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Formulation of vegan ice cream based on Super Chola potato extract (Solanum Tuberosum) using blackberry pulp and vegetable protein to improve their nutritional value.

Elaboración de un helado vegano a base de extracto de patata Super Chola (Solanum Tuberosum), utilizando pulpa de mora y proteína vegetal para mejorar su valor nutricional.

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Abstract
In recent years, dietary prospects have changed, with people seeking new products that are low in calories, made from plant-based raw materials, and free of lactose or animal-derived ingredients to improve their health. Therefore, the objective was to formulate vegan ice cream based on the plant extract of Super Chola potato (Solanum tuberosum), using blackberry pulp and plant protein to enhance its nutritional value. Different percentages of potato extract, blackberry pulp, and plant protein were evaluated. The results showed that the best formulation, both in physicochemical and sensory aspects, is as follows: 60% potato extract - 40% blackberry pulp - 1% plant protein.
Keywords: Vegan, ice cream, plant extract and plant protein.

Resumen
En los últimos años, las preferencias alimentarias han cambiado, y las personas buscan nuevos productos bajos en calorías, elaborados con materias primas de origen vegetal y libres de lactosa o ingredientes de origen animal para mejorar su salud. Por lo tanto, el objetivo fue formular un helado vegano a base de extracto de papa Super Chola (Solanum tuberosum), utilizando pulpa de mora y proteína vegetal para potenciar su valor nutricional. Se evaluaron diferentes porcentajes de extracto de papa, pulpa de mora y proteína vegetal. Los resultados mostraron que la mejor formulación, tanto en aspectos fisicoquímicos como sensoriales, es la siguiente: 60 % de extracto de papa, 40 % de pulpa de mora y 1 % de proteína vegetal.

Palabras clave: Vegano, helado, extracto vegetal y proteína vegetal.

Introduction
Currently, ice cream is a globally distributed product, with its primary consumers being children, adolescents, and older adults, who represent the most significant demographic for purchasing this food product. Its consumption has steadily increased due to its appealing characteristics, such as creamy texture, variety of flavors, and association with moments of happiness, making it highly accepted in the market [1,2].

However, a limitation exists for certain consumers due to its composition. One key ingredient is animal-derived milk, which is unsuitable for vegans or individuals with

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lactose intolerance. Although precise statistics for this population are unavailable in Ecuador, a growing demand for vegan products has been observed in the country, suggesting rising interest in this lifestyle. Additionally, a few products specifically target this consumer group[3,4].

Currently, the market offers several substitutes for animal milk, such as extracts from soy, rice, almonds, oats, and coconut, among others. However, these alternatives can also trigger allergies due to proteins that act as allergens. For this reason, potato extract has been proposed as a viable substitute for animal milk [5–7].

Potato extract is a promising alternative to animal-derived milk due to its nutritional properties, low saturated fat and sugar content, and suitability for lactose-free diets [8,9].

Materials and Methods

Objective

To formulate vegan ice cream based on the vegetable extract of Super Chola potato (Solanum tuberosum), using blackberry pulp and plant protein to enhance their nutritional value.

Vegan Ice Cream

The formulation and production process of the vegan ice cream, based on Super Chola potato (Solanum tuberosum), using blackberry pulp and plant protein, was carried out in two stages. The first stage involved obtaining the potato extract, and the second stage involved obtaining the blackberry pulp, thus achieving a correct formulation to produce this healthy food product.

In this context, Figure 1 shows the flow diagram to produce vegan ice cream, adapted from the methodology presented by Gonzales (2018) [10].

