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Powering Goat Milk with Nature: Functional Foods Enriched with Purslane (Portulaca oleracea) and Probiotics

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A B S T R A C T

Portulaca oleracea (purslane) is rich in bioactive compounds, including flavonoids, polyphenols, and ascorbic acid, making it a promising functional food ingredient. This study evaluated the effect of purslane flour (PF) on the chemical and microbiological characteristics of probiotic ice cream containing *Lactobacillus plantarum*. A Completely Randomized Design (CRD) with four treatments was used: P0 (0% PF; 0% *L. plantarum*), P1 (2% PF; 2% *L. plantarum*), P2 (4% PF; 3% *L. plantarum*), and P3 (6% PF; 4% *L. plantarum*), with five replications each. Parameters analyzed included moisture, fat, fibre, protein, antioxidant activity, pH, and *L. plantarum* population. Data were subjected to one-way ANOVA followed by Duncan's Multiple Range Test at a 5% significance level. Purslane flour significantly affected fat, fibre, protein, antioxidant activity, and *L. plantarum* population ($p < 0.05$), but had no significant effect on moisture content or pH. Increasing PF levels raised fibre content (2.21–3.53%), antioxidant activity (32.86–42.10 ppm), and *L. plantarum* population (0–5.26 log CFU/g), while reducing fat content (3.45–2.41%). These results indicate that purslane flour enhances the functional properties of probiotic ice cream and may exert a prebiotic effect by supporting probiotic growth. The addition of purslane flour improved the chemical and microbiological quality of probiotic ice cream, highlighting its potential as a natural functional food with antioxidant and probiotic benefits.

Contribution to Sustainable Development Goals (SDGs):

SDG 2: Zero Hunger
SDG 3: Good Health and Well-Being
SDG 12: Responsible Consumption and Production.

1. INTRODUCTION

1.1. Research Background

Functional foods are processed food products that contain one or more components with specific physiological functions beyond their basic functions. These components are based on scientific research and proven to be safe and beneficial to health **[1]**. As the relationship between diet and health becomes increasingly well understood, functional foods are gaining attention as a means of supporting disease prevention and improving quality of life. In the contemporary era, the prevalence of functional foods containing probiotics is increasing. Probiotics are live microorganisms that, when ingested in sufficient quantities, can confer health benefits to the body.

It is evident that goat milk, when used as a food ingredient, provides several health benefits. These include nutrients that are more readily digested by the body, a low allergenicity profile, and it being a preferred choice for infants allergic to cow's milk. In addition, there is growing evidence that it can improve digestive health. Goat milk is a nutrient-dense beverage that provides high-

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quality protein, healthy fats, vitamins, and essential minerals. Consequently, goat milk can serve as an excellent base for the development of functional food products **[2].**

Although goat milk offers many benefits, its nutritional profile can be further enhanced by adding bioactive compounds from plants and microorganisms. Purslane *(Portulaca oleracea*) is a plant with potential as a source of bioactive compounds. It has been found to contain various active compounds, including flavonoids, vitamins and omega-3 fatty acids. These have been shown to be beneficial for health, including as antioxidants, anti-inflammatories and for supporting cardiovascular function **[3].**

Antioxidants represent a pivotal component of functional foods, exerting a substantial influence on human health. The function of antioxidants is not confined to preserving food quality; they are also intimately associated with protecting the body from damage caused by free radicals. The role of antioxidants in functional foods for human health encompasses several domains, including the prevention of inflammation and chronic inflammation, as well as protection against free radicals **[4, 5, 6]**. Furthermore, the role of antioxidants in protecting against degenerative diseases has been well-documented in the scientific literature **[7, 8].** It has been established that certain types of lactic acid bacteria (LAB), including *Lactobacillus plantarum*, possess probiotic properties that contribute to maintaining gut microbiota balance, enhancing the immune system, and facilitating digestion **[9, 10]**.

The development of functional food products combining goat milk with purslane flour and *Lactobacillus plantarum* has the potential to create products that are not only nutritious but also provide broader health benefits, supporting digestive and other bodily functions. This innovation has the potential to provide a healthy food alternative that is likely to be positively received by the public, while also supporting a more nutritious diet based on natural ingredients.

