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Study on the Physicochemical and Sensory Qualities of Yoghurt Supplemented with Steamed Purple Sweet Potato

Aulia Aulia, Fatma Maruddin*, Hajrawati Hajrawati and Dewi Musda Pratiwi

Faculty of Animal Science, Hasanuddin University, Jl. Perintis Kemerdekaan Km.10, Tamalanrea, Makassar, South Sulawesi 90245, Indonesia.

Abstract

Purple sweet potato (PSP) is recognized for its high content of anthocyanins, dietary fiber, and bioactive compounds, thereby holding potential to enhance the nutritional value, physicochemical characteristics, and shelf life of the product. This study aimed to evaluate the effects of varying concentrations of steamed PSP on the physicochemical and sensory qualities of yogurt made from commercial milk. A Completely Randomized Design (CRD) with five treatments, P0-P4 (0%, 2%, 4%, 6%, and 8% steamed PSP) and five replications was employed. The parameters observed included pH, total lactic acid, viscosity, antioxidant activity, color (L*, a*, b*), and Sensory evaluation. This method was selected to assess variation systematically and controllably in yogurt quality across different treatments. The results showed that the addition of steamed PSP significantly (P < 0.05) increased antioxidant activity, viscosity, purple color intensity (L*, a*, b*), total lactic acid, and panelists' preference for aroma, taste, color, and texture as demonstrated by the ANOVA results. Among treatments, P2 (4%) and P4 (8%) were most preferred by the panelists, likely due to their optimal balance of natural sweetness, appealing purple colour, and thicker texture, without excessively altering the characteristic properties of yoghurt.

Keywords: Physicochemical Quality, Fermentation, Yoghurt, Purple Sweet Potato

***Correspondence:** fatma_maruddin@unhas.ac.id

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INTRODUCTION

Yoghurt is a widely consumed fermented dairy product with recognized nutritional and health benefits.[1] The fermentation process using lactic acid bacteria (LAB) and probiotics not only transforms milk into yoghurt but also enriches its nutritional content and provides significant health benefits.[2]

In recent decades, numerous studies have focused on developing new variants of yoghurt products, particularly by incorporating natural ingredients that not only enhance nutritional value but also enrich flavor and appearance. Common natural ingredients used in the development of functional yoghurt include fruits, vegetables, seeds, and legumes.[3] Several studies have also incorporated tuber crops, including purple sweet potato (PSP), known for its rich natural pigments and other bioactive compounds.

Various studies have employed purple sweet potato (PSP) in different forms for yoghurt processing. For example, Hariadi et al.[4] used purple sweet potato extract with fresh milk, while Suwannaphan[5] applied purple sweet potato flour using goat milk as a base to produce yoghurt. Khairani et al.[6] utilized purple sweet potato paste as a supplementary ingredient in yoghurt. According to Ivane et al.,[7] purple sweet potato has various potential health benefits, including antidiabetic, anticancer, antimicrobial, hepatoprotective, cardioprotective effects, and the ability to boost the immune system. The bioactive compounds in purple sweet potato are highly appealing for application in yoghurt product development, thereby transforming yoghurt into a functional food that supports broader health benefits beyond probiotic effects.

Despite the growing number of studies using dehydrated or extracted purple sweet potato in yogurt, the impact of incorporating steamed purple sweet potato on yogurt physicochemical and sensory attributes has not been systematically examined. This study addresses that specific knowledge gap. In this study, steamed purple sweet potato was used as an ingredient in the production of yoghurt made from commercial milk. Preliminary results indicated that yoghurt with the addition of steamed purple sweet potato had a significant impact on texture, color, and taste compared to yoghurt supplemented with purple sweet potato flour. The use of steamed purple sweet potato has been relatively underexplored compared to other forms, such as flour or extract, because most previous studies have focused on dried forms due to their longer shelf life. However, steaming is considered more effective than drying or high-temperature processing for preserving bioactive compounds, particularly anthocyanins, and it also produces a fresher, more natural texture and flavor.[8] Therefore, the use of steamed purple sweet potato presents a novel approach in this study, and further investigation is needed to comprehensively understand its effect on the physical, chemical, and sensory qualities.

