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INFLUENCIA DEL MUCÍLAGO DE SEMILLAS DE LLANTÉN (Plantago major) EN LAS PROPIEDADES FÍSICAS DE HELADO SABOR A MORA (Rubus glaucus)

INFLUENCE OF PLANTAGO MAJOR SEED MUCILAGE ON THE PHYSICAL PROPERTIES OF BLACKBERRY-FLAVORED ICE CREAM (Rubus glaucus)

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RESUMEN: La innovación en la Agroindustria está en aumento, con tendencia hacia el reemplazo de estabilizantes sintéticos por naturales para la obtención de diferentes productos. La presente investigación plantea al mucílago de semillas de psyllium (*Plantago major*) como una alternativa evaluando el impacto en las propiedades físicas del helado sabor a mora. Se procedió a establecer las variables (temperatura y tiempo) que permiten obtener mayor cantidad de mucílago, destacándose la extracción a 80°C por 2.5 horas con 29.10% de rendimiento, demostrando que al incrementar la temperatura y tiempo se favorece la extracción del mucílago. Con el mucílago obtenido con estos parámetros se formularon helados variando la concentración de mucílago y crema de leche, analizando posteriormente de cada tratamiento las propiedades físicas por triplicado y aplicando la prueba de comparación de Duncan. Se evidenció diferencia significativa ($p<0.05$) en la viscosidad de todas las muestras, presentando en el helado con 5% de mucílago de semillas de llantén y 28% de crema de leche, el valor más alto (7666.67 cP). El mismo tratamiento presentó diferencia significativa ($p<0.05$) en el tiempo de caída de primera gota a temperatura ambiente (27°C) con una duración de 19 minutos, y en el porcentaje de derretimiento con 6.44% en 10 minutos. Por consiguiente, en todas las pruebas destacó el helado con 5% de mucílago y 28% de crema, seguido del helado con 3% de mucílago y 30% de crema, y por último el helado con 1% de mucílago y 32% de crema. Se demostró que ha mayor porcentaje de mucílago de semillas de llantén en la formulación de helados es posible obtener mejores propiedades físicas y mayor estabilidad a temperatura ambiente.

Palabras clave: *Estabilizante, helado, llantén, mucílago, propiedades físicas, viscosidad*

ABSTRACT: Innovation in the agro-industry is on the rise, with a trend toward replacing synthetic stabilizers with natural ones for the production of various products. This research proposes psyllium seed mucilage (*Plantago major*) as an alternative, evaluating its impact on the physical properties of blackberry-flavored ice cream. The variables (temperature and time) that yield the greatest amount of mucilage were established, with extraction at 80°C for 2.5 hours yielding 29.10%, demonstrating that increasing the temperature and time favors mucilage extraction. Ice creams were formulated using the mucilage obtained under these parameters, varying the concentration of mucilage and cream. The physical properties of each treatment were then analyzed in triplicate, and Duncan's multiple range test was applied. A significant difference ($p<0.05$) was observed

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in the viscosity of all samples, with the ice cream containing 5% plantain seed mucilage and 28% cream exhibiting the highest value (7666.67 cP). The same treatment also showed a significant difference (p<0.05) in the time to first drop at room temperature (27°C), with a duration of 19 minutes, and in the percentage of melting, reaching 6.44% in 10 minutes. Consequently, in all tests, the ice cream with 5% mucilage and 28% cream stood out, followed by the ice cream with 3% mucilage and 30% cream, and finally the ice cream with 1% mucilage and 32% cream. This demonstrates that a higher percentage of plantain seed mucilage in ice cream formulations can result in improved physical properties and greater stability at room temperature.

Keywords: *Ice cream, mucilage, physical properties, plantain, stabilizer, viscosity*

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INTRODUCTION

The development of food products that, in addition to the contribution of nutritional value, present functional characteristics such as the capacity of bioactive compounds to generate beneficial effects for health, has been driven by the sustained growth of the population and the demand for foods. This scenario has increased the interest in the use of ingredients of natural origin that make it possible to improve the technological and functional quality of foods.

Plantago major, commonly known as plantain (llantén), is a plant widely valued for its medicinal properties, which are attributed to the presence of diverse chemical compounds and bioactive nutrients (1). The seeds of this species have been classified as mucilaginous, since, upon hydration, they form a highly viscous layer with characteristics similar to a gum or gel, known as mucilage (2). This type of substances can be obtained from plant, animal, processed, or synthetic sources, and possesses diverse applications in the agri-food industry as emulsifying, stabilizing, suspending, and binding agents, owing mainly to their elevated water-holding capacity (3).