As awareness of the importance of a healthy and nutritious diet grows, along with the high demand for probiotics, research into the development of functional foods based on goat's milk enriched with purslane flour and Lactobacillus plantarum as a probiotic agent has become highly relevant and strategic. The objective of this study is to develop functional food products that provide nutritional benefits and optimally support digestive health and the immune system. Consequently, this research endeavour possesses considerable potential to contribute to the development of functional foods in Indonesia and to facilitate the creation of innovative products by the food industry that meet the needs of a health-conscious market.

A previous study [11] found that the phenolic compounds in yoghurt made with added watermelon juice did not exhibit any specific bactericidal activity in the starter culture used. This was clearly evident on the first day of storage in the refrigerator (4°C), where the number of lactic acid bacteria remained at 10^8 log CFU/g and only decreased to 10^7 log CFU/g by the end of the storage period in the refrigerator (4°C). The antioxidant activity of yoghurt fortified with watermelon juice was observed on the seventh day of refrigerated storage. Furthermore, **[12]** stated that the viability of L. plantarum in ice cream is influenced by the pH value during the ripening process, as is the resulting antioxidant activity. It is evident that further research is required to develop functional foods derived from goat milk (e.g. ice cream) that are enriched with purslane flour (PF), which is a source of bioactive compounds, including antioxidants and anti-inflammatory agents. These bioactive compounds have the potential to promote overall health, along with the probiotic bacterium Lactobacillus plantarum **[3].** It is hypothesised that this functional food will confer superior health benefits, including improved digestive function, strengthened immune function, and antioxidant and anti-inflammatory properties. Furthermore, Lactobacillus plantarum has been shown to possess probiotic properties, with the capacity to balance the gut microbiota, improve digestive function, and enhance immune function. The necessity for this research is evident from public health, food industry, and scientific research perspectives, through the development of goat milk-based functional foods enriched with PF and probiotic bacteria.

1.2. Literature Review

Research on goat milk-based functional foods has accelerated, particularly in the development of products that combine bioactive components and probiotic microorganisms.

1.2.1. Antioxidants

Purslane (*Portulaca oleracea*), a succulent herb, is commonly found in various regions, although it is often considered a weed. Nevertheless, in numerous cultures worldwide, this plant is highly regarded for its exceptional nutritional content and traditional medicinal benefits. Purslane leaves have been found to contain omega-3 fatty acids, potent antioxidants such as flavonoids and carotenoids, as well as vitamins (A, C, E) and essential minerals (magnesium, calcium, potassium) **[13]**. The utilization of this plant has a long historical precedent, spanning many generations. It has been employed both as a food source and an herbal remedy for a variety of health issues. Purslane has recently been identified as the richest vegetable source of alpha-linolenic acid, an essential omega-3 fatty acid **[14].** The scarcity of food sources rich in omega-3 fatty acids has sparked growing interest in cultivating purslane as a new vegetable **[15, 16]**. Purslane is known to thrive across a wide range of biogeographic regions worldwide and is highly adaptable to adverse conditions, including drought, salinity, and nutrient-deficient environments **[17].**

A plethora of purslane varieties, bearing various names, are found across a wide range of climates and regions. Purslane is a culinary herb widely recognised in Central Europe, Asia, and the Mediterranean region. This plant is a significant component of green salads, with its tender stems and leaves consumed raw, either as a standalone dish or in combination with other green vegetables **[14]**. Purslane is also used in culinary contexts, including pickling. Its medicinal properties are evidenced by its use in treating burns, headaches, intestinal, liver, and stomach conditions, coughs, shortness of breath, and arthritis. Its use as a laxative, cardiac tonic, emollient, muscle relaxant, anti-inflammatory, and diuretic makes it significant in the domain of herbal medicine. Purslane has also been used in the treatment of osteoporosis and psoriasis.