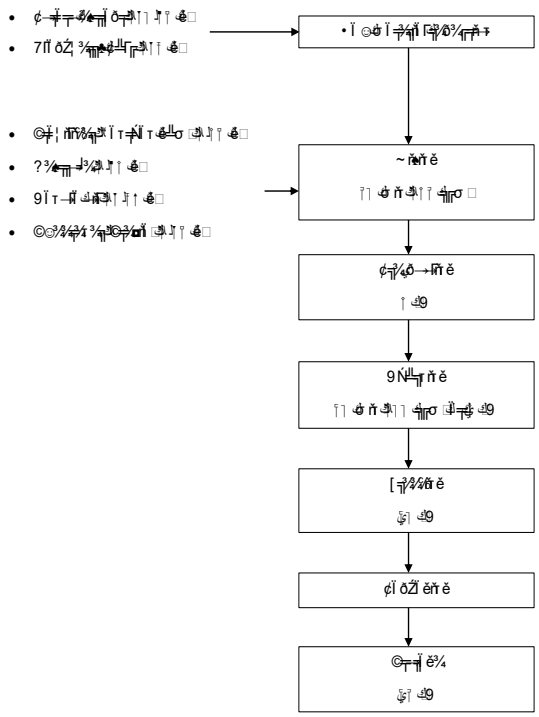


Figure 1. Flow diagram of vegan ice cream.
Source: González (2018)

Base Formulation

For the development of the ice cream, the formulation by González (2018) (shown in Table 1 for creamy ice creams made with coconut milk, cashew seed, and non-caloric sweeteners) was used as a reference. Substitutions and additions of ingredients were made to produce the vegan ice Base Formulation

For the development of the ice cream, the formulation by González (2018) (shown in Table 1 for creamy ice creams made with coconut milk, cashew seed, and non-caloric sweeteners) was used as a reference. Substitutions and additions of ingredients were made to produce the vegan ice cream based on Super Chola potato extract with blackberry pulp and plant protein [10]. The base formulation for the vegan ice cream is presented in Table 1.

Table 1. Proportions used for creamy coconut milk-based ice cream.
Source: González (2018)

№	Description	% Formulation

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1	Coconut milk	70-80%
2	Cashew seed	20-30%
3	Stevia	0-1%
4	Sucralose	0-1%
TOTAL		100%

Table 1 indicates that coconut milk was used; in this study, it has been replaced by potato extract and blackberry pulp, whereas cashew seeds were substituted with plant protein.

STATISTICAL DESIGN

In this study, a completely randomized factorial design was implemented. Table 2 presents the 6 treatments to produce vegan ice cream based on the vegetable extract of Super Chola potato (Solanum tuberosum), along with their respective definitions.

Description:

Factor A: Potato extract – blackberry pulp.
A1: 60% – 40%
A2: 70% – 30%
A3: 80% – 20%
Factor B: Plant protein.
B1: 1%
B2: 2%

Considering the experimental factors, the experimental design was established as presented in Table 2.

Table 2. Experimental design for vegan ice cream based on potato extract (Solanum tuberosum).

Treatments	Definitions
T1	Potato extracts 60% and blackberry pulp 40% + plant protein 1%
T2	Potato extracts 60% and blackberry pulp 40% + plant protein 2%
T3	Potato extracts 70% and blackberry pulp 30% + plant protein 1%
T4	Potato extracts 70% and blackberry pulp 30% + plant protein 2%
T5	Potato extracts 80% and blackberry pulp 20% + plant protein 1%
T6	Potato extracts 80% and blackberry pulp 20% + plant protein 2%

In Table 2, 6 treatments are listed, resulting in a total of 18 experimental units, each with a weight of 500 g.

In this study, physicochemical characterization and sensory evaluation were conducted to identify the optimal formulation for producing vegan ice cream based on the vegetable extract of Super Chola potato (Solanum tuberosum) with blackberry pulp and plant protein. First, normality (Shapiro-Wilk) and homoscedasticity (Breusch-Pagan) tests were applied to determine whether the data were parametric or non-parametric. Based on these results, statistical difference tests between treatments were performed: ANOVA for parametric data and Kruskal–Wallis for non-parametric data. If significant statistical differences between treatments were detected, post hoc tests (e.g., Dunn's test or multiple range tests) were applied, depending on the initial analysis. All statistical analyses were performed using RStudio and InfoStat software.

Methods

Fat: For fat analysis, the Gerber method described in AOAC 2000.18 was applied[11].

Overrun: The overrun in the ice cream was calculated using the equation described by Goff (2013)[12].

$$\% \text{ Overrun} = \frac{(PM-PH)}{PH}\ 100$$

Where:
PM: Weight of the liquid mixture
PH: Weight of the final ice cream

Total Solids: The method specified in ISO 3728:2004 for ice cream, milk ice cream, and similar products was applied to determine the total solids percentages for the formula-tion of the vegan ice cream.

