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Formulation, sensory characterization, and functional food potential of a 70% sugar-reduced jam made from pushgay (*vaccinium floribundum*)

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ABSTRACT

Introduction: Pushgay (Vaccinium floribundum), also known as Andean blueberry, is a native fruit rich in antioxidants and nutrients. Its consumption has been associated with a lower incidence of chronic diseases such as diabetes.

Objective: This study aimed to formulate and evaluate low-sugar jams made with Pushgay, exploring its potential as a functional food.

Methodology: Three formulations were prepared using different gelling agents: FP1 (xanthan gum), FP2 (agar-agar), and FP3 (pectin), employing vacuum cooking (sous-vide) to preserve the fruit's sensory properties. Ten expert judges, all pastry chefs, conducted a sensory evaluation using a 9-point hedonic scale, assessing color, flavor, texture, spreadability, and overall acceptability. Normality tests, ANOVA, and Kruskal-Wallis tests were applied. Additionally, the Mann-Whitney test was used as a sub-analysis for attributes showing significant differences.

Results: A significant difference was found in the color attribute ($p < 0.036$), with FP1 being favored. No significant differences were observed for aroma, flavor, texture, or overall acceptability. The star diagram showed that FP1 stood out for its more intense color (8.00), though it had a less consistent and more clumpy texture. FP2 had the lowest color intensity (6.00), a granular texture, and a sweet, mildly acidic taste. FP3 was the most consistent and homogeneous in texture, with a distinctly sweet and acidic taste, and medium color intensity.

Conclusions: FP1 was preferred in terms of color, while the other sensory characteristics were perceived similarly among the formulations. These findings confirm the potential of Pushgay jam as a functional and appealing seasonal product for consumers.

KEYWORDS

Food innovation, Alternative sweeteners, Natural antioxidants, Healthy preserves, Native Andean fruits, Functional food technology

INTRODUCTION

Pushgay (*Vaccinium floribundum*), commonly known as the Andean blueberry, is a native fruit of Peru, a country in western South America bordered by Ecuador to the north, Colombia to the northwest, Brazil to the east, Bolivia to the southeast, Chile to the south, and the Pacific Ocean to the west[1]. This species thrives in the Andean region, which encompasses approximately 28% of Peru's territory and extends from elevations of 500 meters to over 4000 meters above sea level[1]. The region is characterized by its mountainous and rugged geography, inter-Andean valleys, and high plateaus. In Ecuador, *V. floribundum*—locally known as mortiño—is endemic to the páramo ecosystems and is widely distributed in the wild. It has long been used by local populations, particularly in the preparation of colada morada, a traditional beverage consumed during Day of the Dead festivities. Ecuador hosts three native species of mortiño: *Vaccinium floribundum*, *Vaccinium crenatum*, and *Vaccinium*

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distichum, with *V. floribundum* being the most common, typically cultivated between 3400 and 3800 meters above sea level, especially in high-altitude communities of Bolívar Province[1]. In Colombia, the fruit—also known as agraz—is consumed fresh or transformed into artisanal liqueurs, marmalades, and desserts. It is recognized for its high content of polyphenolic compounds with demonstrated health-promoting properties.

Agrobiodiversity plays a critical role in food security, public health, social equity, nutrition, and environmental sustainability. In Peru, this biodiversity underpins the richness of its globally recognized cuisine, driven by a diversity of native plant species, wildlife, and unique microclimates that support the development of distinct ecosystems. Within this context, *V. floribundum* has notable potential as an alternative to commercial blueberries, particularly during off-seasons. In Peru's mountainous forests, this species is represented by 22 spontaneous genera and one cultivated genus (*Rhododendron*), comprising 132 species—57 of which are native and include both herbaceous and woody plants. Recent advances in micropropagation techniques for *Vaccinium* species highlight their potential for broader agricultural and nutritional applications[2].

Scientific interest in South American berries has grown due to their association with health benefits. Epidemiological studies support the role of diets rich in fruits and vegetables in reducing the risk of chronic conditions such as diabetes, cardiovascular disease, neurodegenerative disorders, and certain cancers. These benefits are largely attributed to the presence of bioactive compounds such as flavonoids, anthocyanins, and vitamin C. Berries, especially red and Andean varieties, are rich in these nutrients[3]. Comparative analyses of the polyphenolic profiles of *V. floribundum* and *V. myrtillus* have shown that *V. floribundum* contains higher levels of phenolic acids and flavonols (41.6 ± 10.2 mg/100 g FW and 13.7 ± 0.2 mg/100 g FW, respectively), while *V. myrtillus* exhibits a higher anthocyanin content (568.8 ± 8.8 mg/100 g FW vs. 376.2 ± 49.9 mg/100 g FW)[4]. Furthermore, *V. floribundum* is rich in quercetin, anthocyanins, and hydroxycinnamic acids, compounds that contribute to its antioxidant, antimicrobial, and anti-inflammatory properties[5].

Given the rise in chronic degenerative diseases—including cancer, osteoporosis, cardiovascular disease, and diabetes—there is a growing demand for functional foods that provide health benefits beyond basic nutrition. However, V. floribundum is a climacteric and highly perishable fruit, which limits its commercial viability. Dehydration has been proposed as a preservation method to retain its antioxidant properties and nutritional value. The culinary versatility of *V. floribundum* makes it suitable for use in modern gastronomy. In this study, three jam formulations were developed using advanced culinary techniques: sous-vide cooking and gelification. Sous-vide is a vacuum-sealed cooking method performed at controlled temperatures below 100 °C, which minimizes nutrient loss and preserves sensory qualities. The optimal cooking temperature for fruits typically ranges between 65–85 °C. Gelification, on the other hand, involves the transformation of a liquid into a gel, which has both liquid and solid characteristics. Initially used in confectionery, gelification is now applied broadly in modern cuisine. Various gelling agents are available, including gelatin, agar-agar, gellan gum, xanthan gum, guar gum, and pectin.