Phenolic compounds are found in various plant tissues, including fruits, seeds, leaves, and stems. There are over 8,000 phenolic compounds, which are then divided into two groups: flavonoids and non-flavonoids. Furthermore, the total flavonoid content in purslane plants varies significantly across organs, with the highest concentrations in leaves. A study **[18]** utilizing purslane from Egypt yielded a lower total flavonoid content in the ethanol flour, at 34.66 ± 4.00 mg QE/g. This finding indicates that

a plant's total flavonoid content can be influenced by its geographical origin. The total phenolic compound (TPC) content in *P. oleracea* varieties ranged from 127 ± 13 to 478 ± 45 mg. The DPPH radical scavenging capacity (IC50) ranged from 1.30 ± 0.04 to 1.71 ± 0.04 mg/mL. In contrast, the ascorbic acid equivalent antioxidant activity (AEAC) ranged from 229.5 ± 7.9 to 319.3 ± 8.7 mg AA/100 g, and the total phenolic content (TPC) varied from 174.5 ± 8.5 to 348.5 ± 7.9 mg **[19].**

1.2.2. Lactic Acid Bacteria (LAB)

Lactic acid bacteria (LAB) are a group of Gram-positive, non-spore-forming microorganisms that are facultative anaerobes and lack catalase activity. These microorganisms are widely recognised in the food industry for their ability to ferment sugars, particularly lactose, into lactic acid. The lactic acid produced as a by-product of this process has been shown to lower pH, thereby affecting milk protein structure and extending the shelf life of fermented products **[20].** Furthermore, LAB activity has been shown to yield bioactive compounds, including exopolysaccharides and other organic acids, which have the potential to improve the flavour and functional value of the final product.

The predominant genera of LAB encompass Lactobacillus, Streptococcus, PFdiococcus, and Leuconostoc. In the domain of yogurt production, the two most commonly utilised species are *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. bulgaricus. The two factors act synergistically: S. thermophilus has been observed to exhibit accelerated growth, producing initial lactic acid and aroma compounds. Concurrently, *Lactobacillus Bulgaricus* has been shown to facilitate fermentation, thereby enhancing the distinctive flavour profile of yoghurt **[21].** The isolation of LAB with strong fermentative properties is a crucial step in developing new starter cultures for both industrial and household applications.

In addition to its role in fermentation, LAB has also been extensively studied as a probiotic candidate due to its ability to survive in the digestive tract. It has been demonstrated that LAB can adhere to the intestinal epithelium, thereby modulating the microbiota and producing antimicrobial compounds that inhibit the growth of pathogenic bacteria. Recent studies have shown that consuming probiotics in fermented dairy products can enhance immune function, improve gastrointestinal health, and reduce cholesterol levels **[22].** Consequently, the development of LAB as a starter culture is significant not only for the fermentation process but also for public health. As demonstrated in earlier studies, probiotic fermented milk has been shown to positively affect gastrointestinal health and enhance the bioactivity of active compounds **[13]**.

A comparable study by **[21]** investigated the viability of LAB isolates under cold storage in fermented milk products. The isolates demonstrated ongoing metabolic activity and maintained stable colony counts up to the seventh day of storage. These findings emphasise the necessity of monitoring the isolates' fermentative activity at the commencement of production, as well as their stability and survival throughout the shelf life **[21]**. This viability is a pivotal indicator in the development of LAB as both a probiotic candidate and a starter culture.

Concurrently, **[23]** examined variations in LAB isolates from several commercial yogurt brands and concluded that each product has distinct isolate characteristics. Consequently, a meticulous selection and characterisation process is imperative to identify superior isolates. This study provides further support for the hypothesis that exploring isolates from commercial yoghurts has strategic value for developing local starter cultures that are both effective and competitive in terms of technology and cost **[24].**

1.3. Research Objective

This study aims to develop and optimise a probiotic goat milk product formulation combining purslane flour and Lactobacillus plantarum to sustainably enhance the bioavailability and stability of bioactive compounds, and the nutritional value.

2. MATERIALS AND METHODS

2.1. Research Materials

The following materials are to be used for research purposes. The materials utilized in this study encompassed fresh milk from Etawa crossbreed goat (ECG), Purslane *(Portulaca oleracea*), in conjunction with *Lactobacillus plantarum*, skim milk, physiological saline, Gram stain, CMC, MRS agar medium, plastic wrap, N-(1-naphthyl) ethylenediamine dihydroxide (NED), KI in acetic acid, chloroform, sulfanyl acid, iron sulfate in concentrated sulfuric acid, petroleum benzene, concentrated H_2SO_4, K_2SO_4, 0.1N H_2SO_4, distilled water, 3% H_3BO_3, 40% NaOH, $CuSO_4$, boiling stones, BCG indicator, MM, and sterilized distilled water.