Protein: The Kjeldahl method, as described in AOAC 2001.11, was used to quantify protein percentages in the treatments for the vegan

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ice cream formulation[11].

Reducing Sugars: The 3,5-dinitrosalicylic acid (DNS) method was employed to determine reducing sugar percentages for the formulation of vegan ice cream [13].

Results

The results and statistical analysis of the investigation are presented below.

Fat content: The six treatments analyzed for the vegan ice cream formulation showed the following results. Table 3 presents the Shapiro-Wilk test results to assess whether the data are parametric or non-parametric.

Table 3. Normality test (Shapiro-Wilk) for fat content

Test	Mean	p-value
Normality (Shapiro-Wilk test)	2,605	0,104862

Table 3 shows a p-value of 0.1048, which is greater than 0.05, indicating a normal distribution.

Table 4. presents the homoscedasticity test to evaluate whether the parametric data assumptions are met.

Test	Mean	p-value
Homoscedasticity (Breusch-Pagan test)	2,605	0,0109

The homoscedasticity test (Table 4) yielded a p-value < 0.05, leading to rejection of this assumption.

Based on data presented in Tables 3 and 4, we conclude that the fat content data from treatments of vegan ice cream made with potato plant extract are non-parametric. Consequently, the Kruskal-Wallis test was employed to establish comparisons between treatments, with results shown in Table 5.

Table 5. Kruskal-Wallis analysis results for fat content in vegan ice cream.

Treatment	Mean % ± SD	p-value
T1	2,50 ± 0,17	0,0205
T2	1,53 ± 0,06	
T3	2,67 ± 0,29	
T4	2,67 ± 0,29	
T5	3,83 ± 0,58	
T6	2,43 ± 0,23	

Table 5 presents the statistical results of the Kruskal-Wallis test applied to the six analyzed treatments regarding the fat percentage in the vegan ice cream. A p-value of 0.0205 (< 0.05) was obtained, indicating a statistically significant difference in at least one pairwise comparison between the developed treatments.

Once the presence of statistically significant differences between treatments was established, Table 6 displays the post hoc analysis performed for this parameter using Dunn's test.

Table 6. Dunn's test results for fat content

Treatment	1	2	3	4	5	6
1	1,0000	1,0000	1,0000	1,0000	0,0738	1,0000
2	1,0000	1,0000	0,5093	0,5093	0,0078	1,0000
3	1,0000	0,5093	1,0000	1,0000	1,0000	1,0000
4	1,0000	0,5093	1,0000	1,0000	1,0000	1,0000
5	0,	0,	1,	1,	1,	0,

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	7 3 8 8	0 0 7 8	0 0 0 0	0 0 0 0	0 0 0 0	3 4 3 7
6	1 , 0 0 0 0	1 , 0 0 0 0	1 , 0 0 0 0	1 , 0 0 0 0	0 , 3 4 3 7	1 , 0 0 0 0

Table 6 displays the results of Dunn's test for fat content, revealing statistically significant differences only between the pair T2 and T5. However, all treatments comply with the Ecuadorian standard NTE INEN 706:2013, as none exceed the maximum fat content limit of 4%.

Overrun: After calculating the overrun data for the vegan ice cream, the normality test (Shapiro-Wilk) was performed to determine if the data were parametric, as shown in Table 7.

Table 7. Shapiro-Wilk normality test – Overrun

Test	Mean	p-value
Normality (Shapiro-Wilk test)	10,26	0,121846

Table 7 shows a p-value of 0.121846 for the normality test, which is greater than 0.05, indicating that this assumption is met. Therefore, the data is parametric.
Table 8 presents the homoscedasticity test to determine whether the data meets parametric assumptions.

Table 8. Homoscedasticity test - Overrun

Test	Mean	p-value
Homoscedasticity (Breusch-Pagan test)	10,26	0,0234

Table 7 demonstrates that the normality assumption is met, while Table 8 shows that this assumption is violated. The failure to meet one of the parametric assumptions indicates that the data are non-parametric.
Having established the non-parametric nature of the data, we proceeded with the Kruskal-Wallis test to determine whether statistically significant differences exist between treatments, as presented in Table 9.

