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INVESTIGATING THE BENEFITS OF PLUM POMACE POWDER AS A NUTRITIOUS ADDITION TO YOGURT

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Abstract

The objective of the study was to examine the impact of enriching yogurt with plum pulp powder (PP) on the physicochemical, antioxidant, and sensory traits of the final product. The milk was sourced locally, and the bioactive ingredients were extracted via the ultrasound-assisted method. The findings indicated a significant enhancement in the antioxidant capacity of the fortified yogurts, achieving values of up to 20.98±1.19 µmol TE/g d.w. at the highest concentration of PP (BPP3). The incorporation of PP enhanced the texture, colour, and smell of the yogurts, which was favourably received by the panellists. The incorporation of PP also resulted in a uniform pink hue and enhanced firmness of the yogurt, without adversely affecting acidity or syneresis during storage. While the most significant advantageous effects were identified at a concentration of 12% PP, an increase in acidity and whey separation was also recorded with time. The results obtained underscore the potential of plum powder as a bioactive component for the formulation of functional dairy products, hence facilitating the advancement of functional products and supporting the principles of a circular economy.

***Key words**: antioxidant activity, dairy products, functional yogurt, pigments, plum pomace.*

INTRODUCTION

A dairy product with a straightforward yet distinctive composition, yogurt is full of different components that provide health benefits. It is an oil-in-water emulsion, with proteins, carbohydrates, and minerals in the water phase and fatty droplets in the oil phase (Kamal et al., 2018). The presence of lactic acid bacteria cultures, such as *Streptococcus thermophilus* and *Lactobacillus bulgaricus*, distinguishes yogurt from other dairy products. Lactic acid, which is produced by these bacteria, lowers the pH and inhibits the formation of potentially harmful pathogens in the yogurt (Nateghi et al., 2018; Santos et al., 2024).

The food ingredients market has expanded significantly owing to the increasing customer demand for a broader range of food products. A multitude of these elements is provided in powdered form, and the technologies used for their production are gaining significance as their functionality and quality progressively align with the efficiency of manufacturing processes (Guiné et al., 2020). Powdered fruit ingredients can enhance the color and flavor of various foods and pharmaceutical products while providing additional health-related benefits (Orădan et al., 2024). Fruits and other natural plant components are exceptional sources of bioactive compounds (Vlaicu et al., 2023). Plums have garnered significant attention among fruits due to their economic relevance in fruit production and their cultivation on a substantial portion of the agricultural area within the European Union (Rusu et al., 2024).

Recent studies have examined the impact of incorporating plum pulp into yogurt. A study by

Arora et al. (2021) evaluated the sensory qualities and physicochemical properties of yogurt enhanced with varying percentages of plum pulp (*Prunus domestica*) at 10%, 15%, and 20%, revealing several changes in the final product.

Consequently, the examined samples exhibited an increase in acidity and a reduction in pH value after storage, indicating heightened metabolic activity of lactic acid bacteria. The yogurt with 10% plum pulp received the top ratings for flavor, aroma, color, and consistency, indicating strong consumer approval. In this context, plum pulp may serve as a valuable functional component for incorporation into yogurts, enhancing both nutritional value and sensory appeal, and can be utilized to create natural, functional, and health-promoting dairy products.

Yogurt, an extremely common fermented dairy product, exists in numerous varieties and is recognized for its nutritional and nutraceutical advantages. The incorporation of natural or modified compounds into yogurt has gained popularity as an option to augment its functioning and nutraceutical properties. Reports indicate the incorporation of many natural ingredients in yogurt production, such as date extract, grape skin, mulberry fruit and leaf powder, lentil flour, assorted fibers, lemon and mint essential oils, and various fruit press powders (Bankole et al., 2023; Stoica et al., 2024).