The mucilages extracted from plant seeds correspond to polysaccharides of hydrocolloid nature, which present functional properties and potential benefits for health associated with their physicochemical structure (4). In the specific case of *Plantago major*, the mucilage is composed of monosaccharides such as glucose, xylose, rhamnose, galactose, arabinose, and glucuronic acid, which confers upon it thickening, stabilizing properties and capacity for foam formation (2). Although its use has been widely documented in the pharmaceutical industry, its employment in food matrices is still limited, despite its potential from the technological point of view.

Ice cream presents a simple elaboration process; however, it is considered a complex food system at the physicochemical and structural level. Consequently, how to formulate and process this product has evolved significantly over time, with the objective of improving attributes such as texture, stability, smoothness, and resistance to melting (5). In this context, the stabilizing and emulsifying agents play a fundamental role, since they make it possible to increment the viscosity of the mix, control the

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formation of ice crystals, and maintain a homogeneous distribution of the non-miscible components of the system (6); (7).

Currently, the stabilizers most utilized in the elaboration of ice creams are of synthetic origin or derived from plant gums such as pectins, carboxymethylcellulose, and hemicelluloses (8). However, current consumption trends prioritize minimally processed foods, with natural and easily accessible ingredients, which has motivated the search for functional alternatives of plant origin (9).

A wide variety of plant mucilages has been evaluated for their capacity to improve viscosity, water retention, and stability against ice recrystallization, in the search for stabilizers for ice creams (10); (11). Among the most studied are found the mucilages of chia (*Salvia hispanica L.*) and flaxseed (*Linum usitatissimum L.*), which have demonstrated positive effects on stability and the reduction of melting rate in ice creams. However, their use can present technological limitations, such as excessive increases in viscosity, interference with aeration, and sensory alterations when they are utilized at relatively low concentrations (11); (12). On the other hand, the mucilage of plantain (*Plantago spp.*) is characterized by its high content of highly branched arabinoxylans, which confers upon it a high water-holding capacity, a pseudoplastic rheological behavior, and greater stability against freeze–thaw cycles (13). These properties favor the formation of more homogeneous and stable matrices, with a lower negative impact on the texture and sensory acceptability of the final product, which positions it as a differentiated alternative to other plant mucilages traditionally utilized in the elaboration of ice creams.

For the foregoing reasons, the mucilage of plantain seeds represents a promising option, owing to its hydrocolloid properties and to the scarce information available on its application in foods in comparison with the pharmaceutical ambit (14).

Therefore, the present study has as its objective to evaluate the stabilizing effect of the mucilage of plantain seeds (*Plantago major*) on the physical properties of blackberry-flavored ice cream (*Rubus glaucus*), with the purpose of substituting a commercial stabilizer and promoting the use of this mucilage as a functional additive of natural origin in the food industry.

MATERIALS AND METHODS

Materials

The seeds of plantain (*Plantago major*) were used for the extraction of the mucilage and pulp of blackberry (*Rubus glaucus*) for the elaboration of the ice cream. The remaining ingredients employed were whole milk, cream, powdered milk, and sugar, all of food grade acquired from local supermarkets. An analytical balance brand Mettler Toledo with capacity of 120 g (precision of 0.0001 g) was used.

Experimental design

The present investigation presents a completely randomized design; for the extraction of the mucilage 3 treatments were evaluated considering different parameters (temperature and time) in the process. In the formulation of blackberry ice cream 3

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treatments were elaborated with different concentrations of plantain seed mucilage and cream.

Extraction of plantain seed mucilage

For the extraction of the mucilage the procedure indicated by (15) was followed, with slight modifications based on (14) and (16). The treatments established were T1 (50 °C during 1.5 h), T2 (75 °C during 2 h), and T3 (80 °C during 2.5 h). The mucilage was precipitated with 80 % ethyl alcohol in a 1:3 ratio (sample:alcohol), filtered, and stored at 4 °C until its use for the obtaining of the ice cream.

Determination of mucilage yield

The yield of the mucilage was determined by means of a gravimetric method, calculating the percentage in function of the initial weight of the seeds and the weight of the mucilage obtained, in accordance with the method described by (17).

Formulation and elaboration of the ice cream

Table 1. Formulation of blackberry-flavored ice cream using plantain seed mucilage.

