southern Mexico and northern Guatemala, with a high nutrient content and technological properties. Currently, its seed has stood out, since it has 5 to 6% soluble fibers, which are exuded when the seeds are placed in water, forming a transparent capsule around the seeds. The extraction of chia mucilage involves three processes: hydration, extraction, and drying. The amount of mucilage extracted can be affected by several factors related to extraction conditions, such as chia ratio: water, extraction temperature, hydration time, agitation, and separation. In addition, its incorporation into food contributes to sensory and physical characteristics, with regard to texture, stabilization, formation of gels and emulsions, volume, inhibition of syneresis among other factors. Thus, the present study aimed to analyze studies that differ with regard to the extraction methodology, in addition to the application of this gel in food products. The review was carried out in July 2023, on the Periódicos CAPES electronic platform of scientific articles, which used chia mucilage as a substitute for commercial additives in foods. The selected articles were published between 2018 and 2023 and the following terms were used for the search: "mucilage", "chia", "applications". In the studies analyzed, it was possible to observe a variation in yield of 3.4 to 8.5% depending on the methodology used by the authors, which shows the relationship in the change of the variables: seed/water, time, temperature, and use of ultrasound. Regarding the application of mucilage in food formulation, the analyzed studies provided good results in the physicochemical and sensory characteristics of food products.

Keywords: Fat, Gum, Gel, Seeds, Texture, Stabilization.

1 INTRODUCTION

Plant seeds are rich in nutrients, fiber, and fatty acids, which make them an important food for human nutrition. Due to these functional properties, the *U.S. Food and Drug Administration* has considered plant seeds to be a dietary supplement (CHIANG et al., 2021; ROSAS-RAMÍREZ et al., 2017).

An example is chia (*Salvia hispanica L.*), a herbaceous plant, native to southern Mexico and northern Guatemala, which was used by many ancient civilizations as a food source. The nutritional compounds present in chia have gained importance in research in recent years, as it is a source of oil rich in polyunsaturated fatty acids (omega-3 and omega-6), proteins, fiber, minerals, and antioxidant compounds (CAPITANI et al., 2018; FERNANDES et al., 2020).

In addition to its high nutrient content, chia has technological properties that are gaining prominence today, due to the fact that it has 5 to 6% soluble fibers, which are exuded when the seeds are placed in water, forming a transparent capsule around the seeds, with gel-like characteristics (CAPITANI et al., 2016; MUTLU; KOPUK; PALABIYIK, 2023).

This gel is known as mucilage, considered as a tetrasaccharide with high branches. Its incorporation into food contributes to sensory and physical characteristics, with regard to texture, stabilization, formation of gels and emulsions, volume, inhibition of syneresis.

As they have in their composition other nutritional components such as proteins, oil and carbohydrates, it becomes an alternative in the replacement of fats, gelling agents, thickeners and stabilizers. (FERNANDES; MOLLADO, 2018; MUTLU; KOPUK; PALABIYIK, 2023; HIJAZI, 2022). This substitution is in line with the population's growing search for low-energy foods, which consequently challenges the industry to seek strategies for the replacement of fatty components, without changing the characteristics of the products (CHAVES et al., 2018).

The objective of this study was to explain the application of chia mucilage in the substitution of commercial agents in food, as well as to analyze the different conditions of extraction, performing a literature review.

2 RESEARCH METHOD

The present study addresses a systematic review carried out in July 2023 on the *Periódicos CAPES* electronic platform of scientific articles that used chia mucilage as a substitute for commercial additives in foods. The articles considered for this study were published between 2018 and 2023, in order to carry out a review of recent studies, in addition to the following terms were used in the search: "mucilage", "chia", "applications". For the choice of articles, we considered 08 (eight) that presented at least two combinations of keywords in the title, disregarding articles that were not in accordance with the research. A total of 61 articles were found . The research constituted the search for promising applications in the production of safe and healthy foods that replace commercial agents in their formulation.

3 RESULTS AND DISCUSSIONS

3.1 REASONS FOR THE APPLICATION OF CHIA SEED MUCILAGE (MSC)

Isolated chia seeds have been increasingly investigated; many studies are focused on optimizing the extraction yield, as well as its application in the food industry, due to its good ability to retain oil and have a strong emulsifying and stabilizing property, which makes it promising in replacing synthetic compounds (CHIANG et al., 2021; SILVA et al., 2022).