Extracts from fruits and other plant components significantly enhance the nutritional and functional value of yogurts by augmenting antioxidant activity, bioactive component content, and health benefits, as indicated by a studies conducted by Wajs et al. (2023) and Gavril et al. (2024). Nonetheless, variations in sensory acceptability exist, and elevated concentrations of additives may adversely impact texture and flavor. Further investigations are necessary to optimize formulations that balance consumer preferences with functional improvements.

This study aimed to assess the effects of incorporating plum pomace powder into yogurt at varying concentrations (4%, 6%, and 8%) on the physicochemical, phytochemical, sensory attributes, and color characteristics of the final product.

MATERIALS AND METHODS

One hundred liters of cow's milk were supplied by the Rediu Iași Research Station of the University of Life Sciences. Ten kilograms of perfectly ripe plums (*Prunus domestica* var. *Stanley*) were gathered in September 2024 from the Vasile Adamachi Experimental Educational Station in Iasi, Romania. Following that, the plums were kept at 4°C until they were prepared for processing. The plums were first sorted, then washed with distilled water, cut in half, and the seeds were taken out before being shredded and compressed.

The Bosch MES3500 machine, manufactured by Philips Consumer Lifestyle B.V. in Drachten, Netherlands, was utilized to extract pumpkin juice, resulting in plum pomace (PP). The plum pomace (PP) was kept at –20°C in plastic bags prior to the freeze-drying procedure. The plum pomace (PP) underwent freeze-drying for forty-eight hours at –42°C at a pressure of 0.10 mBar. A freeze-dryer with a moisture content of 6.0% (BIOBASE BK-FD10T, Jinan, China) was used for performing the process. The obtained PP, which had a mean particle diameter of 450 μm, was ground up for 50 seconds in a grinding mill. Subsequently, it was kept in an airtight glass jar at room temperature until analysis. Before the yogurt was introduced, the PP underwent sterilization with a UV lamp in order to destroy contaminants.

Milk collection, sampling, and analysis

From the farm's storage tank, 100 liters of milk were extracted transferred into sanitized containers, where they were stored for twenty-five hours at 4°C. Subsequently, milk had been included into the laboratory's analytical procedures following appropriate homogenization. The physicochemical parameters of milk samples, such as moisture content, total solid, pH, solid non-fat content, protein content, and fat content, were determined according to AOAC protocols (Raţu et al., 2021). The reagents used to perform chemical analyzes of the obtained products (DPPH (2,2-diphenyl1-picrylhydrazyl), gallic acid solution, sodium acetate solution, potassium chloride solution, ethanol, methanol, sodium carbonate, Folin–Ciocalteu reagent, sodium hydroxide, aluminum chloride, sodium carbonate) were purchased from Sigma Aldrich (Schnelldorf, Germany).

Extraction of biological active compounds from PP

The bioactives were extracted from PP using the ultrasound-assisted extraction technique. Thus, 1.0 g of PP were combined with 10 mL of an 80% ethanol solution that had been acidified with citric acid (at a ratio of 7:1, v/v) before being subjected to ultrasound treatment for 25 minutes at 40°C and 37 kHz using a sonication water bath (Elmasonic S 180 H, Elma, Germany). The resulting supernatant was centrifuged for ten minutes at 6500 rpm and 10°C. The PP extract was then utilized to analyze the antioxidant activity of phytochemicals (anthocyanins, polyphenols, and flavonoids).

Antioxidant activity (DPPH)

The procedure outlined by Karaaslan et al. (2011) was followed in order to neutralize the DPPH radical and assess antioxidant activity. A calibration curve was applied, using Trolox as the standard. In a 100 mL volumetric flask, 3.8 mg of DPPH was homogenized with methanol to the appropriate level to create the DPPH stock solution. Next, 3.9 mL of DPPH (A sample) and 100 µL of the sample to be examined (PP extract) were added into a test tube. For the control sample, 3.9 mL of DPPH (A control) and 100 µL of methanol were used.