Although purple sweet potato has been previously incorporated into yogurt in various processed forms such as flour, paste, or extract, the use of *steamed* purple sweet potato remains underexplored. Steaming is a gentle thermal treatment that better preserves heat-labile bioactive compounds, particularly anthocyanins, compared to drying or baking.[8] Additionally, the fresh matrix of steamed PSP may interact more actively with milk proteins, influencing fermentation dynamics and potentially affecting the physicochemical and sensory attributes of yogurt in distinct ways. This study thus introduces a novel, minimally processed approach to enhance yogurt functionality and aligns with the growing demand for clean-label, nutrient-rich dairy products.

Recent work shows that plant-derived carbohydrates and proteins boost dairy fermentation and functionality. Heart-of-date-palm raised camel-milk peptide content and displayed anticancer activity,[9] sweet lupine powder maintained low-fat Labneh texture and sensory scores,[10] and date syrup doubled antioxidant activity without affecting pH or starter counts.[11] These advances (Elkot and Ismail)[12] support applying steamed purple sweet potato as a fresh, nutrient-rich yogurt supplement.

Nutritional composition data for purple sweet potato reported by Suparni et al.[13] indicates that per 100 grams, it contains 27.9 grams of carbohydrates, 1.8 grams of protein, and 0.7 grams of fat. The carbohydrates and proteins present in purple sweet potato serve not only as energy sources but also function as binding and stabilizing agents in the nutritional matrix of yoghurt.[14] This can influence the physical characteristics of the final product, such as texture and consistency. Moreover, purple sweet potato can act as a nutrient source for yoghurt starter microorganisms, affecting the chemical and microbiological changes during fermentation.

Tari[15] reported that the addition of purple sweet potato extract to yoghurt improved its microbiological properties, with bacterial viability reaching 10^9 CFU/mL within 2 weeks and the pH decreasing to 3.78. This demonstrates that purple sweet potato enhances lactic acid production during fermentation, directly influencing yoghurt quality and stability. Additionally, regarding bioactive content, purple sweet potato contains purple pigments, namely anthocyanins, throughout the skin to flesh.[16] Anthocyanins are antioxidant compounds that also function as natural colorants. These anthocyanins may confer health benefits to consumers while imparting an attractive natural color to yoghurt. Therefore, the functional properties of anthocyanins in yoghurt are also an essential aspect of this study.

Based on this background, the present research aims to evaluate the effectiveness of steamed purple sweet potato addition on the physicochemical and sensory qualities of yogurt. It is expected that the resulting yoghurt product will not only exhibit improved nutritional and health functionality but also possess desirable sensory properties accepted by consumers, along with added value from bioactive compounds and natural coloring. This study will contribute to the development of functional yoghurt products based on locally sourced natural ingredients with promising potential for broader commercialization.

MATERIALS AND METHODS

Preparation of steamed purple sweet potato

A local Purple-fleshed sweet potato variety was thoroughly washed, peeled, and cut into 2 cm cubes. The sweet potatoes were then steamed for 6 minutes using a pot steamer. After steaming, the sweet potatoes were blended to a smooth consistency in a blender and used immediately without prior storage.

Starter preparation

The starter culture used was commercial yoghurt (Biokul®). The growth medium for both the mother culture and the starter was prepared with 10% (w/v) reconstituted skim milk. The medium was sterilized at 105 °C for 5 minutes and then cooled. This condition follows Sulmiyati et al.[17] who reported that 105 °C for 5 min in a Tomy SX-500 autoclave effectively sterilises milk-based media while limiting advanced Maillard reactions; preliminary plate-count tests in our laboratory confirmed sterility (no colonies after 48 h incubation). Once cooled, the sterile medium was inoculated with 3% (v/v) of the commercial yoghurt. The culture activation process was carried out twice before being used as the yoghurt starter. The mother or starter culture was harvested after incubation at 37 °C for 14 hours, as indicated by a decrease in pH to approximately 4.5, a marker of optimal bacterial growth.[18] The resulting starter was then ready to be used for the production of purple sweet potato yoghurt.