Table 9. Kruskal-Wallis analysis results – Overrun

Treatment	Mean % ± SD	p-value
T1	10,57 ± 1,07	0,0560
T2	11,99 ± 2,53	
T3	10,23 ± 1,12	
T4	10,78 ± 0,52	
T5	8,12 ± 0,61	
T6	9,69 ± 0,16	

Therefore, Table 9 presents the Kruskal-Wallis test results for ice cream overrun, showing a p-value of 0.0560 (> 0.05), which indicates no significant difference exist among the six treatments. Consequently, all treatments may be considered suitable for inclusion in the vegan ice cream formulation.
Total Solids: For the total solids data, we conducted the Shapiro-Wilk normality test, as shown in Table 10.

Table 10. Shapiro-Wilk Normality Test - Total Solids

Test	Mean	p-value
Normality (Shapiro-Wilk test)	18,583	0,131019

Table 10 shows a p-value > 0.05, indicating a normal distribution of the statistically analyzed data in the Shapiro-Wilk test. Table 11 presents the homoscedasticity test for total solids.

Table 11. Homoscedasticity Test - Total Solids

Test	Mean	p-value
Homoscedasticity (Breusch-Pagan test)	18,583	0,0476

Regarding the homoscedasticity test, Table 11 shows a p-value < 0.05, leading to rejection of this assumption. This finding, combined with

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the normality test results, confirms that the total solids data are non-parametric, as they fail to meet both normality and homoscedasticity assumptions.

Having established the non-parametric nature of the data, we conducted the Kruskal-Wallis test to evaluate potential statistically significant differences between treatments. These results are presented in Table 12.

Table 12. Results of Kruskal-Wallis AnalysisTotal Solids.

Treatment	Mean % ± SD	p-value
T1	17,30 ± 0,52	0,183
T2	20,30 ± 1,94	
T3	17,73 ± 0,69	
T4	17,15 ± 0,56	
T5	20,04 ± 0,61	
T6	18,98 ± 1,18	

Table 12 presents the pairwise comparisons from the Kruskal-Wallis test, showing no significant differences ($p > 0.05$) between any treatment pairs for total solids.

Protein Analysis: Following protein content determination, we conducted parametric assumption testing. Table 13 displays the normality test results for these protein data.

Table 13. Shapiro-Wilk Normality Test - Protein

Test	Mean	p-value
Normality (Shapiro-Wilk test)	1,761	0,0329777

Table 13 shows a p-value of 0.0329 (< 0.05) for the normality test, indicating this assumption is violated. Consequently, we proceeded with the homoscedasticity test to further assess parametric assumptions, with results presented in Table 14.

Table 14. Homoscedasticity Test - Protein

Test	Mean	p-value
Protein	1,761	0,0001

Table 14 demonstrates a p-value of 0.0001 for the homoscedasticity test, confirming violation of parametric assumptions. The failure to satisfy both normality (Table 13) and homoscedasticity requirements establishes the non-parametric nature of the protein data. Consequently, we performed the Kruskal-Wallis test to evaluate potential statistically significant differences between treatments, with results presented in Table 15.

Table 15. Kruskal-Wallis Test Results - Protein

Treatment	Mean % ± SD	p-value
T1	1,55 ± 0,01	0,0623
T2	2,19 ± 0,06	
T3	1,44 ± 0,00	
T4	2,01 ± 0,01	
T5	1,44 ± 0,01	
T6	1,94 ± 0,02	

The Kruskal-Wallis test (95% confidence level) was employed to compare protein levels across ice cream treatments, yielding a p-value of 0.06228 (> 0.05). As shown in Table 15, this indicates no significant differences exist among the six treatments studied.

All treatments complied with the Ecuadorian standard INEN 706:2013, which specifies a minimum protein content of 1.5% for vegetable fat-based ice creams.

Reducing Sugars Analysis: Following the reducing sugars quantification for each experimental unit, we conducted the

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normality test, with results presented in Table 16.

Table 16. Shapiro-Wilk Normality Test - Reducing Sugars

Test	Mean	p-value
Normality (Shapiro-Wilk test)	24,356	0,000680022

Table 16 presents the Shapiro-Wilk normality test results for reducing sugars, showing a p-value < 0.05, which confirms non-normal data distribution.