2.2. Research Methods

2.2.1. Experimental Design.

The experimental design is outlined as follows. The study was conducted using a completely randomised design (CRD) with four treatments (P0 = 0% PF; P1 = 2% PF; P2 = 4% PF; and P3 = 6% PF), each replicated 5 times. The data were analysed using SAS software using analysis of variance at the 5% significance level, followed by the Least Significant Difference (LSD) test.

2.2.2. Research Implementation.

The research implementation included producing purslane flour, activating the starter culture (L. plantarum), and conducting preliminary research to optimise the ice cream formula. The subsequent phase of the research program involved fabricating ice cream using the formula outlined in Table 1. This was accompanied by the observation and analysis of several parameters, including: (a) the physical characteristics of the ice cream; (b) the viability of *L. plantarum*; (c) the antioxidant content; and (d) the nutritional content (proximate analysis) **[13, 14, 15].**

*2.2.3. **Research Variables.** *

The Chemical and physical characteristics, total antioxidant, and hedonic scale were observed.

pH Analysis.

The pH meter (model 211; manufactured by HANNA, USA) was calibrated using standard solutions of pH 4.0 and 7.0. The pH of the sample was determined by immersing the pH electrode in the sample, which was placed in a 10 mL measuring cylinder, in accordance with the method described in **[25].** The value was read directly from the display. Before examining each subsequent

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sample, the pH meter was thoroughly rinsed with filtered water to ensure optimal performance. Each sample was replicated three times.

Table 1. Ice Cream Ingredients and Composition in different levels of PF and *L. plantarum*

Ingredient	Amount
Goat's milk (ml)	500
Whipping cream (g)	155
Powdered sugar (g)	75
Emulsifier (Sp) (g)	5
Flavour (Vanilla) (g)	3
Purslane Flour (PF)	0%; 2%; 4%; and 6%
Lactobacillus plantarum	0%; 2%; 3%; and 4%

Total* Antioxidant *Content.

The antioxidant content of the samples was analysed by spectrophotometry using the DPPH (2,2-diphenyl-1-picrylhydrazyl) method **[26]**. A 10 g sample was macerated in 95% ethanol at a ratio of 1:3. The sample was then left to soak for 24 hours in a closed container. The soaking results were then filtered and evaporated using a water bath to obtain a thick extract. 1 mL of the extract, previously diluted with ethanol, was added to 1 mL of DPPH concurrently. The homogeneous mixture was then incubated in the dark for 30 minutes. Absorbance was measured at 517 nm using a UV spectrophotometer. The antioxidant levels were calculated using the following formula:

$$\textbf{Antioxidant}\ (\%) = \frac{Absorbance\ control - Absorbance\ sample}{Absorbance\ control}\ x\ 100$$

The IC50 value is the concentration of an antioxidant compound that inhibits free radicals by 50% **[27]**. The potency of a compound is classified as follows: very strong (IC50 value < 50), strong (50-100), moderate (100-150), and weak (151-200). It has been demonstrated that an elevated IC50 value is indicative of diminished antioxidant activity **[28, 29]**.

3. RESULT AND DISCUSSION

3.1. Physicochemical Properties of Ice Cream

Based on the analysis of variance for various chemical and microbiological parameters of ice cream containing purslane (Portulaca oleracea) flour (Table 2), the treatment showed a significant effect on most parameters, except water content and pH.

Table 2. Chemical composition of probiotic ice cream sample enriched with different levels of PF and *L. plantarum*

PARAMETERS	P0	P1	P2	P3
Water	58.23 ± 0.11	58.26 ± 0.99	57.42 ± 0.70	57.56 ± 0.56
Fat	$(3.32 \pm 0.35)^a$	$(3.45 \pm 0.12)^c$	$(2.95 \pm 0.04)^b$	$(2.41 \pm 0.25)^a$
Fiber	$(2.21 \pm 0.06)^a$	$(2.57 \pm 0.20)^b$	$(3.14 \pm 0.03)^c$	$(3.53 \pm 0.23)^d$
Protein	$(4.32 \pm 0.07)^b$	$(4.75 \pm 0.05)^c$	$(3.19 \pm 0.23)^a$	$(4.23 \pm 0.16)^b$
Antioxidants	$(32.86 \pm 0.15)^a$	$(39.52 \pm 0.12)^b$	$(41.17 \pm 0.23)^c$	$(42.10 \pm 0.49)^d$
Lb. plantarum	$(0.0 \pm 0.0)^a$	$(4.85 \pm 0.22)^b$	$(5.07 \pm 0.14)^b$	$(5.26 \pm 0.09)^c$