In this research, three gelling agents—xanthan gum, agar-agar, and pectin—were individually tested in the formulation of jams made from *Vaccinium floribundum*. The objective was to evaluate these formulations as part of a novel culinary preparation using sous-vide cooking and gelification techniques. Sensory evaluation was performed by a panel of expert judges to assess the organoleptic properties of the three jam samples, with the goal of exploring their potential as functional food products.

Vaccinium floribundum

Notably, *V. floribundum* is characterized by high levels of polyphenols and anthocyanins, which contribute to its strong antioxidant activity. One study assessed the effects of drying techniques (convection drying and lyophilization) and ripeness (50% and 100%) on antioxidant properties, finding that lyophilized fruits at full ripeness had the highest contents of polyphenols (4733.50 mg gallic acid/100 g DW) and anthocyanins (778.70 mg cyanidin-3-glucoside chloride/100 g DW), while antioxidant activity was comparable between drying methods at full ripeness (87.28–88.62 mmol TE/kg DW)[6]. These results are further supported by studies showing that blueberries, including wild species, possess anti-inflammatory, cardioprotective, anticancer, neuroprotective, and anti-obesity effects due to their high anthocyanin content[7].

The antioxidant activity of wild berries often exceeds that of cultivated varieties. Koca and Karadeniz[8] observed a strong correlation between antioxidant capacity and phenolic content in wild blueberries and blackberries. However, other studies such as that by Lohachoompol et al.[9] did not find significant differences in antioxidant potential between fresh, dried, or frozen berries, suggesting that processing may not drastically affect bioactivity under certain conditions. The bioactive potential of *V. floribundum* extends beyond antioxidant properties. It has shown anti-adipogenic and anti-inflammatory effects in vitro, attributed to its anthocyanins and proanthocyanidins. Phenolic extracts from *V. floribundum* have been found to inhibit lipid accumulation in 3T3-L1 adipocytes and reduce pro-inflammatory markers such as nitric oxide and prostaglandin E2 in RAW 264.7 macrophages, indicating its relevance in modulating metabolic and inflammatory pathways[10].

A recent study further evaluated the antioxidant and immunomodulatory effects of *V. floribundum* (Pushgay) berries fermented with *Lactiplantibacillus plantarum*. Fermentation was found to increase the content of quercetin aglycone and enhance intracellular antioxidant capacity in human umbilical vein endothelial cells (HUVECs), as well as modulate immune responses in RAW 264.7 macrophages. These results suggest that bioprocessing strategies may enhance the health-promoting properties of Pushgay berries[11]. Other research has highlighted the functional versatility of polyphenol-rich berries in food products. For example, tea infusions prepared with dried V. floribundum showed retained antioxidant capacity[6], while similar results were observed in jaboticaba peel infusions, which preserved high radical-scavenging activity. Tea and similar infusions are well-recognized vehicles for delivering dietary polyphenols and antioxidants.

Overall, although the body of literature on *Vaccinium floribundum* remains relatively limited compared to other berries, the available evidence strongly supports its classification as a functional food. Its rich phenolic profile, antioxidant and anti-inflammatory effects, and adaptability to processing and fermentation make it a promising ingredient for the development of health-promoting food products.Despite its promising nutritional and functional potential, *Vaccinium floribundum* remains relatively under-researched. However, a number of key studies have provided valuable insights into its bioactive properties over the past decade, as shown in Figure 1. Between 2010 and 2012, initial investigations focused on characterizing its anthocyanin and proanthocyanidin content, revealing antioxidant activity and potential inhibitory effects on adipogenesis and inflammation, along with possible benefits for glycemic regulation. By 2012, further studies had elucidated its inhibitory effects on enzymes related to diabetes[10].

From 2018 to 2020, research efforts advanced to include compositional profiling and **in vivo** assays, which demonstrated cytoprotective effects against oxidative damage, a high polyphenol content, and partial bioaccessibility of phenolic compounds following digestion[10]. Between 2022 and 2024, the focus of investigation shifted toward food processing and sensory evaluation. These studies highlighted how environmental factors such as altitude and fruit maturity significantly influence the phytochemical composition and associated bioactivity of *V. floribundum*. Sensory analyses—particularly hedonic evaluations—further indicated that ripeness and drying processes impact both antioxidant properties and consumer acceptance. Notably, bioprocessing techniques were shown to enhance the functional effects of the fruit. (Characterization of Andean Blueberry in Bioactive Compounds, Evaluation of Biological Properties and *in vitro* Bioaccessibility)[6,11]. By 2024, comprehensive assessments of anthocyanin bioactivity had been conducted, including comparative studies with *Rubus glaucus*.

These investigations also underscored the importance of microencapsulation technologies for improving anthocyanin stability and bioactivity, effectively linking advances in food processing with the development of functional ingredients[3].