Production of purple sweet potato yoghurt

The yoghurt production process referred to the modified method.[19] The procedure began with the preparation of ingredients: 200 mL of UHT milk (Greenfield®), 10 g of original skim milk powder (Tropicana Slim®), 10 g of sugar (Gulaku®), 5% starter culture, and steamed purple sweet potato at concentrations of 2%, 4%, 6%, and 8% (P1-P4) for each sample. All ingredients were mixed in a single container and sterilized in an autoclave at 105 °C for 5 minutes. The mixture was then incubated at 37 °C for 18 hours. After fermentation, the samples were analyzed for pH, total lactic acid content, viscosity, antioxidant activity, L*a*b* color parameters, and sensory evaluations.

pH testing

The pH measurement was carried out using a pH meter, following the method described by Dewi and Purnamayati.[20] The pH meter was calibrated using standard buffer solutions at pH 4 and 7 for 15-30 minutes, then rinsed with distilled water and dried. Subsequently, the pH meter electrode was immersed in 20 ml of the yoghurt sample without touching the bottom of the container and allowed to stand for a few seconds until the reading stabilized.

Total lactic acid content test

The total lactic acid content was determined by titration with 0.1 N NaOH and phenolphthalein as an indicator. The sample was diluted and then titrated until a pink color appeared. The acid content was calculated as a percentage of lactic acid.[21]

Total Lactic Acid = [Vol NaoH (ml) × N NaoH × Factor of Phenolphthalein × Molar Mass / Sample Weight (mg)] × 100

Viscosity test

The viscosity test was conducted following the methods of previous studies, with modifications,[22,23] comprising two main steps: measuring density with a pycnometer and viscosity with an Ostwald viscometer. The density of the yoghurt sample was determined by weighing the empty pycnometer and the pycnometer filled with the sample. Then, 5 mL of yoghurt was placed into the Ostwald viscometer, and the flow time was measured using a stopwatch. The viscosity was calculated using the following formula:[24]

$$\text{Viscosity} = \frac{\rho\ \text{sample} \times t\ \text{sample}}{\rho\ \text{water} \times t\ \text{water}} \times \eta\ \text{water}$$

$$\rho\ \text{sample} = m' - m / V$$

Where:
m' = mass of pycnometer filled with sample (g)
m = mass of empty pycnometer (g)
V = volume of sample (mL)
t sample = flow time of sample (seconds)
ρ water = density of water (g/mL)
t water = flow time of water (seconds)
η water = viscosity of water (cP or mPa·s)

Viscosity was measured with a Brookfield viscometer at 25 ± 1 °C using a fixed spindle speed; results are expressed in centipoise (cP). Flow time was additionally recorded with an Ostwald viscometer, giving a range of 11-53 s depending on the concentration of steamed purple sweet potato.

Antioxidant activity

The antioxidant activity was determined using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay with modification.[25] The yoghurt extract solution was prepared by dissolving 1 g of yoghurt in 5 mL of methanol. Subsequently, 0.2 mL of the extract was transferred into a test tube and mixed with 0.06 mM DPPH solution until homogeneous. The mixture was incubated in the dark for 30 minutes, after which the absorbance was measured at 517 nm using a UV-Vis spectrophotometer. The average absorbance of the blank DPPH solution (negative control) was 0.000, while the positive control (BHT, 50 μg mL^{-1}) gave an absorbance of 1.335 ± 0.01 (n = 3). The percentage of DPPH radical scavenging activity was calculated using the following formula given by Benguedouar et al.[25]

Antioxidant Activity (%) = [(Absorbance of control - Absorbance of sample) / Absorbance of control] x 100

Color measurement

Color measurement was performed using a digital color meter (135 A) according to the method of Maruddin et al.[26] after calibration with a white standard. The measured values of L*, a*, and b* were directly displayed on the device screen.