Subsequently, we conducted the homoscedasticity test for reducing sugars data, with results displayed in Table 17.

Table 17. Homoscedasticity Test - Reducing Sugars

Test	Mean	p-value
Homoscedasticity (Breusch-Pagan test)	24,356	0,0303

The homoscedasticity test results (Table 17) show a p-value < 0.05, rejecting the null hypothesis of equal variances. This outcome, combined with the earlier non-normality finding (Table 16), confirms that the reducing sugars data in the vegan ice cream are non-parametric.

Consequently, we applied the Kruskal-Wallis test to evaluate potential statistically significant differences between treatments.

Table 18. Kruskal-Wallis Test Results - Reducing Sugars

Treatment	Mean % ± SD	p-value
T1	37,57 ± 7,66	0,0743
T2	19,97 ± 1,35	
T3	23,11 ± 4,68	
T4	24,53 ± 3,20	
T5	21,12 ± 0,93	
T6	19,84 ± 1,59	

Table 18 displays the results of the Kruskal-Wallis test, showing a p-value of 0.0743 (> 0.05). In other words, there are no statistically significant differences between treatments for this parameter.

Sensory Analysis: the sensory evaluation was conducted in the Sensory Analysis Laboratory at the State Polytechnic University of Carchi. Acceptance testing measured the following sensory attributes: color, odor, flavor, texture, and overall acceptability. Seventy (70) untrained panelists evaluated the products using a 7-point hedonic scale, as detailed in Table 19.

Table 19. Hedonic Scale

Score	Description
1	Dislike extremely
2	Dislike very much
3	Dislike slightly
4	Neither like nor dislike
5	Like slightly
6	Like very much

Table 20 presents the mean scores obtained in the sensory evaluation. For statistical analyses, the exact mean scores for each treatment were used without rounding, while for categorization within the hedonic scale (Table 19), the means were rounded to the nearest whole number.

Table 20. Sensory Analysis of Super Chola Potato-Based Vegan Ice Cream.

Treatments	Sensory Attributes				
	Color	Odor	Flavor	Texture	Overall Acceptability
T1	4^{A} (Neither like nor dislike)	4^{A} (Neither like nor dislike)	3^{B} (Dislike slightly)	3^{A} (Dislike slightly)	3^{B} (Dislike slightly)
T2	4^{A} (Neither lik	4^{A} (Neither lik	4^{A} (Neither lik	3^{A} (Dislike sligh	4^{A} (Neither like nor

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	e nor dislike)	e nor dislike)	e nor dislike)	tly)	dislike)
T3	4^{AB} (Neither like nor dislike)	4^{A} (Neither like nor dislike)	3^{A} (Dislike slightly)	3^{A} (Dislike slightly)	4^{AB} (Dislike slightly)
T4	4^{A} (Neither like nor dislike)	4^{A} (Neither like nor dislike)	4^{A} (Neither like nor dislike	3^{A} (Dislike slightly)	4^{AB} (Neither like nor dislike)
T5	3^{C} (Dislike slightly)	4^{A} (Neither like nor dislike)	3^{A} (Dislike slightly)	3^{A} (Dislike slightly)	3^{AB} (Dislike slightly)
T6	4^{BC} (Neither like nor dislike)	4^{A} (Neither like nor dislike)	3^{A} (Dislike slightly)	3^{A} (Dislike slightly)	3^{AB} (Dislike slightly)
P-Value	**0.00001**	**0,2998**	**0,00001**	**0,4999**	**0,2226**

Based on Table 19 results, significant differences exist in color ($p < 0.05$) and flavor ($p < 0.05$) parameters among treatments. Conversely, no significant differences were found in odor, texture, or overall acceptability (all $p > 0.05$).

a) The color analysis revealed three distinct groupings: treatments T1, T2, T3, and T4 formed Group A (highest color acceptability), treatments T3 and T6 comprised Group B (intermediate acceptability), while Group C (lowest acceptability) included T5 and T6. Notably, all Group A treatments demonstrated superior color acceptance, with T3 appearing in both Groups A and B, suggesting transitional color properties, whereas T6 spanned Groups B and C, indicating variable performance depending on formulation.