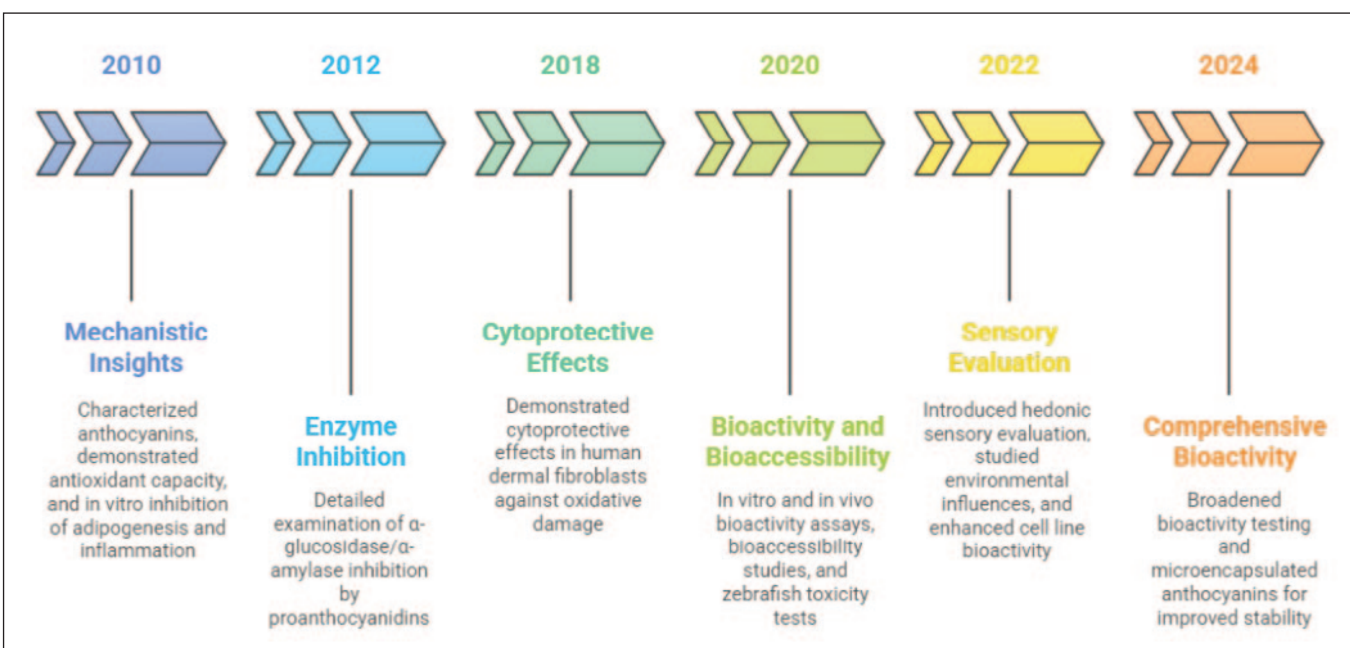

Figure 1. Key Milestones in *Vaccinium floribundum*, Pushgay Research (2010–2024)

MATERIALS AND METHODS

In the present study, we formulated three samples of 70% sugar-reduce Pushgay Jam: FP1 (with xanthan gum), FP2 (with agar agar), and FP3 (with pectin). The Jam was prepared using different types of thickeners.

Formulation of Pushgay FP1

Pushgay FP1 was prepared by vacuum-packing Pushgay pulp with sucrose. The mixture was cooked sous vide at 70 °C for 25 minutes. After cooking, it was cooled to room temperature, mixed thoroughly, and strained through a fine mesh sieve. Xanthan gum was then added, and the mixture was blended until fully homogenized.

Formulation of Pushgay FP2

Pushgay FP2 was prepared by vacuum-packing Pushgay pulp with sucrose. The mixture was cooked sous vide at 75 °C for 25 minutes. After cooking, it was mixed and strained through a fine mesh sieve. The resulting smoothie was transferred to a pot and heated to 80 °C. Hydrated agar-agar was added and the mixture was cooked for 5 minutes. Finally, the temperature was increased to 90 °C and maintained for an additional 5 minutes.

Formulation of Pushgay FP3

Pushgay FP3 was prepared by vacuum-packing Pushgay pulp with 75% of the total sucrose. The mixture was cooked sous vide at 80 °C for 25 minutes. After cooking, it was mixed and strained through a fine mesh sieve. The mixture was then transferred to a pot and heated to 80 °C. Pectin, previously blended with the remaining 25% of sucrose, was added. The mixture was then heated to 104 °C to complete the preparation.

Preparation Considerations for sugar-reduce Pushgay Formulas FP1, FP2, FP3

For Pushgay FP1, it is important to allow the smoothie base to cool before incorporating xanthan gum. Failure to do so may prevent the activation of its gelling properties. After addition, the xanthan gum must be thoroughly mixed to ensure