Note: PO (0%PF; 0% L.plantarum); P1 (2%PF; 2% L.plantarum); P2 (4%PF; 3% L.plantarum) P3 (6%PF; 4% L.plantarum)

The total solids and water content of the control and optimised ice cream samples were 37.74 ± 0.33% and 62.26 ± 0.33%, respectively, and 33.68 ± 0.38% and 66.32 ± 0.38%, respectively ($P<0.05$). The optimized ice cream had a high water content due to the water content in goat's milk. Normal ice cream generally has a water content of 61.7%. Total solids content is a key factor that directly affects ice cream quality. Excessive total solids content can result in a curd-like texture, while low content can lead to ice crystal formation and a rough texture **[30]**. The fat content of the optimised ice cream was significantly higher ($P<0.05$) than that of the control formulation (Table 2), thereby improving its taste and texture. Goat's milk and Whipping cream provided the fat in the ice cream. Fat improves the taste and aroma of ice cream, retains air in the foam system, forms a soft structure, and increases viscosity. The optimised ice cream had a lower protein content (2.93±0.24 %) than the control ice cream (4.24±0.13%) ($P<0.05$). Plant-based ice cream has a lower protein content than cow's milk, which affects overrun. This suggests that some protein sources should be added to increase the protein content in non-dairy ice cream **[30]**. Total phenols and % DPPH scavenging in the control sample were significantly ($P<0.05$) lower than in the optimized sample (Table 2). A combination of goat's milk, purslane (Portulaca oleracea) flour, and L. plantarum inoculation can serve as an excellent base for the development of functional food products **[2].**

3.1.1. Water Content

The water content of ice cream ranged from 57.42–58.26% with a significance value ($p = 0.3481$), indicating that the addition of purslane flour had no significant effect on the water content of the ice cream. This value indicates that adding purslane flour up to the P3 level did not significantly affect the product's total water content. The composition of total solids, stabilizers, and the freezing process primarily influences the water content of ice cream. Therefore, although purslane flour has a natural water content, its contribution to the overall water content is relatively small. This indicates that the addition of purslane flour did not significantly affect the ice cream's water content. This value indicates that adding purslane flour up to the P3 level did not significantly affect the product's total water content. The total solids composition, the use of stabilizers, and the freezing process primarily determine the water content of ice cream. Therefore,

although purslane flour contains natural water, its contribution to the total water content is relatively small.

3.1.2. Fat Content

Fat content showed a significant difference (p = 0.0019) between treatments, with the highest value in P1 (3.45%) and the lowest in P3 (2.41%). The decrease in fat content with increasing purslane flour addition is likely due to the reduced proportion of milk or cream in the formulation, which is replaced by the fat-free purslane flour. Furthermore, hydrophilic compounds in purslane, such as flavonoids and polysaccharides, can bind water, reducing the availability of the fat phase. Fat plays an important role in providing softness, savoury flavour, and a creamy texture to ice cream, so a decrease in fat content may affect the product's sensory characteristics.

All fractions had very low lipid content, with 0.47% in stems, 0.51% in leaves, and 0.54% in flowers. In general, polyunsaturated fatty acids (PUFAs) were found to be the most abundant in all fractions, followed by saturated fatty acids (SFAs) and monounsaturated fatty acids (MUFAs). The most dominant fatty acids are 18:3n-3 (50%) in the leaves, 18:3n-6 (46%) in the stems, and 18:2n-6 (30% of total fatty acids) in the flowers **[31].**

As a significant source of omega-3 fatty acids, purslane can provide significant health benefits to vegetarian and other diets that exclude fish oil. Scientific analysis of its chemical components has demonstrated that this weed possesses exceptional nutritional value, making it a potentially important food for the future. Its high content of antioxidants (vitamins A and C, alpha-tocopherol, beta-carotene, and glutathione) and omega-3 fatty acids, along with its wound-healing and antimicrobial effects and traditional use in the topical treatment of inflammatory conditions, suggest that purslane is a very likely candidate for a beneficial cosmetic ingredient **[32].**

3.1.3. Fibre Content

The results showed a significant increase in fiber content (p = 0.0001) from 2.21% (P0) to 3.53% (P3). This increase in fiber content stems from the natural fiber content of purslane, which is known to contain high levels of both soluble and insoluble dietary fiber. Fibre from purslane flour can enhance the functional value of ice cream by acting as a prebiotic, supporting the growth of probiotic bacteria and helping create a denser, more stable texture.