b) Analysis of Odor Parameter: The ANOVA results for odor showed a p-value of 0.2998 ($p > 0.05$), indicating no statistically significant differences between treatments. This suggests that all formulations produced statistically equivalent odor profiles under the tested conditions.

c) Statistical Analysis of Flavor Characteristics: The flavor evaluation revealed significant differences among treatments ($p = 0.001 < 0.05$), with two distinct homogeneous groups identified: Group A (T2, T3, T4, T5, T6) demonstrated sensorially acceptable flavor profiles, while Group B (T1) showed significantly different flavor characteristics, suggesting that all Group A formulations met the minimum flavor acceptability thresholds, whereas T1 may require reformulation to improve its sensory performance.

d) Texture Analysis Results: Fisher's test applied to the texture parameter of the vegan ice cream yielded a p-value of 0.4999 (> 0.05), indicating no statistically significant differences between treatments, which confirms that all formulations produced statistically equivalent texture profiles under the tested conditions.

e) Overall Acceptability Analysis: The results presented in Table 19 show no significant differences in overall acceptability among the six treatments ($p = 0.2226 > 0.05$), indicating that all formulations were equally acceptable for the potato-plant-extract-based vegan ice cream. This demonstrates that the experimental modifications did not negatively impact consumer preference, and all tested variants meet the minimum acceptability threshold for this product category.

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Discussion

This study aimed to develop a formulation for vegan ice cream that complies with the Ecuadorian standard NTE INEN 706:2013, while meeting nutritional requirements and achieving satisfactory sensory acceptance[14]. The results demonstrate that the Super Chola potato extract based formulation successfully served as a viable alternative to conventional dairy ingredients, addressing key challenges in vegan product development.

Physicochemical analyses identified Treatment T2 as optimal, formulated with 60% potato extract and 40% blackberry pulp, achieving 2% plant protein content and a low-fat content of 1.53% (the lowest among treatments). Notably, the canola oil used provides unsaturated fatty acids that boost HDL (high-density lipoprotein) cholesterol, while this reduced fat level also yields a lower-calorie ice cream [15]. The final product exhibited a high total solids content of 20.30%, representing one of the highest values achieved, which enhances its nutritional profile. Additionally, the protein content increases the ice cream's density, leading to more concentrated and intensified flavors[16].

The incorporation of air into the mixture resulted in an overrun of 11.99%. According to Michue-Mango (2015), water-based or plant-extract ice creams should have a maximum overrun of 15%, where higher overrun yields a lighter, spongier texture. While all treatments fell within this parameter, Treatment T2 emerged as optimal within its group due to its higher mean overrun value, enhancing profitability by increasing final product volume without requiring additional base mixture[17].

Regarding reducing sugars, statistical analysis showed no significant differences among the six treatments ($p > 0.05$). Therefore, the value of 19.97% from Treatment T2 was selected as optimal, representing one of the lowest mean values to achieve a lower-sugar formulation. All parameters of this selected treatment comply with Ecuadorian standard NTE INEN 706:2013 requirements[14].

In the sensory evaluation conducted with 70 panelists, Treatment T2 was selected as optimal due to its superior acceptability in flavor and color parameters; however, for odor, texture, and overall acceptability, all treatments proved viable for the vegan ice cream formulation, as no significant differences were found among them ($p > 0.05$).

In this study, Treatment T2 provides a fat content of 1.53% and a protein content of 2.19%; this is because the protein content of the raw material (potato) is low compared to ice creams made from dairy derivatives.

The total solids content in the potato-based vegan ice cream was 20.30%; total solids comprise all non-aqueous ingredients, including sugars, fats, proteins, stabilizers, and emulsifiers. An appropriate total solids ratio is crucial for achieving high-quality ice cream, as it directly affects creaminess, melt resistance, and storage stability. According to Mohammed (2022), total solids in ice cream should ideally range between 36% and 40%, a key parameter for ensuring a creamy texture and optimal melt resistance. The study also highlights the importance of adequate protein content for stabilizing texture and structure [18,19]. The potato-based ice cream, despite having a lower total solids content, achieved good stability and texture, making it a lower-calorie food product.