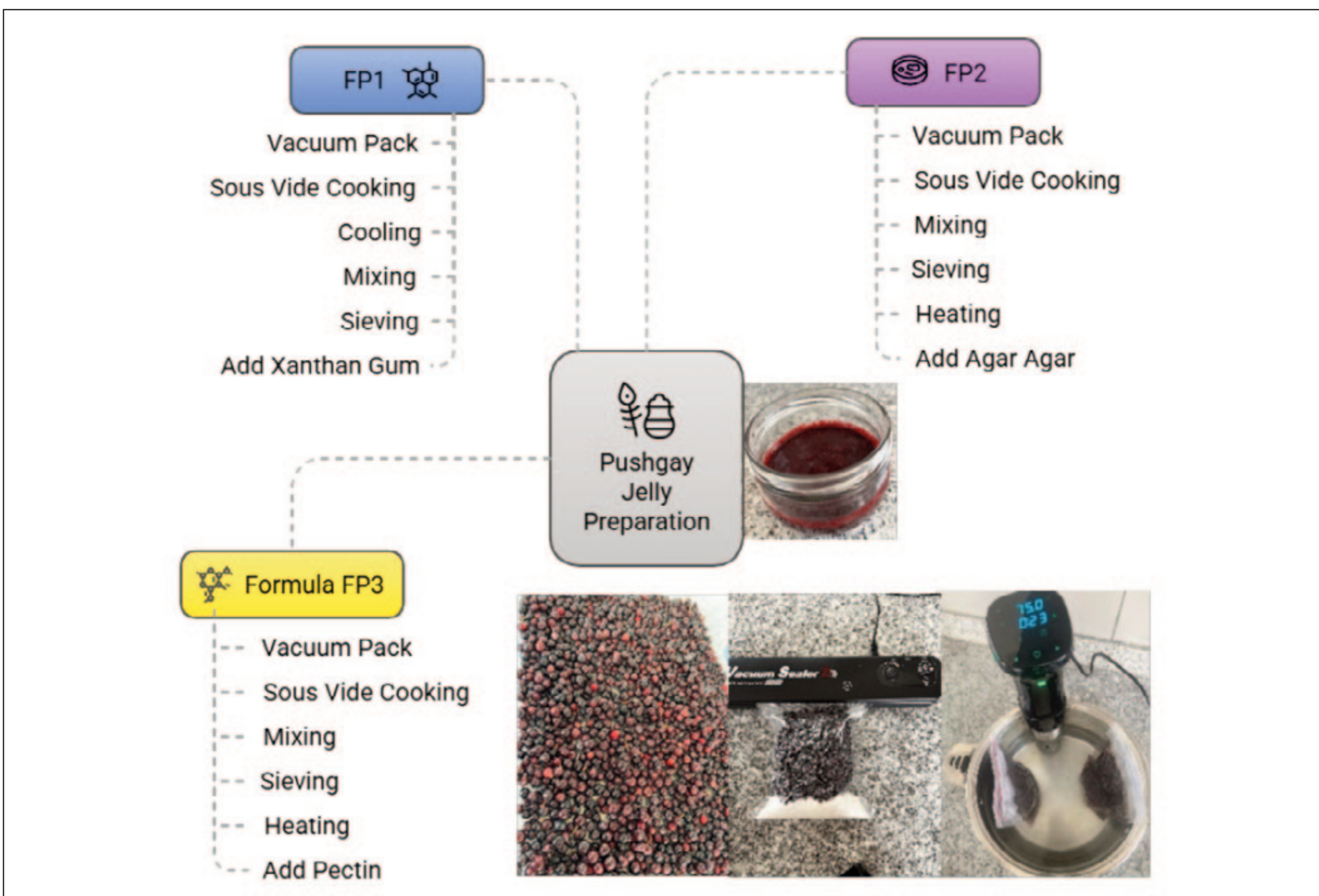

Figure 2. Processing steps of Pushgay Formulations

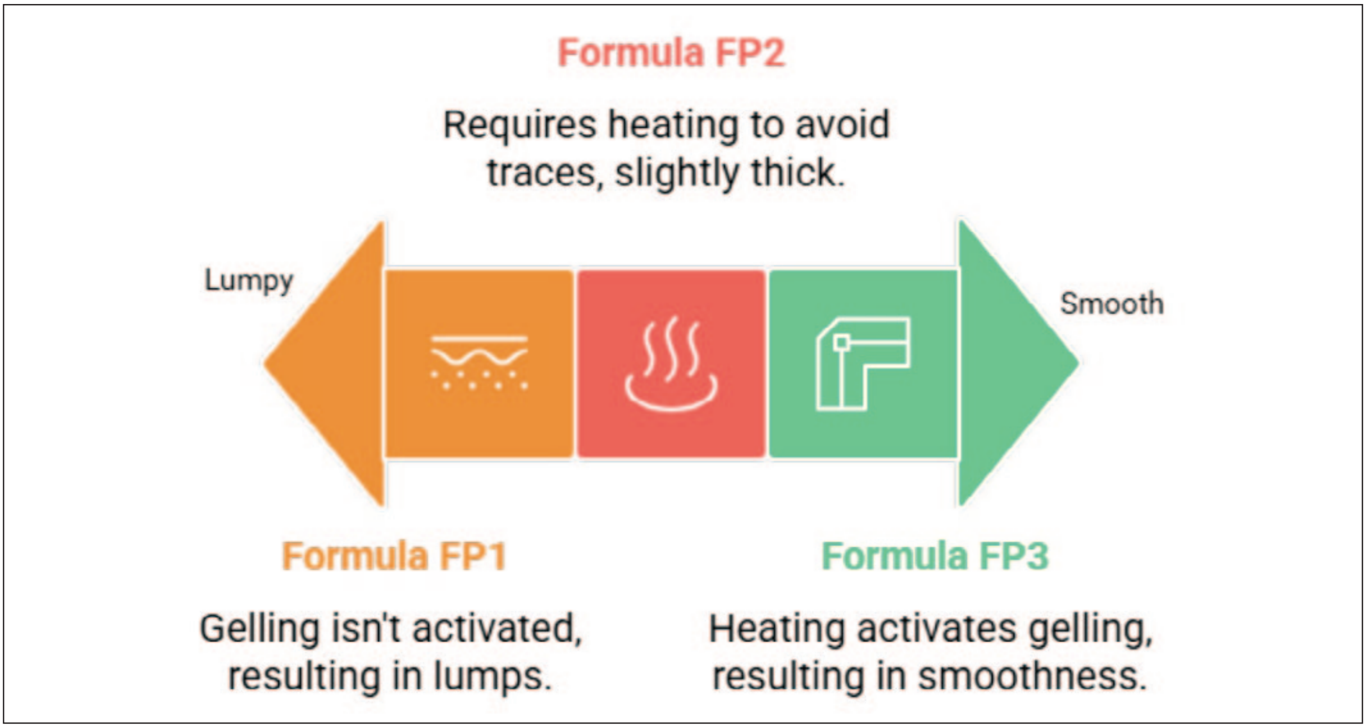

Figure 3. Comparing sugar-reduced Pushgay Jam formulas based on smoothness and texture

uniform dispersion throughout the mixture. Although the resulting texture is generally acceptable, the final product may exhibit slight lumpiness.