3.2 EXTRACTION AND PROPERTIES OF MUCILAGINOUS GEL

Basically, the extraction of chia mucilage involves three processes: hydration, extraction, and drying. The amount of mucilage extracted can be affected by several factors related to the extraction conditions, such as chia ratio: water, extraction temperature, hydration time, agitation and, especially, the way the mucilage is separated from the seeds (CHAVES et al, 2018). As a result, the studies analyzed in this review differ in terms of extraction time and temperature, and water/seed ratio. Some studies perform additional steps, such as ultrasound treatment, in order to increase the extraction yield. These changes in methodology are compared in Table 1.

The lowest yield observed in the table was in Feizi's work (3.4%). However, he worked with a low seed:water ratio, and low hydration time. Silva also had a low yield, as he worked at room temperature. Antigo et al. (2020) obtained a yield of 4.68% under extraction conditions of 1:30 (w/w) for the proportion of chia: water, 50 ^{oC} and 2h of hydration. Fernandes' work, Mellado (2018), on the other hand, shows a yield of 5.81% when using a proportion of chia:water higher, however, a lower extraction temperature (25 ^{oC}).

However, the highest yield was observed in the work of Chaves et al. (2018) who, in turn, extracted chia mucilage with the intention of obtaining a high moisture content by using wet mucilage, which resulted in 18.25% yield in relation to wet mass. However, for the purpose of comparison of yield with the literature, they dried and obtained a powder mucilage yield equal to 8.49%.

With the use of ultrasound in the work of Silva et al. (2022), it was noted that the mucilage fibers formed denser aggregates compared to samples that were only agitated. The increase in the viscosity of the solutions occurred mainly after 10 min, which resulted in a greater compaction of the mucilage and there was a greater loss of the gel due to its adhesion in the filtration. The timing is interesting, as longer ultrasound applications (30min and 6h) resulted in less viscous solutions, which facilitated the separation process and consequently increased the yield. However, the samples that were not sonicated had lower or similar yields to the samples that were not ultrasounded. The author obtained apparent viscosity values at 100 $^{s-1}$ between 0.200 and 0.280 Pa.s for the samples that were not sonicated, and between 0.057 and 0.273 Pa.s for the sonicated samples. In addition, thermal stability has increased with the use of ultrasound.

Table 1. Comparison of mucilage extraction of the articles selected for the research.

Seed/water ratio (p/p)	Time	Temperature Oc	Ultrasound	Drying	Average yield (%)	Author/year
1:40	2h	25	N/A	Lyophilization	5,8	FERNANDES; MELLADO, 2018
1:30	2h	50	N/A	Oven drying with forced air circulation 50 ^{oC} for 96 hours / freeze drying	4,7	ANTIGO et al., 2020
1:30	3h 4,5 6h	25	Yes	Lyophilization	3,4	SILVA et al., 2022
1:40	2h	80	N/A	Lyophilization	8,5	CHAVES et al., 2018
1:20	20min	50	N/A	Lyophilization	3,4	FEIZI et al., 2021
3:30	3h	60	N/A	Lyophilization	-	RIBES et al., 2022
1:20	2h	30-50	N/A	Lyophilization	-	AK; CARDER, 2021
1:50, 2:25, 1:10	15h	37	N/A	Lyophilization	7,6	TOMIC et al., 2022

Source: authors, 2023.

3.3 APPLICATION OF MUCILAGE AS A FAT SUBSTITUTE AND/OR STABILIZERS IN FOOD PRODUCTS

Chia mucilage has characteristics that enhance its use as an alternative in replacing fat in a range of foods. In the work of Fernandes, Mellado (2018), different formulations of mayonnaise with freeze-dried chia mucilage were prepared, replacing the oil or egg yolk. Among the results obtained by the authors, the substitution of the oil for the mucilaginous gel increased the stability and texture of the mayonnaise, while the addition of the hydrogel in place of the egg yolk presented lower values in which they resemble the control mayonnaise. When sensorially analyzed, the result differed, the mayonnaise with egg substitution showed greater acceptability than the mayonnaise with oil substitution.