Ingredients	T1	T2	T3
Cream (%)	32	30	28
Whole milk (%)	20	20	20
Plantain mucilage (%)	1	3	5
Sugar (%)	12	12	12
Blackberry pulp (%)	25	25	25
Powdered milk (%)	10	10	10
Total (%)	**100**	**100**	**100**

Three treatments were elaborated varying the concentration of mucilage (1 %, 3 %, and 5 %) and concentration of cream (32 %, 30 %, and 28 %). The mucilage used for the different ice cream treatments corresponded to the extraction treatment with the highest yield.

The elaboration process included mixing, pasteurization (85 °C during 5 min), homogenization, maturation (5 h), whipping, packaging, and storage at −18 °C, in accordance with what is stipulated in the standard (18), as observed in Table 1.

Determination of viscosity

The viscosity of the ice cream mixes was determined by means of the Brookfield rheometer (model DV-II, spindle #3) at 60 rpm at 4 °C, following the procedure described by (5).

Determination of melting percentage

The melting percentage was evaluated by gravitational drainage, determining the relation between the mass of melted ice cream and the initial mass of the sample, in accordance with the methodology described by (19).

Determination of time to first drop

The time to first drop was determined at room temperature, measuring the time elapsed from the exposure of the ice cream until the appearance of the first drop of melting, according to (5).

Physicochemical analyses

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The total fat content was determined by means of the Weibull-Berntrop gravimetric method, in accordance with (20). The weight/volume relation was determined by means of the pycnometer method according to AOAC 986.14. The total solids content was determined in accordance with (21). The milk protein content was determined by means of the Kjeldahl method, according to (22). The cholesterol content was determined in accordance with (23).

Microbiological analysis

Microbiological analyses were performed for the detection of indicator and pathogenic microorganisms, including count of mesophilic aerobes, total coliforms, *Escherichia coli, Staphylococcus aureus, Salmonella spp.* and *Listeria monocytogenes*, following the standards (24), (25), and (26), as corresponded.

Statistical analysis

The data obtained were analyzed by means of analysis of variance (ANOVA) under a completely randomized design. The comparison of means was performed utilizing Duncan's test at 5 % probability.

RESULTS

Determination of the best process of extraction of plantain seed mucilage according to yield varying time and temperature for its subsequent use in the elaboration of blackberry-flavored ice cream.

For the obtaining of the mucilage the plantain seeds were received eliminating the presence of branches, impurities, and foreign materials. Next, the seeds were dried during 2 hours at 100 °C, in order to reduce or eliminate microorganisms, in addition to facilitating the process of hydration of the seeds. With distilled water the seeds were hydrated, applying different parameters (temperature and time) for each treatment, with constant agitation. For Treatment 1 a temperature of 50 °C for 1.5 hours was applied, Treatment 2 at 75 °C for 2 hours, and finally Treatment 3 at 80 °C for 2.5 hours. For the extraction of the mucilage 80 % ethyl alcohol was utilized, in 1:3 ratio (sample/alcohol) in each treatment; finally filter paper with the aid of a mesh (2 mm) was utilized to separate the seeds from the mucilage.

The percentage of yield of plantain seed mucilage was calculated with Eq. 1 (%Yield = W1 × W2 / 100) for each treatment; the results obtained are detailed in Table 2. Duncan's test at 5 % probability showed that, according to the results obtained in the analysis of variance, there exists significant difference among the treatments ($p < 0.05$). Treatment 3 presented the highest percentage of yield (29.10 %), followed by Treatment 2 (22.35 %), demonstrating that as the time and temperature increased during the process of extraction of plantain seed mucilage, the greater was the yield.

Table 2. Percentage of yield of the extraction of mucilage from plantain seeds varying time and temperature.

Treatment	Means (%)
T1	8.40a
T2	22.35b
T3	29.10c
S.E.	2.40
C.V.	28.04
Significance	***

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Means with a different letter indicate significant difference (p < 0.05). S.E. = Standard error; C.V. = Coefficient of variation. * = p < 0.05; ** = p < 0.01; *** = p < 0.001 and ns = not significant.

Evaluation of the physical properties (viscosity, time to first drop, and melting percentage) in the blackberry-flavored ice cream with the addition of different concentrations of plantain seed mucilage with best yield.

In Table 3 it is evidenced that there existed significant difference ($p < 0.05$) among the samples of blackberry-flavored ice creams with plantain seed mucilage in relation to the viscosity parameter. Ice cream 3 (5 % of plantain seed mucilage and 28 % of cream) presented the highest mean of viscosity (7666.67 cP), followed by ice cream 2 (3 % of plantain seed mucilage and 30 % of cream) (4583.33 cP). Consequently, the percentage of plantain seed mucilage incorporated, as well as the percentage of cream, influences the result of viscosity obtained in each treatment. According to the formulation employed in the process of ice creams, the greater was the percentage of plantain seed mucilage and of cream incorporated in the mix, the greater was the result of viscosity in the ice cream sample.