For Pushgay FP2, proper hydration of agar-agar is essential. Once incorporated into the smoothie base, the mixture should be heated to 90 °C for 5 minutes to ensure complete dissolution. Omitting this step may result in undissolved agar-agar residues within the final sugar-reduced Pushgay jam. This formulation yields a pleasant texture, though it tends to be somewhat thick.

For Pushgay FP3, pectin must be pre-mixed with sugar to ensure complete dissolution. If added separately, the pectin may not fully integrate into the jam matrix. The mixture should be heated to 104 °C, as pectin's gelling functionality is activated at this temperature. This formula produces a desirable texture—smooth and free from lumpiness or excessive thickness.

Table 1. Ingredients of each Sugar-reduced Pushgay Jam

Ingredients	Formulation (FP1) Xanthan Gum	%	Formulation (FP2) Agar agar	%	Formulation (FP3) Pectin	%
Pushgay	500	76.80%	500	76.72%	500	62.11%
Sugar	150	23.04%	150	23.02%	150	18.63%
Xanthan Gum	1	0.15%	-	-%	-	-%
Agar agar	-	-%	1.7	0.26%	-	-%
Pectin	-	-%	-	-%	5	0.62%
Water	-	-%	-	-%	150	18.63%
Total	651	100%	651.7	100%	805	100%

Flavor, aroma and textura

Sensory evaluation

A sensory evaluation of three 70% sugar-reduced Pushgay Jam samples made with Xanthan Gum(FP1), Agar agar (FP2) and Pectin(FP3) was conducted with a panel of experts. This evaluation utilized both a Likert scale and a star diagram to identify additional sensory characteristics perceived by the expert panel. Furthermore, the sensory evaluation was conducted with an expert panel (n=10) was composed of professional pastry chefs selected for their extensive training and experience in food preparation and tasting. As noted by Frøst et al., 2023, culinary professionals work intensively with their senses and possess a highly educated palate, making them well-suited for sensory evaluation tasks. Their expertise enables them to detect aromas more readily and articulate sensory impressions with greater precision, thereby contributing to more reliable and nuanced assessments. This background supports their effective participation in structured sensory methodologies and enhances the validity of the evaluation process[12–14]. The sensory evaluation utilized a nine-point scale: "Dislike Extremely", "Dislike Very Much", "Dislike Moderately", "Dislike Slightly", "Neutral", "Like Slightly", "Like Moderately", "Like Very Much" and "Like Extremely".

STATISTICAL METHODOLOGY

In the analysis of the sensory evaluation data, the Statistical Package for the Social Sciences (SPSS) software was used. To determine the appropriate statistical tests, the Shapiro-Wilk test was conducted, revealing that Flavor and Texture (excluding formulation FP3) followed a normal distribution, while Aroma, Overall Acceptability, and Color (in FP1 and FP3) did not meet the assumption of normality ($p < 0.05$). Additionally, Levene's test for equality of variances showed that most attributes had homogeneous variances, except for Texture ($p = 0.016$). Based on these results, a one-way ANOVA was applied to the Flavor attribute, which satisfied both the normality and homogeneity assumptions. For the attributes Color, Aroma, Texture, and Overall Acceptability, the Kruskal-Wallis non-parametric test was employed due to violations of the assumptions of normality or variance homogeneity. Furthermore, Microsoft Excel was used to construct a radar (star) diagram to visually represent the sensory performance of the three reduced-sugar Pushgay Jam samples as evaluated by the expert panel.

RESULTS

It is important to note that only the texture attribute satisfied the assumptions of normality and homogeneity of variances, allowing the use of a one-way ANOVA for its analysis. In contrast, the attributes color, aroma, flavor, and overall acceptability did not meet these assumptions; therefore, the non-parametric Kruskal-Wallis test was applied to evaluate differences among the three jam formulations for these sensory attributes.

The sensory analysis of three reduced-sugar Pushgay jam formulations (FP1, FP2, FP3), evaluated by 10 trained expert judges, revealed that only the color attribute showed a statistically significant difference among the samples ($p = 0.036$), as determined by the Kruskal-Wallis test due to non-normal data distribution. In contrast, attributes such as aroma ($p = 0.326$), taste ($p = 0.723$), texture ($p = 0.357$, based on ANOVA), and overall acceptance ($p = 0.249$) did not exhibit significant differences, indicating a perceived similarity across the formulations for these characteristics.