After 90 minutes of resting in the dark, the absorbance was measured at a wavelength of 515 nm. Trolox equivalents (TE)/g d.w. were expressed as µmol of the results. The change in antioxidant capacity was assessed by determining the inhibition (I%) for each sample using the following formula:

$$I(\%) = \frac{A_{control} - A_{sample}}{A_{control}} \times 100$$

Total monomeric anthocyanin content

Total monomeric anthocyanin content was measured using a modified pH differential approach used by Stoica et al. (2024). The absorbance of diluted extracts using different buffer solutions at pH 1.0 and 4.5 was measured at 520 nm and 700 nm. The results showed that the cyanidin-3-glucoside (C3G) content was mg/g of dry weight (d.w).

Total polyphenolic content

Horszwald & Andlauer (2011) described the Folin-Ciocâlteu spectrophotometric approach, which was applied. 200 µL of the PP extract, 1 mL of the Folin-Ciocâlteu reagent, and 15.8 mL of distilled water were added into a test tube.

Following ten minutes of standing, three milliliters of 20% sodium carbonate were added, and they were then allowed to stand for an hour at room temperature in the dark. The absorbance was measured at a wavelength of 765 nm. The results were expressed as milligrams of gallic acid equivalents per gram of sample (mg GAE/g d.w.) based on a gallic acid standard curve.

Total flavonoid content

The technique described by Arnous et al. (2002) was employed to quantify the total flavonoid content in PP extract. Subsequently, 2 mL of distilled water was combined with 0.25 mL of the PP extract and 0.075 mL of 5% sodium nitrite. Following a five-minute waiting period, 0.15 milliliters of 10% aluminum chloride were introduced, and the mixture was let to react for an additional six minutes. Subsequently, 0.5 mL of 1M sodium hydroxide was introduced. The absorbance of the resulting combination was measured immediately at 510 nm. The catechin standard curve has been used to determine the total flavonoid content, expressed as mg catechin equivalents per gram of sample (mg CE/g d.w.).

Texture profile analysis of yogurt

To determine the texture profile, the samples underwent a double penetration test utilizing a Brookfield CT3 Texture Analyzer (Brookfield Ametek, Middleboro, MA, USA) and an acrylic cylinder with a diameter of 38.1 mm. The test parameters included a trigger load of 0.067 N, a load cell capacity of 9.8 N, a target distance of 15 mm, and a penetration speed of 1 mm/s. All measurements were conducted at 20°C in a controlled environment. TexturePro CT V1.5 software was utilized to analyze the deformation-stress response and compute textural qualities such as gumminess, cohesiveness, hardness, and adhesiveness. Each sample underwent three replications.

Preparation of yogurt enhanced with PP

Full-fat milk was used in the technological procedure. The milk underwent pasteurization for 30 minutes at 62°C, was subsequently chilled to 36°C, and then inoculated with certain lactic bacteria. At 42°C, milk was blended with the starter culture YF-L812 (a commercial product from Chr. HANSEN, Denmark), consisting of a

2:1 mixture of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*.

The final pH of 4.8 was achieved after fermenting the inoculated milk for approximately 6.5 hours at 42°C. At this stage, 60 g/kg of sterile PP powder was combined with yogurt and subsequently put into pots. The samples were preserved at 4°C and examined immediately after production. Two distinct varieties of yogurt were manufactured. Four yogurt batches were produced from each production batch: the control batch (CB, which included no PP), and three enhanced yogurt batches (BPP1-4%PP, BPP2-6%PP, BPP3-8%PP) (Figure 1).

The techniques recommended by the Association of Official Analytical Chemists (AOAC) were employed to assess the samples' pH, fat, ash, moisture content, and total protein (Usturoi et al., 2017).

Colour analysis

Using the portable colorimeter with illuminator C-MINOLTA ChromaMeter CR-410 (Konica Minolta, Osaka, Japan), the color of the value-added and control yogurts was assessed. L*, a*, and b* were the color parameters that were identified. Each sample was provided in three separate replicates.