Table 3. Viscosity of blackberry-flavored ice creams with plantain seed mucilage.

Samples	Means (cP)
H1	3766.66a
H2	4583.33b
H3	7666.67c
S.E.	556.03
C.V. (%)	7.28
Significance	***

Means with a different letter indicate significant difference (p < 0.05). S.E. = Standard error; C.V. = Coefficient of variation. * = p < 0.05; ** = p < 0.01; *** = p < 0.001 and ns = not significant.

Table 4 evidences the significant difference ($p < 0.05$) among means where it is compared how the percentage of plantain seed mucilage and the percentage of cream added to the ice cream mix influenced in relation to the time to first drop in the ice cream samples. Ice cream 3 (5 % of plantain seed mucilage and 28 % of cream) presented greater stability upon exposing it to room temperature (27 °C), beginning to melt at 19 minutes. While Ice cream 2 (3 % of plantain seed mucilage and 30 % of cream) showed itself relatively stable at room temperature (27 °C) and melted in 13 minutes. However, Ice cream 1 (1 % of plantain seed mucilage and 32 % of cream) was little stable upon being exposed to room temperature (27 °C), beginning to melt in a time of 8 minutes. Therefore, the greater was the percentage of mucilage employed in the ice cream samples, the greater was the stability that it presented upon being exposed to room temperature.

Table 4. Time to first drop in blackberry-flavored ice creams with plantain seed mucilage.

Samples	Means
H1	8.83a
H2	13.76b
H3	19.17c
S.E.	1.04
C.V.	4.75
Significance	***

Means with a different letter indicate significant difference (p < 0.05). S.E. = Standard error; C.V. = Coefficient of variation. * = p < 0.05; ** = p < 0.01; *** = p < 0.001 and ns = not significant.

In order to evidence the difference among means of the melting percentage, a scatter plot was used that shows the behavior of the melting percentage according to time; this was obtained by weighing the quantity of melted ice cream (in grams) every 10 minutes.

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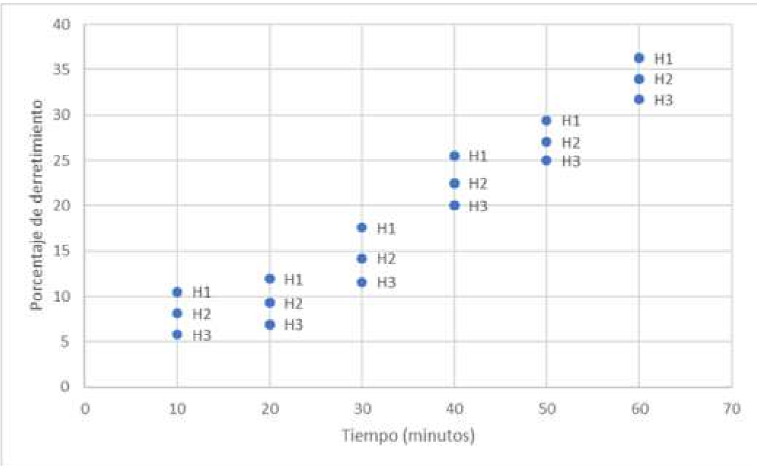
Figure 1 exposes the average value of each treatment on the basis of the melting percentage of the ice cream in relation to the quantity of cream and of plantain seed mucilage. The sample of Ice cream 3 (H3) (5 % of plantain seed mucilage and 28 % of cream) registered a melting percentage of 6.44 % in 10 minutes, a behavior that was maintained constant until 60 minutes that the sample was exposed to room temperature (27 °C). Followed by Ice cream 2 (H2) (3 % of plantain seed mucilage and 30 % of cream) with a melting percentage of 7.44 % in 10 minutes, demonstrating that, the greater is the quantity of mucilage applied, the lower will be the melting percentage at room temperature.

Figure 1. Scatter diagram among means of ice cream samples in relation to melting percentage. Where: H1: Ice cream 1, H2: Ice cream 2, H3: Ice cream 3.



Analysis of physicochemical parameters (total fat, weight/volume, milk protein, total solids, and cholesterol), and microbiological parameters (mesophiles, coliforms, E. coli, Staphylococcus, Salmonella, Listeria monocytogenes), on the basis of NTE INEN 706:2013 of requirements for ice creams to the treatment with best result on the viscosity property.