The Kruskal-Wallis test revealed a statistically significant difference in the color attribute among the formulations (Chi-Square = 6.656, $p = 0.036$). To identify which formulations differed, post-hoc Mann-Whitney U tests were performed (Table 3). For the color attribute, a non-parametric Kruskal-Wallis test revealed a statistically significant difference among formulations ($\chi^2(2) = 6.656$, $p = 0.036$). Post-hoc Mann-Whitney U tests indicated that FP1 was perceived with a significantly different color compared to both FP2 and FP3. Specifically, a significant difference was found between FP1 and FP2 ($U = 20.000$, $Z = -2.373$, $p = 0.018$), with FP1 having a higher mean rank (13.50 vs. 7.50). Similarly, FP1 significantly differed from FP3 ($U = 20.000$, $Z = -2.373$, $p = 0.018$), with FP1's mean rank (12.80) again being higher than FP3's (8.20). Conversely, no statistically significant difference in color was observed between FP2 and FP3 ($U = 39.000$, $Z = -0.873$, $p = 0.383$). These results collectively demonstrate that formulation FP1 was perceived with a significantly distinct color (consistently higher mean ranks) from FP2 and FP3, while FP2 and FP3 were not significantly different from each other in this attribute.

The star diagram illustrates the specific flavor characteristics evaluated by the expert panel. The sensory analysis of the three sugar-reduced Pushgay jam formulations (FP1, FP2, FP3) focused on key attributes such as color, aroma, taste, texture, and overall acceptance are complemented by a star diagram that visualizes the sensory profiles of each formulation (Figure 4).

The sensory evaluation of the three formulations (FP1, FP2, and FP3) focused on five key attributes: color, aroma, taste, texture, and overall acceptance. The Kruskal-Wallis test indicated a statistically significant difference in the color attribute among the formulations (Chi-Square = 6.656, $p = 0.036$). Post-hoc comparisons using the Mann-Whitney U test showed that FP1 was perceived as having a significantly different color compared to both FP2 and FP3, with higher mean ranks (13.50 vs. 7.50 for FP2, and 12.80 vs. 8.20 for FP3), and both comparisons yielding $p = 0.018$. No significant difference was found between FP2 and FP3 ($p = 0.383$). The star diagram for the "Intense Color" attribute supports these results, showing FP1 with the highest

Table 2. Descriptive statistics of Sugar-reduced Pushgay Jam formulations

		N	Mean	Standard Deviation	Standard Error	Confidence Interval for Mean at 95%		Min	Max	Test	Sig.
						Lower Limit	Upper Limit				
Color	FP1	10	8,20	,632	,200	7,75	8,65	7	9	Kruskal -Wallis	.036
	FP2	10	7,10	1,197	,379	6,24	7,96	5	9		
	FP3	10	7,50	1,080	,342	6,73	8,27	5	9		
	Total	30	7,60	1,070	,195	7,20	8,00	5	9		
Aroma	FP1	10	6,70	1,567	,496	5,58	7,82	4	9	Kruskal -Wallis	.326
	FP2	10	7,10	1,197	,379	6,24	7,96	4	8		
	FP3	10	7,50	,707	,224	6,99	8,01	7	9		
	Total	30	7,10	1,213	,222	6,65	7,55	4	9		
Taste	FP1	10	7,50	1,509	,477	6,42	8,58	4	9	Kruskal -Wallis	.723
	FP2	10	7,30	1,160	,367	6,47	8,13	5	9		
	FP3	10	7,70	1,059	,335	6,94	8,46	6	9		
	Total	30	7,50	1,225	,224	7,04	7,96	4	9		
Texture	FP1	10	6,00	2,357	,745	4,31	7,69	1	9	ANOVA	.357
	FP2	10	6,60	1,350	,427	5,63	7,57	4	8		
	FP3	10	7,30	,949	,300	6,62	7,98	5	8		
	Total	30	6,63	1,691	,309	6,00	7,26	1	9		
Overall acceptance	FP1	10	7,40	1,647	,521	6,22	8,58	3	9	Kruskal -Wallis	.249
	FP2	10	7,30	,675	,213	6,82	7,78	6	8		
	FP3	10	7,70	,483	,153	7,35	8,05	7	8		
	Total	30	7,47	1,042	,190	7,08	7,86	3	9		

Table 3. Mann-Whitney Test statistics of Sugar-reduced Pushgay Jam formulations on color sub-analysis

FP1 - FP2		FP2 – FP3		FP1 – FP3	
	Color		Color		Color
Mann-Whitney U	20,000	Mann-Whitney U	27,000	Mann-Whitney U	39,000
Wilcoxon W	75,000	Wilcoxon W	82,000	Wilcoxon W	94,000
Z	-2,373	Z	-1,882	Z	-,873
Asymp. Sig. (2-tailed)	,018	Asymp. Sig. (2-tailed)	,060	Asymp. Sig. (2-tailed)	,383
Exact Sig. [2*(1-tailed Sig.)]	,023[b]	Exact Sig. [2*(1-tailed Sig.)]	,089[b]	Exact Sig. [2*(1-tailed Sig.)]	,436[b]

a. Grouping Variable: Formulation. b. Not corrected for ties.