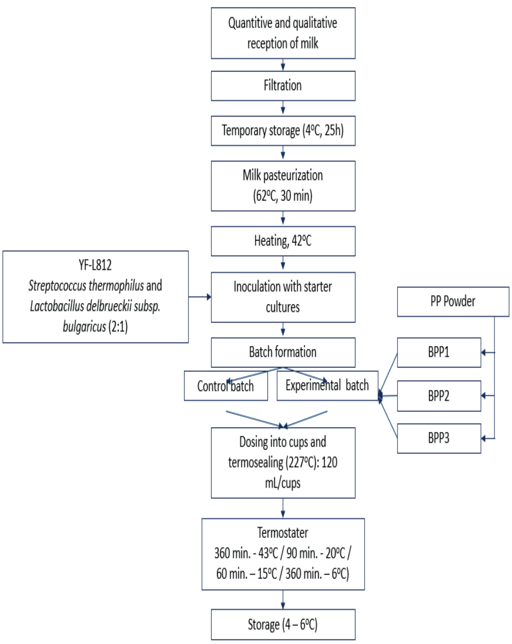

Figure 1. Flow diagram of functional yogurt

Sensorial analysis

A sensory assessment of yogurt samples was conducted by a panel of 16 panellists. The sensory qualities were evaluated using a hedonic scale, where 1 represented the weakest or least pleasant and 9 indicated the strongest or most pleasant. The evaluated qualities included appearance, colour, scent, texture, taste, odour, aftertaste, and overall acceptability. The panellists' ages span from 24 to 50 years, and they were non-smokers. An arbitrary configuration of the samples was used. The overall goal of the study and the procedures for managing personal information were explained to the participants.

Statistical analysis

The data was statistically analyzed using Minitab 19, a statistical processing program, and the data analysis tools package of Microsoft Excel software. Experiments conducted in triplicate were used to compute standard deviations.

RESULTS AND DISCUSSIONS

Spectrophotometric methods were employed to quantify the concentrations of polyphenols, flavonoids, and anthocyanins in ethanolic extracts from PP extract (Table 1). The overall polyphenolic content was 5.11±0.035 mg GAE/g d.w., whereas the total flavonoid content was 1.41±0.014 mg CE/g d.w. A substantial concentration of total anthocyanin content was recorded at 1.44±0.24 mg C3G/g d.w., alongside a notable antioxidant activity of 20.76±0.19 µmol TE/g d.w.

Table 1. Phytochemical characterizations and colorimetric parameters of the PP powder

Parameters	PP Powder
Total anthocyanin content (mg C3G/g d.w.)	1.44±0.24
Total flavonoid content (mg CE/g d.w.)	1.41±0,014
Total polyphenol content (mg GAE/g d.w.)	5.11±0,035
Antioxidant activity (DPPH, µmol TE/g d.w.)	20.77±0,03
Inhibition %	88.16± 0.45
L*	22.346±0.16
a*	10.37±0.05
b*	3.29±0.02

The PP powder was placed in quadrant I (+a*, +b*) based on the colour indices. The projected values for the L*, a*, and b* parameters are 22.46, 10.27, and 3.29, respectively, based on colour characteristics. Due to its elevated anthocyanin concentration, PP powder exhibited a high a* value, indicating a strong inclination towards red.

Bajić et al. (2020) obtained comparable results in the production of sugar, amidated low-methoxyl pectin, plum pomace lyophilisate, and high-quality plum spread. Textural parameters (maximal force, work of penetration, work of adhesion, intersection time, and intersection force), colour (L*, a*, b*, chroma, and hue angle), and chemical constituents (total phenolic content, total flavonoid content, total monomeric anthocyanins, antioxidant activity) were used to characterize plum spread.