Analysis of physicochemical parameters

Table 5 shows the result of physicochemical analyses performed on the ice cream sample on the basis of (18), where the results obtained are appreciated. It is observed that the treatment of ice cream 3 complies with the requirements established by the standard in each parameter analyzed. With respect to milk protein, fat, and total solids, the values were close to the established limit, while for the cholesterol parameter the analyses reflect the established limit with a value of 0.09 mg/kg of sample, while what is stipulated by the standard is 0.10 mg/kg of sample; in relation to Weight/Volume expressed in g/L of sample a value of 470 g/L was reflected.

Table 5. Physicochemical parameters of sample of blackberry-flavored ice cream with plantain seed mucilage and what is established by standard NTE INEN 706:2013.

Parameters	Unit	Results	Requirement
Milk protein	%	2.27	2.50
Total fat	%	7.32	8
Total solids	%	28.55	32
Cholesterol	mg/Kg	0.09	0.10
Weight/Volume	g/L	470	475

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Analysis of microbiological parameters

In Table 6 it is shown that according to the standard (18) ice cream 3 complies with the requirements stipulated and in force in Ecuadorian legislation. Therefore, absence of pathogenic microorganisms such as Salmonella sp. and Listeria monocytogenes is observed. The counts of the indicator microorganisms are found below the permitted limit in the standard.

Table 6. Microbiological parameters of sample of blackberry-flavored ice cream with plantain seed mucilage and what is established by standard INEN 706:2013.

Parameters	Unit	Results	n	m	M
Count of mesophilic m.o.	cfu/g	1×10^2	5	10 000	100 000
Count of coliforms	cfu/g	1×10^2	5	100	200
Count of E. coli	cfu/g	<10	5	<10	<10
Count of Staphylococcus	cfu/g	<10	5	<10	<10
Detection of Salmonella	/25g	Absence	5	Absence	Absence
Detection of Listeria monocytogenes	/25g	Absence	5	Absence	Absence

DISCUSSION

In order to obtain mucilage from plantain seeds (*Plantago major*), a heat-assisted extraction method was utilized with the addition of ethyl alcohol as solvent, following the procedure described by (27). The efficiency of the process was evaluated in function of the yield of mucilage obtained, considering the influence of the time and the temperature of extraction. In this sense, three treatments were established with different combinations of these factors, which made it possible to analyze the variability in the percentage of mucilage extracted.

The results showed that the increase of the time and the temperature of extraction increments significantly the yield of mucilage, a behavior that coincides with what was reported by (14), who indicated that thermal conditions close to 80 °C and prolonged extraction times facilitate the solubilization of the mucilaginous polysaccharides present in the seed. However, differently from these authors, who utilized distilled water as solvent and obtained a yield of approximately 45 g of mucilage, in the present study the use of ethyl alcohol under the same parameters of temperature (80 °C) and time (2.5 h) made it possible to reach a higher yield (75 g). This result highlights the influence of the type of solvent on the efficiency of the extraction process, in accordance with what was indicated by (9), who emphasizes that variables such as temperature, time, seed/solvent ratio, and the nature of the solvent determine the yield of mucilage. The positive effect of the increase of temperature and extraction time on the yield of the mucilage can be explained by the physicochemical changes observed in the polysaccharide matrix of the seed. At temperatures close to 80 °C, the thermal energy favors the rupture of intra- and intermolecular hydrogen bonds, which stabilize the polysaccharide chains, increasing their solubility and facilitating the diffusion of high-molecular-weight macromolecules in the extraction medium (28). In addition, the polarity and the dielectric constant of the system are modified by means of the use of ethyl alcohol as solvent, in contrast with distilled water, which favors a more efficient precipitation of the mucilaginous polysaccharides and reduces the coextraction of low-molecular-weight compounds, which results in a higher general yield of the process (29); (30). In addition, the greater concentration of mucilage in the formulation of the ice cream made it possible to reduce the content of cream without affecting negatively the sensory perception, since the

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polysaccharides with high water-holding capacity contribute to the formation of a continuous and viscous matrix that imitates the rheological functions associated with the fat phase, such as oral lubrication, creaminess, and mouthfeel (31). This behavior has been described widely in natural hydrocolloids utilized as fat mimetics in frozen systems, where the water–air–fat interaction is crucial for the structural stability and the sensory acceptance of the final product.