3.1.4. Protein Content

Protein content differed significantly (p = 0.0001), with the highest value in P1 (4.75%) and the lowest in P2 (3.19%). This variation indicates that adding purslane flour in certain amounts can affect ice cream protein content, either through dilution or interactions with milk proteins. Purslane contains small amounts of plant protein, but if its addition reduces the ice cream composition, the precented of protein content of ice cream can decrease. Protein is crucial in ice cream systems because it functions as an emulsion stabilizer and foam builder.

3.1.5. Antioxidant Level

Antioxidant levels increased significantly (p = 0.0001) with increasing purslane flour concentration, from 32.86 ppm (P0) to 42.10 ppm (P3). This indicates that purslane flour is rich in bioactive compounds, including flavonoids, ascorbic acid, β-carotene, and polyphenols, which can scavenge free radicals. This increase confirms that the addition of purslane flour can enhance the functional value of ice cream as an antioxidant-rich food, potentially providing health benefits such as protection against oxidative stress.

3.1.6. Lactobacillus plantarum Population

The *Lactobacillus plantarum* population differed significantly (p = 0.0001) between P1 (4.85 log CFU/g) and P3 (5.26 log CFU/g)**.** This indicates that purslane flour supports the growth of *L. plantarum*. It is suspected that the bioactive compounds and soluble fiber in purslane function as prebiotic substrates, accelerating the growth of probiotic bacteria. Thus, ice cream enriched with purslane flour not only serves as a recreational food product but also as a functional probiotic food [21], with the potential to improve digestive health. Based on Table 3, which shows the results of the analysis of variance for the physical parameters of ice cream, the following discussion can be conducted:

Table 3. Results of the analysis of variance for the physical parameters of ice cream

PARAMETERS	P0	P1	P2	P3
Melting Point (minutes)	32.00 ± 1.00^{a}	35.33 ± 1.52^{a}	47.33 ± 2.08^{b}	$58.66 \pm 3,05^{c}$
Overrun (%)	9.14 ± 9.42	9.95 ± 2.86	11.02 ± 1.89	11.44 ± 0.88
pH	6,78 ± 0,41	6,19 ± 0,13	6,39 ± 0,05	6,55 ± 0,24

3.2.1. Melting Point (minutes)

In the melting point parameter, there was a significant difference between treatments (**P0, P1, P2, P3**), with a significance value (Sig.) of 0.001, which is less than the 0.05 threshold. This indicates that the treatment altered the ice cream's melting point. The average melting point increased with each treatment, from **P0** (32.00 ± 1.00 minutes), P1 (35.33 ± 1.52), P2 (47.33 ± 2.08), and **P3** (58.66 ± 3.05) minutes. This increase may be due to factors affecting the ice cream's ingredient composition, such as water content or binders, which can slow the melting process. Warren and Hartel **[33]** found that the degree of overrun significantly influences the melting rate of ice cream, as air acts as an effective insulator, thereby impeding heat penetration into the ice cream. The melting point conforms to the established standard **[34]**.

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3.2.2. Overrun (%).

The overrun parameter, which indicates the increase in ice cream volume due to air trapped during the manufacturing process, showed an insignificant result (Sig. = 0.9407), greater than 0.05. This indicates that there was no significant difference in overrun between treatments. Although there was a slight fluctuation in mean values between treatments (e.g., P0: 9.14 ± 9.42% and P3: 11.44 ± 0.88%), this variation may be due to experimental factors

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or minor differences in the manufacturing process, which were not large enough to significantly affect the results.