Table 2. Chemical contents values of raw milk

Parameters	Mean
Water (%)	87.17±0.05
Fat (%)	3.85±0.03
Protein (%)	3.35±0.03
Total Solids (%)	12.83±0.07
Solid-non fat (%)	8.98 ±0.06
pH	6.55±0.01

To determine the quality parameters for the raw milk, the main chemical quality indices have been determined. Table 2 presents the chemical composition values of cow's milk samples. The raw milk had a water content of 87.17±0.05% and a total solids content of 12.83±0.07%. The average solid-non-fat content was 8.98±0.06%, with an average fat content of 3.85±0.03%. The average protein level was 3.35±0.03%. The results indicate that each raw milk quality indicator meets the criteria for assessing the milk's overall quality.

Table 3 presents the phytochemical profile and the DPPH free radical scavenging ability of the supplemented and control yogurt. To ascertain the overall phytochemical makeup of the products, an analysis was conducted. Compared to the control batch, the incorporation of PP powder into yoghurt products enhanced phytochemical levels (including anthocyanins, flavonoids, and polyphenols) in a dose-dependent way and improved their ability to scavenge free radicals.

Other authors have similarly documented increases in phytochemical levels. Postolache et al. (2022) demonstrated that increasing the concentration of rhododendron flower powder from 1% to 2% resulted in an increase in anthocyanins, flavonoids, polyphenols, and in vitro antioxidant activity in fortified yogurts, thus demonstrating a dose-dependent impact. Demirkol et al. (2018) found that yogurt infused with grape pomace increased polyphenol content (20 to 52 mg/100 g yogurt) and increased DPPH values. Also, Kennas et al. (2019) documented the beneficial effect of additional fruit by-products on yogurt polyphenols and identified a positive correlation between yogurt polyphenol concentrations and the amount of pomegranate added peel.

The anthocyanin concentration in the PP-supplemented yogurt varieties ranged from 0.73±0.51 mg C3G/100 g d.w. to 1.85±0.019 mg C3G/100 g d.w.

The antioxidant capacity has increased to 20.98±1.19 μmol TE/g d.w. (BPP3) instead of 10.98±1.17 μmol TE/g d.w. for BPP1. Total polyphenolic compounds, total flavonoids, total anthocyanins, and the DPPH free radical scavenging capacity all increased when PP powder was added to the yoghurts' recipe. The antioxidant activity of the improved yoghurts was significantly influenced by the bioactive ingredients derived from PP, resulting in superior values compared to the control samples.

The results in Table 3 validate their value by enhancing the total anthocyanin content and antioxidant activity in yogurt samples included with PP powder. Comparable findings have been documented in additional research concerning the quality evaluation of yogurts. Research by McCullum et al. (2024) indicates that Greek-style yogurt including freeze-dried Illawarra plum powder can enhance its color, total solids, and phytochemical content when refrigerated for up to one month. The study indicates that yogurt can be enhanced by incorporating freeze-dried powder derived from fresh Illawarra plums.

The anthocyanins in the powder provide a uniform, attractive pink colour and contribute to the yoghurt's firmness, so improving its texture. According to Khoo et al. (2017), in addition to serving as natural colorants, several anthocyanin-rich fruit and flowering plants have been extensively utilized in medicine to address different medical conditions. Conversely, plant anthocyanins have been thoroughly investigated for their therapeutic properties. Anthocyanins exhibit antidiabetic, anticancer, anti-inflammatory, antibacterial, and anti-obesity properties, in addition to preventing heart diseases. Moreover, the fortification does not influence the acidity or syneresis of the yogurt during storage. While the powder enhances levels of anthocyanins, phenolic compounds, and antioxidant activity, further research is required to ascertain the practical benefits of these modifications.