Sensory evaluation

Sensory evaluation was conducted on a 6-point hedonic scale for texture, aroma, colour, taste, and overall preference. Twenty-five panellists (19-26 years) received 20 mL of each sample at 10 ± 2 °C in a controlled room (air-conditioned, isolated booths). Three-digit sample codes were generated from a random-digit table (Williams Latin-square order) to guarantee balanced presentation and minimise carry-over bias. Panellists were isolated bye ≥1 m to prevent cross-talk.

One-way ANOVA was applied to the individual panellist scores (n = 25) for each attribute; when $P < 0.05$, Duncan's multiple-range test was used to separate means.

Table 1. Mean values of ANOVA result for the physicochemical quality of yoghurt with the addition of steamed purple sweet potato

Treatment	Experimental Treatments				
	P0	P1	P2	P3	P4
pH	4.78 ± 0.07[a]	4.69 ± 0.07[ab]	4.62 ± 0.08[bc]	4.57 ± 0.08[c]	4.48 ± 0.02[d]
Titratable Acidity (%)	0.38 ± 0.00[a]	0.56 ± 0.14[b]	0.64 ± 0.18[b]	0.74 ± 0.16[b]	0.94 ± 0.07[c]
Viscosity (cP)	29.99 ± 0.38[a]	46.60 ± 0.42[b]	79.26 ± 0.36[c]	115.23 ± 0.47[d]	135.81 ± 0.59[e]
Antioxidant Activity (%)	31.20 ± 3.56[a]	48.40 ± 2.30[b]	60.60 ± 5.23[c]	70.60 ± 4.78[d]	83.00 ± 6.08[e]

P0 (control, without addition of purple sweet potato), P1 (addition 2% purple sweet potato), P2 (addition 4% purple sweet potato), P3 (addition 6% purple sweet potato), P4 (addition 8% purple sweet potato). Data are mean ± standard deviation (SD) (n = 5). Based on ANOVA results, superscript in the same row indicate significant differences (P < 0.05)

The protocol was approved by the Research Ethics Committee of Institut Kesehatan Helvetia No. 027.1/EC/KEPK-IKH/06/2025. All participants provided written informed consent after being informed of minimal risk and their right to withdraw at any time.

Data analysis

The study used a Completely Randomized Design (CRD) with five treatments and five accurate replications. Each replicate was an independent batch of yogurt (200 mL milk + respective PSP level, separately cooked and fermented), not subsamples from a single bulk mixture. Data were statistically analyzed using Analysis of Variance (ANOVA) and processed with SPSS version 25 software. If ANOVA results indicated a significant effect among treatments, a further Duncan's multiple range test was conducted to determine differences between treatments.

In the present study, formal normality (Shapiro–Wilk, Kolmogorov–Smirnov) and homogeneity-of-variance (Levene, Bartlett) tests were not performed before one-way ANOVA and Duncan's test for any parameter-physicochemical (pH, titratable acidity, viscosity, colour, antioxidant activity) or sensory. This decision was pragmatic: the experiment was set up as a balanced Completely Randomised Design (CRD) with five independent replicates prepared under identical laboratory conditions, and sensory scores were collected from 25 panellists, each evaluating every sample once (n = 25 judgments per treatment). The resulting equal cell sizes and controlled environment justify the use of ANOVA for comparative purposes. Still, we acknowledge that future work should include explicit diagnostic tests to strengthen statistical rigour.

RESULTS AND DISCUSSION

Potential hydrogen (pH)

Based on the results of Duncan's post-hoc test, the addition of steamed purple sweet potato in yoghurt production had a significant effect on pH values across treatments (P0 to P4) (Table 1). The control treatment without purple sweet potato addition (P0) showed the highest average pH, at 4.48, while the treatment with 8% steamed purple sweet potato addition (P4) exhibited the lowest pH, at 4.48. This decrease in pH values corresponded to the increasing amount of purple sweet potato incorporated into the yoghurt.