3.2.3. pH

The pH values of ice cream showed less variation between treatments, ranging from 6.19 ± 0.13 (**P1**) to 6.78 ± 0.41 (**P0**). The analysis of variance for pH showed a p-value of 0.0984, which is greater than 0.05, indicating no significant difference in pH between the treatments. Although pH decreased in treatment P1, the change was not significant enough to affect overall pH quality, suggesting that the pH is within the safe pH range for ice cream (between 6 and 7).

3.3. Ice Cream Hedonic Test

Based on Table 4, which shows the results of the analysis of variance for the hedonic scale parameters of ice cream, the discussion can be conducted as follows:

Table 4. Results of the analysis of variance for the hedonic scale parameters of ice cream

PARAMETERS	P0	P1	P2	P3
Color	6.52 ± 1.36	5.48 ± 1.47	6.14 ± 1.88	5.66 ± 1,72
Aroma	5.71 ± 1.98	6.38 ± 1.20	5.67 ± 1.32	5.33 ± 1.68
Taste	6.76 ± 1.37	6.29 ± 1.74	6.62 ± 1.91	5.86 ± 1.79
Texture	5.95 ± 1.43	5.81 ± 1.47	5.62 ± 1.69	5.57 ± 1.69

3.3.1. Color

The colour parameter showed relatively large variation in ratings across treatments. The average colour score for treatment P0 was 6.52 ± 1.36, while those for treatments P1, P2, and P3 were lower at 5.48 ± 1.47, 6.14 ± 1.88, and 5.66 ± 1.72, respectively. Although there was a slight decrease in the scores for treatments P1 and P3, the difference was not significant and still reflects differences in preferences for ice cream colour. In this case, the colour of P0 received higher ratings, indicating that the ice cream in that treatment was considered more appealing by the panellists.

3.3.2. Aroma

For aroma parameters, the average value for treatment P1 (6.38 ± 1.20) was higher than those of the other treatments, with P0 (5.71 ± 1.98), P2 (5.67 ± 1.32), and P3 (5.33 ± 1.68) having lower values. Although **P1** had a higher value, the differences between treatments were not significant, indicating that the treatments did not significantly affect the ice cream's aroma in the panellists' opinion. Aroma in **P3**, which had the lowest value, may be due to the ingredients used or to the manufacturing process, which can affect aroma perception.

3.3.3. Taste

The taste parameter showed relatively good results in treatment P0 (6.76 ± 1.37), with a significant decrease in treatment **P3** (5.86 ± 1.79). Treatments **P2** (6.62 ± 1.91) and **P1** (6.29 ± 1.74) also received relatively high ratings. The sharp decline in **P3** indicates that its taste was less favourable than that of the other treatments, although overall, the ice cream's taste in this experiment still tended to be in the fairly good category. This could be due to variations in raw materials or manufacturing techniques that reduced the taste quality in **P3**.

3.3.4. Texture

For the texture parameter, the average values obtained were fairly uniform across treatments, with **P0** (5.95 ± 1.43), **P1** (5.81 ± 1.47), **P2** (5.62 ± 1.69), and **P3** (5.57 ± 1.69) showing small differences. All treatments received nearly identical ratings, indicating that the ice cream texture was not significantly affected by the treatments. Panellists tended to rate the ice cream texture within a fairly similar range, though P3 received the lowest score. Overall, treatment **P0** received the highest scores for most parameters, particularly colour and flavour, whereas treatment P3 showed decreases in flavour and texture parameters.

4. CONCLUSION

Based on this study's findings, the incorporation of purslane (Portulaca oleracea) flour significantly influenced the chemical and microbiological characteristics of ice cream. The addition of purslane flour increased dietary fiber content, antioxidant activity, and the population of Lactobacillus plantarum, while simultaneously reducing fat content. Protein content varied with the proportions of milk and purslane flour used in the formulation. The melting properties of the ice cream were also affected by purslane supplementation, whereas pH and overrun showed no significant changes. Among the treatments evaluated, the highest level of purslane flour addition (P3) yielded the most favorable chemical and microbiological profile, indicating its potential as a functional ingredient for the development of nutritionally enhanced probiotic ice cream.These results demonstrate that purslane flour can serve as a promising natural functional ingredient for improving the nutritional value, antioxidant capacity, and probiotic viability of ice cream, thereby contributing to the development of healthier functional dairy products.

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