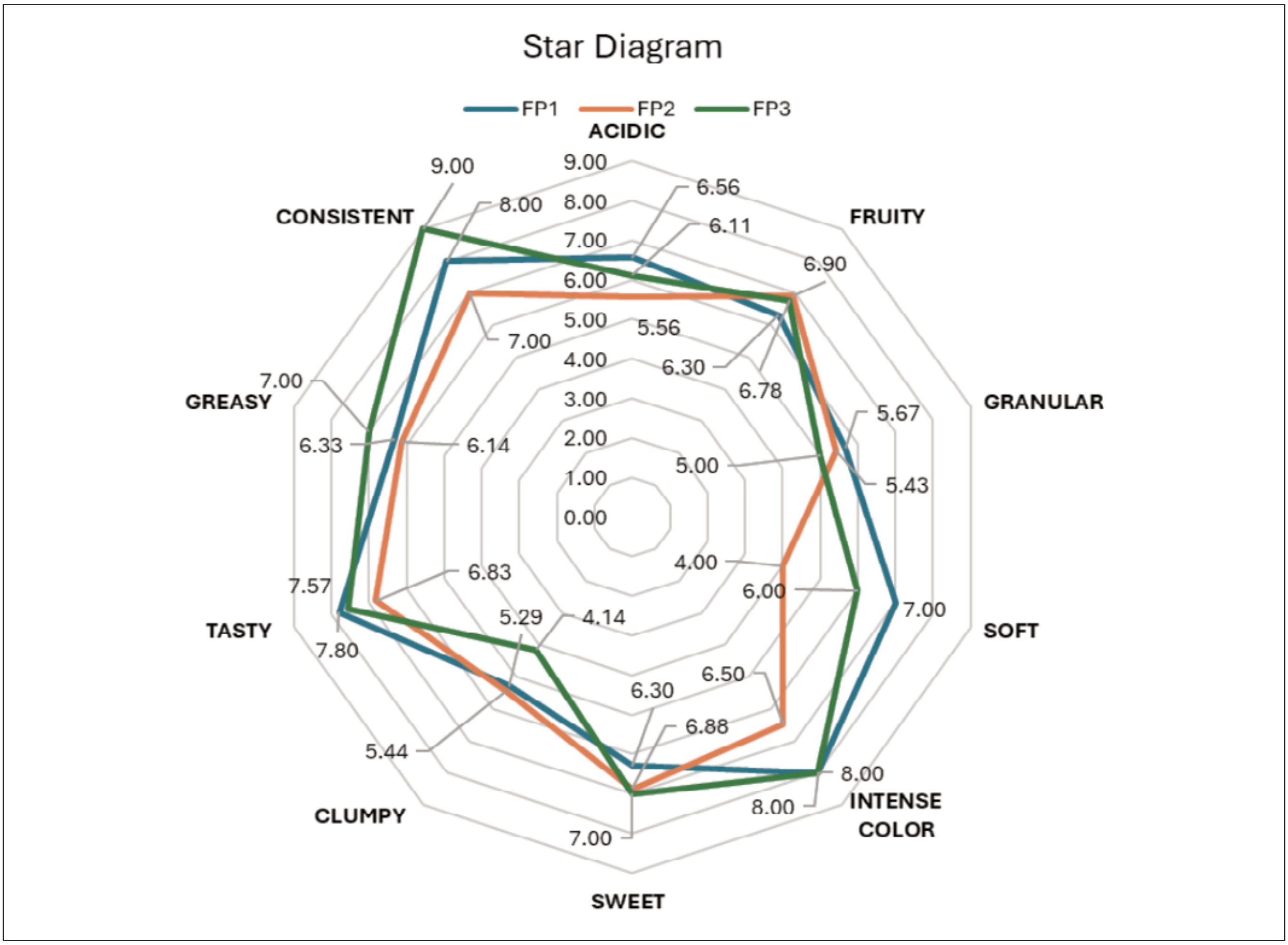

Figure 4. Star Diagram. Formulation (FP1)-(with Xanthan Gum). Formulation (FP2) (with Agar agar) and Formulation (FP3) (with Pectin)

score (8.00), followed by FP3 (7.00) and FP2 (6.00). In contrast, no statistically significant differences were found in the aroma attribute (Kruskal-Wallis, $p = 0.326$), and the "Fruity" aroma values were fairly close: FP1 (6.90), FP2 (6.11), and FP3 (6.56). Similarly, no significant differences were observed in the taste attribute (Kruskal-Wallis, $p = 0.723$), which is reflected in the similar "Tasty" scores across formulations: FP1 and FP3 (7.57) and FP2 (7.80). Sub-attributes related to taste, such as "Acidic" (FP1: 6.00; FP2: 5.56; FP3: 6.30) and "Sweet" (FP1: 6.88; FP2: 6.50; FP3: 7.00), also displayed similar patterns. For texture, although the data met the normality assumption, ANOVA revealed no significant differences among the formulations ($p = 0.357$). The star diagram highlights some variability: FP1 was less "Consistent" (6.00) and more "Clumpy" (7.00) than FP3, and more "Greasy" (7.00) than FP2; however, these differences were not sufficient to yield statistical significance. Regarding overall acceptance, no significant differences were found (Kruskal-Wallis, $p = 0.249$), which aligns with the overall similarity across the sensory attributes evaluated. The individual sensory profiles derived from the star diagram further illustrate these trends. FP1 stood out for its high "Intense Color" (8.00), moderate taste perception ("Tasty" 7.57, "Acidic" 6.00, "Sweet" 6.88), and distinct texture profile (lower "Consistent" and higher "Clumpy" and "Greasy" values). FP2 showed the lowest "Intense Color" (6.00), appeared less "Greasy" (6.33), and was rated highest in "Tasty" (7.80) and lowest in "Acidic" (5.56). FP3 was the most "Consistent" (9.00) and least "Clumpy" (5.44), with the highest scores for "Acidic" (6.30) and "Sweet" (7.00), and a moderate "Intense Color" (7.00). These results collectively indicate that while color perception significantly differed, the other sensory attributes were largely similar among the three jam formulations.

The panel of expert judges perceived statistically significant differences only in the color attribute, where formulation FP1 stood out due to its higher intensity compared to FP2 and FP3. Despite these color differences and some variations in texture profiles visualized in the star diagram (especially for FP3 in "Consistent" and "Clumpy"), these did not translate into statistically significant differences in overall acceptance or other key attributes such as aroma or taste. This suggests that, despite individual variations in attribute perception, the overall preference for the three jams is comparable. The results provide valuable insights for optimizing the formulations, especially if standardization or differentiation of the product's color is desired.