Table 3. The content of phytochemical compounds and the antioxidant activity of added-value yogurt samples

Parameters	Type of yogurts			
	BC	BPP1	BPP2	BPP3
Total anthocyanin content (mg C3G /100 g d.w.)	-	0.73±0.51[c]	1.14±0.021[b]	1.85±0.019[a]
Total flavonoid content (mg CE/g d.w.)	0.72±0.006[b]	1.12±0.021[ab]	1.29±0.031[ab]	1.43±0.007[a]
Total polyphenol content (mg GAE/g d.w.)	0.98±0.013[d]	1.62±0.011[c]	2.31± 0.031[b]	3.34±0.047[a]
Antioxidant activity (μmol TE/g d.w.)	2.52±0.25[d]	10.98±0.12[c]	16.07±1.13[b]	20.98±0.14[a]

Different letters in rows indicate statistically significant differences across the samples ($P < 0.05$).

Table 4 summarizes the results of the chemical composition analysis of the tested materials. The data analysis indicates significant variations in protein and total solids among yogurts with additional plum pomace powder ($p < 0.05$). The results presented in Table 4 indicate that the protein content of the value-added yogurts with PP powder is significantly higher than that of the control ($p<0.05$). Conversely, the fat content of the value-added yogurts is comparable to that of the control. The ash content exhibited a marginal rise with higher PP powder concentration, rising from 0.95±0.005% in BPP1 to 1.19±0.006% in BPP3.

Comparable results were achieved by Güzeler et al. (2018), who assessed the impact of including dried plums at different concentrations (0%, 6%, 9%, and 12%) on the physicochemical and sensory attributes of probiotic yogurt over a 15-day storage duration. The study indicates that incorporating 12% dried plum into probiotic yogurt initially enhances its physicochemical and sensory attributes; nevertheless, over time, it leads to increased acidity and whey separation. After eight days, the acidic nature of the yogurt resulted in a decline in sensory scores. The findings indicate that 12% dry plum is recommended for probiotic yogurt production due to its favourable balance of flavour, acidity, and functional benefits. Other vegetable by-products have demonstrated an improvement in their antioxidant properties.

Table 4. Chemical composition of added-value yogurts samples

Parameters	Type of yogurts			
	BC	BPP1	BPP2	BPP3
Moisture (%)	87.32±0.031[a]	84.12±0.039[b]	81.09±0.041[c]	79.84±0.045[d]
Total solid (%)	12.68±0.031[d]	15.88±0.039[c]	18.91±0.017[b]	20.16±0.017[a]
Fat (%)	3.73±0.017[b]	4.01±0.015[a]	4.02±0.015[a]	4.03±0.012[a]
Protein (%)	3.65±0.011[b]	4.12±0.012[ab]	4.20±0.011[a]	4.28±0.006[a]
Ash (%)	0.74±0.009[d]	0.95±0.005[c]	1.08±0.004[b]	1.19±0.006[a]
pH	4.65±0.004[a]	4.54±0.009[b]	4.46±0.011[c]	4.39±0.006[d]

Different letters in rows indicate statistically significant differences across the samples ($P < 0.05$).

Table 5. Color of BC, BPP1, BPP2, and BPP3 yogurts

Parameters	Yogurts type			
	BC	BPP1	BPP2	BPP3
L*	94.51±0.17[a]	75.66±0.61[b]	72.74±0.192[c]	69.09±0.601[d]
a*	-4.60±0.025[d]	5.50±0.056[c]	6.72±0.038[b]	7.47±0.092[a]
b*	14.04±0.078[a]	13.50±0.106[b]	13.78±0.068[ab]	13.85±0.107[ab]

Different letters in rows indicate statistically significant differences across the samples ($P < 0.05$).

The results of the Lipșa et al. (2024) study underscore the potential utility of onion leaf extract as a source of bioactive compounds with significant antioxidant properties. The study showed that adding 1% powder to ricotta cheese did not interfere with the commercial LAB starter's ability to ferment the cheese. A bovine whey cheese with distinct functional, physicochemical, and sensory qualities was produced as a result of this enrichment.