With respect to the application of mucilage in the formulation of ice creams, the results obtained confirm that upon increasing the concentration of mucilage a significant increment in the viscosity of the system is generated. This behavior has been described previously by (32), where they evaluated the use of mucilage of leaves and seeds of nopal at concentrations of 3 %, 5 %, and 7 %, identifying a progressive increment in the viscosity as the content of hydrocolloid increased. In the present study, the treatment with the highest proportion of plantain seed mucilage (5 %) showed the highest viscosity values, confirming the thickening and stabilizing effect of this biopolymer. Likewise, the observed rheological behavior is characteristic of pseudoplastic systems, in which the viscosity increases with the concentration of the stabilizing agent.

(5) indicate that the emulsifying and thickening agents utilized in the production of ice cream affect directly the quality of the final product by limiting the formation of ice crystals, improving the structural stability, and providing a smoother and more homogeneous texture. In accordance with what was mentioned, the results obtained demonstrate that with the use of plantain seed mucilage it is possible to achieve functions similar to commercial stabilizers, without reaching the point of affecting negatively the physical properties of the product, such as viscosity, time to first drop, and melting percentage.

On the other hand, the obtaining of excessively viscous or gelatinous textures has been warned in diverse studies, mentioning that the high concentrations of mucilage would be the cause, giving as a result a negative affectation on the sensory acceptability of the ice cream. (32) informed that, although the treatment with 7 % of nopal mucilage showed greater viscosity, it was not the most accepted in terms of sensory evaluation, being the treatment with 5 % the most accepted. A similar behavior was observed in this study, where the formulations with greater content of mucilage showed a texture less characteristic of conventional ice cream, while the formulations with 3 % of mucilage presented viscosity and stability values comparable to those reported for commercial ice creams.

With respect to thermal stability, (33) reported melting times superior to 70 minutes in ice creams formulated with 0.8 % of yam mucilage, while lower concentrations showed shorter melting times. In the present study, the ice creams formulated with plantain seed mucilage showed times to first drop and of melting within the ranges established for conventional ice creams. In particular, the treatment with 3 % of mucilage had times to first drop between 12 and 17 minutes and a complete melting time of less than 35 minutes, values close to those reported by (5), who indicate that a quality ice cream presents a time to first drop between 12 and 15 minutes, and an approximate melting time of 30 minutes.

The physicochemical and microbiological results obtained evidenced the compliance with the limits established by (18). The values of milk protein, total fat, total solids, and

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cholesterol were registered within the permitted ranges, and the microbiological analyses confirmed the absence of *Staphylococcus aureus, Salmonella spp.* and *Listeria monocytogenes*. These results support the safety of the product and evidence that the incorporation of plantain seed mucilage as natural stabilizer does not compromise the quality nor the safety of the ice cream.

CONCLUSIONS

The mucilage obtained from the seeds of plantain (*Plantago major*) by means of heat-assisted extraction showed yields significantly influenced by the time and the temperature of the process. The results confirmed that the more severe extraction conditions favor the liberation of mucilaginous polysaccharides, which makes possible the identification of optimal parameters for maximizing the yield of mucilage, reinforcing the importance of the control of parameters in the process.

The plantain seed mucilage influenced the physical properties of the blackberry-flavored ice cream in a significant manner ($p < 0.05$), since upon increasing the concentration of mucilage a higher viscosity value was evidenced, a decrease in the melting percentage, and a more prolonged time for the fall of the first drop, confirming that the mucilage presents a behavior of functional hydrocolloid, and its potential use in the industry.

From a technological point of view, it was observed that the formulations with intermediate concentrations of mucilage showed an adequate equilibrium between the physical stability and the inherent characteristics of the ice cream, avoiding excessively viscous or gelified textures. This is important for the development of the product, since it highlights the necessity of optimizing the concentration of the natural stabilizer according to the final quality desired and the acceptance of the consumer.

The blackberry-flavored ice cream upon adding plantain seed mucilage complied with the physicochemical analyses such as proteins, total fat, total solids, and cholesterol indicated in the current Ecuadorian regulations. In addition, the microbiological analyses confirmed the safety of the product upon declaring absence of pathogenic microorganisms and counts of indicator microorganisms below the established limit. These results support the viability of the use of plantain seed mucilage from a regulatory and food safety perspective.

The present investigation manifests that the plantain seed mucilage is a viable alternative as natural stabilizer in the production of ice creams, and its potential use in the development of foods that require ingredients of plant origin and a lower dependence on synthetic additives, contributing to innovation and sustainability in the food industry.

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