Arnak and Tarakçi (2021) applied powdered mucilage as a substitute for commercial stabilizers and emulsifiers, as these ingredients incorporate several physicochemical benefits into the final product, such as improved viscosity, stability, texture, shelf life, and melting properties. In this way, the authors evaluated chia mucilage as a substitute for the thickener salep, a product obtained from dried orchid tubers, widely used in Turkey, but of high cost and limited by law. The authors used ice cream as a food matrix. Due to this substitution, there has been a significant increase in melting. In addition, higher concentrations of mucilage powder reduced the hardness and viscosity of the ice cream. However, no significant effects were observed on water content, pH and acidity; In addition, ice cream made with 0.4% mucilage was considered the most promising to maintain quality, reducing costs and still being sensorially attractive. Another point was the analysis of air incorporation (*overrun*), which resulted in higher values as the concentration of chia in the formulation increased.

On the contrary, the study by Feizi et al. (2021) applied mucilage as a fat substitute in ice cream and observed that the incorporation of air (Overrum) decreased as the concentration of chia mucilage in the formulation increased. The highest *overrun* value was for formulations containing 0.1% w/w of mucilage and the lowest for 0.2% w/w, obtaining respectively 108 and 96% of air incorporation. Regarding rheological properties, it was observed that ice cream mixtures containing the addition of mucilage had an increase in apparent viscosity compared to control samples. Regarding melting, performed at 20oC, the effect of the addition of mucilage reduced the melting rate compared to the other samples without mucilage; This is a result of fat aggregation and/or partial coalescence in the emulsion, partially coalesced fats provide an ice cream with desirable characteristics such as firmness, texture, melting and creaminess, which was observed with the addition of the mucilaginous gel. In short, the ice cream produced presented desirable characteristics and, according to the results obtained in the sensory analysis, the best ice cream contained 0.2% mucilage (w/w).

Chaves et al. (2018) used the combined effect of chia mucilage with carob gum (*Ceratonia siliqua L.*) in a kind of frozen yogurt, that is, a frozen goat's milk dessert. The formulations, at higher levels of chia mucilage, led to increased moisture content, apparent viscosity and texture; however, they reduced the *overrun*, because there was difficulty in the incorporation of air. With regard to melting, a critical parameter for a frozen product, even formulations with lower fat content showed a reduction in melt rate, which was desirable. The fat reduction was significant, since the formulations provided a reduction of 56.33% of fat in the sample composed of 100% chia mucilage, when compared to the sample with 0% mucilage. According to the authors, although fat is an important ingredient in the incorporation of air in frozen products, the alternative of replacing chia presented characteristics and values close to the original formulation.

Tomic et al. (2022), when evaluating chia seed mucilage as a fat substitute in the formation of gluten-free biscuits, observed that biscuits exhibited desirable physical and sensory properties. The incorporation of mucilage favored the composition of fatty acids, not significantly affecting hardness, weight and volume. Thus, the use of the hydrogel did not alter the structure and texture of the biscuit. In this work, it was observed that the viscosity of the hydrogel increases with higher concentrations and all samples showed characteristics of weak gels. One point analyzed is that 5% chia seed hydrogels were more susceptible to deformation than 10% chia seed hydrogels, which were too rigid to replace fat, so biscuits with 8% hydrogels had higher quality.

The work of Ribes et al. (2022) evaluated the addition of chia seed mucilage in the production of a chicken and vegetable soup, as an alternative to the use of thickeners. An analysis of the rheological properties of the soup showed that the product showed characteristics of a weak gel. In addition, the soup showed greater consistency and firmness when compared to the control and with modified starch. Regarding the rheological properties, the viscosity of the mash (at $^{10s-1}$ and $^{50s-1}$) increased with the addition of mucilage, as expected due to the higher content of total solids.

4 CONCLUSION

This review addresses different conditions of chia mucilage extraction, where the seed/water ratio, time, temperature, and use of ultrasound were varied. When comparing the selected studies, it was possible to observe a variation in yield of 3.4 to 8.5% depending on the methodology used by the authors. In addition, the application of chia mucilage to replace commercial agents in food has been explored. Thus, the analyzed studies provided good results in the use of mucilage with regard to the physicochemical and sensory characteristics of the food products mentioned in the present study, such as ice cream, frozen dessert, chicken puree with vegetables, gluten-free biscuits and mayonnaise.

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