According to Stoica et al. (2024), color is a significant sensory attribute that affects how well-liked foods are by consumers. The CIELAB colorimetric parameters were also used to analyze the yogurts. Table 5 presented the results of the color parameters L*, a*, and b* measurements for both the control and PP-supplemented yogurts. The significant rise in the a* value with elevated PP powder content ($p<0.05$) suggests that the bioactive compounds included in the powder have a tendency to assume a red hue. Furthermore, an increase in the concentration of PP powder results in the value-added yogurts displaying diminished degrees of lightness and yellowness, as shown by the L* and b* values. In the analyzed yogurt models, a* increased while L* and b* parameters decreased concurrently with the powder concentration.

Du et al. (2021) observed a comparable tendency by including mulberry pomace, a natural source of pigment, antioxidants, and dietary fiber, into stirred-type functional flavored yogurt.

A nine-point hedonic scale was used to assess the yogurts' sensory qualities. Appearance, color, scent, texture, taste, odor, aftertaste, and general acceptability were the next characteristics listed.

Figure 2 displays the average results obtained from the sensory analysis. Because PP powder contains pigments, particularly anthocyanins, the red color of the resulting yogurts deepened as the concentration of PP powder rose (Figure 2). The BPP2 sample achieved the highest ratings across all nine attributes and maintained an acceptable 6% PP. The panellists noted that the yogurts exhibited a spectrum of hues, with BPP2 displaying the most pronounced red, as the incorporation of PP into the yogurt samples enhanced their red pigmentation. The yogurt samples infused with PP powder were praised for their appealing colour, scent, and odour. The yogurts with additional PP powder were assessed to possess a balanced aftertaste, scent, and taste. The incorporation of PP powder does not significantly influence the fundamental sensory attributes (colour, taste, and scent) regarding consumer approval. The panellists gave all the suggested yogurts favourable reviews. According to the concentration of PP powder used, the produced samples have an appealing colour with red undertones. According to sensory analysis, PP-containing yogurts offer respectable quality attributes and can be well-liked by customers.

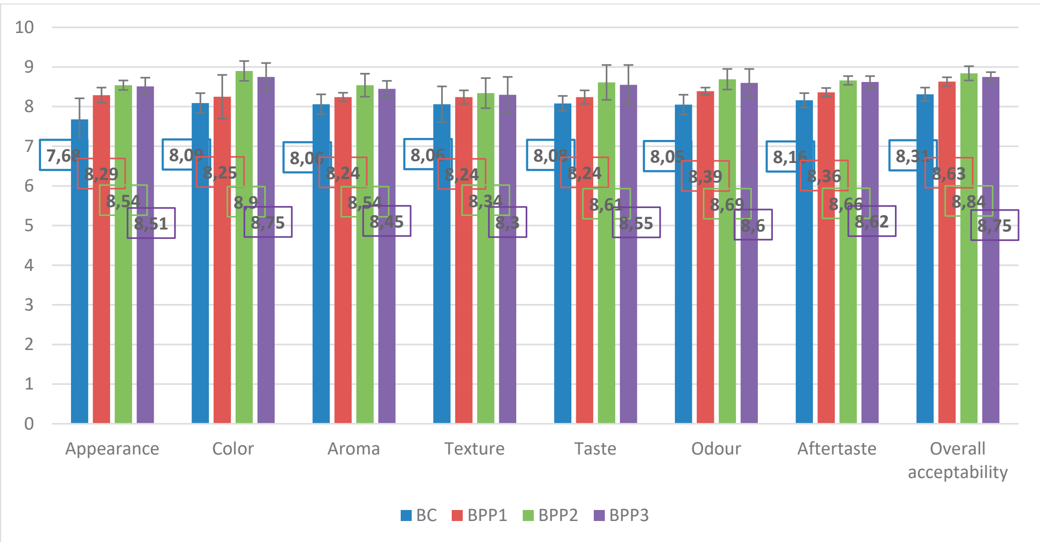

Figure 2. Sensory evaluation values of control and added-value yogurts (BC, BPP1, BPP2, BPP3)

Regarding the texture analysis, the configuration of the protein network and the structure of fermented dairy products affect their textural properties. The findings of the texture profile analysis are shown in Table 6. All of the yogurts' textural qualities were considerably impacted by the addition of powder made from pressing plums.