When comparing our results with prior research, Zurita, Herrera & Robalino (2020) reported values of 2.20% fat and 6.21% protein in lupin milk-based blackberry ice cream, while our Treatment T2 formulation (potato extract-based) contained lower amounts at 1.53% fat and 2.19% protein. This nutritional difference stems from potato's inherently lower protein content compared to lupin; however, both options represent excellent choices for balanced and healthy diets, particularly for consumers seeking plant-based protein sources and healthy fats [20].

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stability of vegan ice cream made with soy milk and yellow pitahaya, the optimal formulation contained 25.4% total solids, 1.64% protein, and 6.29% fat, demonstrating that plant-based alternatives can achieve comparable stability to conventional ice creams while offering distinct nutritional profiles [18]. When compared to conventional and other plant-based formulations, the potato extract ice cream demonstrates a nutritionally optimized profile - while containing lower total solids (20.30% vs typical 25-40%) and reduced fat content (1.53% vs 6-15% in dairy versions), it provides higher protein levels (2.19% vs 1.64% in soy-based alternatives), making it both a nutrient-dense and lower-calorie frozen dessert option that meets contemporary consumer demands for healthier indulgent products.

Ricaurte 2023 study on whey-and-mortiño ice cream identified Treatment T1 (70% whey, 9.8% dairy cream, 15% mortiño pulp) as optimal, with 38.70% total solids, 1.61% fat, and 6.02% protein - values substantially higher than our potato-based formulation (20.30% solids, 1.53% fat, 2.19% protein) [19]. However, our plant-based alternative provides complex carbohydrates that undergo gradual hydrolysis, delivering sustained caloric availability while maintaining a nutritionally balanced profile suitable for lactose-intolerant and vegan consumers [19]. This represents a drawback for consumers seeking low-calorie food options, as the higher carbohydrate content and subsequent caloric availability may not align with their dietary goals.

The development of potato-based vegan ice cream represents a healthy and nutritious alternative, with the future goal of promoting its commercial use to benefit vegan populations by providing them with a sustainable and accessible frozen dessert option that meets their dietary preferences and nutritional needs.

Conclusion

Experimental analysis identified Treatment T2 as the optimal formulation for vegan ice cream, consisting of 60% Super Chola potato extract, 40% blackberry pulp, and 2% plant protein, with stevia added to enhance both nutritional value and flavor profile. This specific combination demonstrated superior performance in preliminary testing.

The selected formulation showed the following physicochemical characteristics: 1.53% fat content, 20.30% total solids, 2.19% protein, 19.97% reducing sugars, and 11.99% overrun. All parameters complied with the requirements established in the Ecuadorian standard INEN 706:2013 for frozen desserts.

Sensory assessment of the potato-based vegan ice cream revealed Treatment T2 achieved the highest acceptability scores: 3.53 for flavor and 4.29 for color (on a 7-point hedonic scale). Other attributes received moderate scores: 3.74 for odor, 3.09 for texture, and 3.71 for overall acceptability, indicating areas for potential formulation improvements while maintaining their viability as a plant-based alternative.

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Ethics Statement

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participants, animal subjects, or any material that requires ethical approval.

Informed Consent Statement

This study did not involve human participants, and therefore, informed consent was not required.

Clinical Trial Registration

All manuscripts reporting clinical trial data must include a statement indicating that the trial has been registered in a publicly accessible registry before patient recruitment. Authors are required to provide the trial registration number and name of the registry in the manuscript.
Please follow the format below for citing the clinical trial registration:

- Clinical Trial Registration:
- *This trial is registered at [Name of Registry] with the registration number [Registration Number].*

If statement is not there mentioned this statement "This research does not involve any clinical trials."
Failure to provide a valid registration number at the time of submission will result in delays in the peer review process or rejection of the manuscript.

Author Contributions

Gualberto Leon: Conceptualization, software, validation, investigation, writing—original draft preparation, writing—review and editing and project administration
Damaris Cadena: Conceptualization, formal analysis, investigation, resources, writing—original draft preparation, visualization and funding acquisition
Carlos Rivas: methodology, validation and writing—review and editing
Liliana Chamorro: validation and data curation
Miguel Anchundia: resources, data curation and supervision.

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