DISCUSSIONS

Pushgay (Vaccinium floribundum) is a nutrient-dense fruit rich in essential minerals such as iron, calcium, magnesium, and potassium, as well as high concentrations of vitamin C, thiamine, riboflavin, niacin, beta-carotenes, and antioxidants. These components contribute to its potential role in the prevention and management of non-communicable diseases, including obesity and cancer. Specifically, the presence of anthocyanins and ascorbic acid may support free radical neutralization and modulate carcinogenic mechanisms[15]. Arango-Varela et al. (2020) further validated these findings, emphasizing Pushgay's antioxidant capacity and its potential anticancer, anti-inflammatory, antimicrobial, neuroprotective, and cardioprotective effects[16]. Culinary versatility is one of Pushgay's key advantages. It can be consumed fresh or incorporated into various food products such as salads, yogurts, sauces, baked goods, and even gourmet dishes. It is also used in wine production due to its distinct organoleptic properties. Andrade-Cuvi et al. (2017) reported a growing interest in Pushgay, prompting the development of methods for its preservation and long-term storage[17]. Notably, freeze-drying proved to be more effective than convection drying in preserving bioactive compounds such as polyphenols and anthocyanins, which are susceptible to degradation at high temperatures[18]. Pushgay's preservation potential positions it as a competitive berry for global markets, especially during off-seasons when other berries, such as blueberries, are less available. Its ability to retain nutritional and sensory qualities during refrigeration further enhances its marketability[19]. However, environmental and anthropogenic threats such as deforestation, land-use change, and limited awareness about native plant species jeopardize the natural habitat and sustainability of Pushgay. Rodríguez et al. (2018) and Caranqui et al. (2022) both highlighted these challenges, noting that human-driven factors may pose a more immediate threat to native species than climate change[20,21].

This study also introduced a jam formulation based on Pushgay with reduced sugar content, aiming to enhance the fruit's natural flavor while minimizing the adverse health effects associated with excessive sugar intake. Delgado (2017) linked high glucose and fructose consumption with the development of non-communicable diseases[22], while Carvallo et al. (2019) emphasized the role of added sugars in obesity, liver disease, cardiovascular conditions, diabetes, and dental caries[23]. Thus, a lower-sugar Pushgay jam aligns with current public health goals by promoting functional food alternatives. In the sensory evaluation, three 70% sugar-reduced Pushgay jam samples prepared with different gelling agents (pectin, xanthan gum, and agar-agar) were assessed by a panel of expert judges. The "fruity" attribute received consistently high ratings across all samples (6.30, 6.90, and 6.78), indicating its recognizability and appeal[24]. Other sensory attributes evaluated included acidity, texture, sweetness, appearance, and spreadability. Notably, sample C (prepared with pectin) received the highest scores across multiple categories, including color (8.00), appearance (7.27), flavor (6.44), and texture (6.73), suggesting that pectin may enhance sensory quality more effectively than the other agents[25].

Color plays a crucial role in sensory perception, often influencing consumer preference. Studies on plum peel jam and blueberry jam demonstrated the effectiveness of pectin in enhancing color intensity[26,27]. Similarly, in the present study, pectin-based jam (sample C) received one of the highest color ratings (8.00), comparable to xanthan gum-based jam (sample A) and superior to the agar-agar variant (sample B), which scored 6.50. Sweetener type also influences color attributes. Erythritol has been shown to yield brighter, redder shades in jam, while sucrose may result in darker tones[24]. In this study, all three samples were sweetened with sucrose, yet favorable color ratings were achieved across the board, with an average of 7.5, suggesting the natural pigmentation of Pushgay compensates for any color loss attributable to the sweetener. Spreadability, another important quality in jams, is closely linked to gel consistency, which in turn depends on pectin, sugar, and acid content. As shown in a study on mixed açaí and cocoa honey jellies, the right balance of these ingredients contributes to ideal gel[28]. In line with this, the present study found that sample C (pectin-based) scored highest in spreadability (7.00), followed by samples A (6.33) and B (6.14), supporting the role of pectin as a superior gelling agent in jam formulations. Additional support for these findings comes from research on cryoconcentrated blueberry juice in gelatin gels, where minimal changes in color due to the neutrality of sugar solutions did not significantly alter visual properties[29]. This aligns with our observation that the use of sucrose did not negatively impact color perception among the tested jam samples[30].

CONCLUSIONS

This study introduced a reduced-sugar jam formulation using Pushgay (Vaccinium floribundum), aiming to preserve its natural flavor while supporting healthier dietary choices. Given the known health risks associated with excessive sugar consumption—such as obesity, diabetes, and cardiovascular diseases—this formulation aligns with current public health recommendations. The jam not only highlights

Pushgay's bioactive and nutritional potential but also promotes its value as a functional food ingredient. This study revealed that only the color attribute exhibited a statistically significant difference ($p< 0.036$) as perceived by a trained expert panel. Specifically, formulation FP1 consistently displayed a significantly more intense color compared to both FP2 and FP3, while no significant color difference was observed between FP2 and FP3. Despite minor variations in the mean scores for aroma, taste, and texture, and their visual representation in the star diagram, these differences were not statistically significant, implying a largely similar perception of these attributes across all formulations. Overall, Pushgay demonstrates strong potential for functional food development, combining health benefits, sensory appeal, and versatility. Its ecological adaptability and availability during off-seasons further enhance its value as a sustainable, commercially viable alternative to other berries.

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