Table 6. Texture of yogurts supplemented with PP after 1, and 14 days

Parameters	Yogurt type	Storage Period (Days)	
		1	14
Hardness, N	BC	5.64±0.01^{dA}	5.67±0.01^{dA}
	BPP1	7.52±0.01^{cA}	7.54±0.01^{cA}
	BPP2	9.35±0.01^{bA}	9.38±0.01^{bA}
	BPP3	12.59±0.01^{aA}	12.62±0.01^{aA}
Gumminess, N	BC	1.65±0.01^{dA}	1.67±0.01^{dA}
	BPP1	2.84±0.00^{cA}	2.95±0.00^{cA}
	BPP2	4.15±0.02^{bA}	4.23±0.02^{bA}
	BPP3	5.98±0.02^{aA}	6.04±0.02^{aA}
Cohesiveness	BC	0.31±0.02^{bA}	0.33±0.02^{bA}
	BPP1	0.35±0.01^{aA}	0.36±0.01^{aA}
	BPP2	0.36±0.01^{aA}	0.38±0.01^{aA}
	BPP3	0.37±0.01^{aA}	0.39±0.01^{aA}
Springiness	BC	0.55±0.00^{aA}	0.52±0.00^{aA}
	BPP1	0.32±0.01^{bA}	0.35±0.02^{bA}
	BPP2	0.22±0.02^{cA}	0.27±0.01^{cA}
	BPP3	0.19±0.00^{dA}	0.23±0.00^{cA}
Adhesiveness, mJ	BC	-2.51±0.01^{dA}	-2.55±0.01^{dA}
	BPP1	-8.72±0.01^{cA}	-8.76±0.01^{cA}
	BPP2	-11.31±0.03^{bA}	-11.39±0.01^{bA}
	BPP3	-13.65±0.01^{aA}	-13.72±0.02^{dA}

A significant difference ($p < 0.05$) exists between any two means of each sample inside the same column with a different lowercase superscript. A significant difference ($p < 0.05$) exists between any two means of the same sample throughout time inside the same row, indicated by a distinctive superscript capital letter.

The main factor affecting yogurt's texture is its hardness, defined as the force required to induce a specific deformation. The hardness of yogurt supplemented with PP increased with the quantity of powder applied. The dietary fibers in PP absorb more moisture due to its elevated water retention capacity, resulting in increased hardness of the samples. Compared to the control sample, PP-supplemented yogurts demonstrated elevated hardness, gumminess, cohesion, and adhesiveness, alongside reduced elasticity. Over time, every textural attribute of the PP-enriched yogurt increased. The documented results align with previous findings in the field, including the research conducted by Kabir et al. (2020), which utilized banana peels to enhance the storage capacity and bioactive qualities of yogurts.

CONCLUSIONS

Our findings underscore the importance of PP powder as a potent source of bioactive compounds with antioxidant properties. Consequently, the authors suggest including it as a natural component in fortified yogurt.

In comparison to plain yogurt, the PP-supplemented yogurts exhibited elevated total phenolic content and enhanced antioxidant potential. Panellists expressed approval on the improved hue of the yogurt samples, as indicated by a sensory analysis.

The value-added yogurts were considered satisfactory overall. The dairy sector has additional opportunities to satisfy the increasing customer demand for functional meals by producing distinctive, nutritious, and delectable yogurt products. The results obtained confirm the quality of natural components with bioactive potential in plum powders for application in the food sector to develop functional products that promote the circular economy concept.

The results obtained validate the quality of natural components with bioactive potential derived from fruit pomace powders for use in the food sector to produce functional products that promote the circular economy.

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