The subset grouping results indicated that P0 and P1 were significantly different from P4. This suggests that higher amounts of steamed purple sweet potato significantly reduced yoghurt pH. These findings are in line with the study by Julianti et al.,[27] which found that increasing amounts of purple sweet potato paste decreased yoghurt pH. The pH decline is presumably due to the carbohydrate content in purple sweet potato, which serves as a substrate that can be further fermented by lactic acid bacteria, resulting in increased acidity and consequently a lower final product pH.[28]

Thus, it can be concluded that the higher the addition of steamed purple sweet potato, the lower the resulting yoghurt pH value. This indicates that purple sweet potato enhances the fermentation activity of lactic acid bacteria, thereby directly affecting the acidity level of yoghurt. The final pH values (4.48-4.78) are slightly higher than the 3.7-3.9 reported for purple-sweet-potato yoghurts fermented for 24 hrs,[6] reflecting the shorter incubation (18 hrs) and the higher buffer capacity of the UHT full-fat milk used in the present study.

Titratable acidity

Data analysis using Duncan's multiple range test showed that the lactic acid content in yoghurt tended to increase with the increasing amount of steamed purple sweet potato added in the formulation. Treatment P4 resulted in the highest lactic acid content of 0.94%, while P0 (without steamed purple sweet potato addition) had the lowest lactic acid content of 0.38% (Table 1). Based on the subset grouping results, P4 was not grouped with P0, indicating a statistically significant difference between them. This finding suggests that the higher the concentration of steamed purple sweet potato added, the greater the lactic acid content produced. The increase is attributed to the carbohydrate content of purple sweet potato, which serves as an additional substrate for lactic acid bacteria during fermentation,[29] thereby accelerating acid production. The extra fermentable sugars released from steamed PSP provide an easily utilizable substrate for the yoghurt starter culture, accelerating conversion of lactose to lactic acid and thus the observed rise in titratable acidity.[10]

Viscosity

An increase in the amount of steamed purple sweet potato added to yoghurt production showed a consistent trend toward higher final product viscosity. This is evident from the viscosity analysis results, which revealed significant differences among treatments. The control treatment (P0), without steamed purple sweet potato addition, exhibited the lowest viscosity value of 29.99 cP (Table 1). The low viscosity in the control sample (P0) may result from the lack of dietary fiber and starch, both of which are known to enhance gelation and structural integrity in yoghurt matrices.

In contrast, the P4 treatment (8% steamed purple sweet potato) yielded the highest viscosity of 135.99 cP. This indicates that solid components such as starch in purple sweet potato contribute substantially to the increased thickness of the yoghurt. Generally, this increase can be explained by the fibrous structure of purple sweet potato, which has the ability to absorb water and form a denser matrix within the yoghurt mixture.[30] Swollen PSP starch granules act as active fillers, physically occupying interparticle spaces within the casein network, increasing hydrodynamic volume and apparent viscosity without additional fat.[31]

El-Attar et al.[31] also reported that the microstructural analysis of set yoghurt supplemented with purple sweet potato flour showed a denser gel matrix with small pores, indicating that fibers and starch granules from purple sweet potato formed a compact structure. Furthermore, Kilinc et al.[32] found that purple sweet potato significantly increased yoghurt viscosity more effectively than orange sweet potato, due to its higher fiber content, resulting in a thicker, more consistent, and physically stable yoghurt.

The gradual increase in viscosity from P1-P4 treatments occurred in a stepwise manner, with each treatment level producing a statistically significant change in viscosity. This is also supported by the formation of non-overlapping subsets among treatments, indicating that each level had a distinct statistical effect on viscosity. Thus, the higher the amount of steamed purple sweet potato added, the greater its impact on enhancing yoghurt viscosity. These findings are consistent with those of Julianti et al.,[27] who reported that increasing the amount of purple sweet potato paste in yoghurt production improved viscosity. This demonstrates that purple sweet potato not only enriches the nutritional profile but also enhances the product's physical texture. Although absolute values are lower than pectin-fortified yoghurts (>200 cP), they agree with PSP-flour systems at equal dry-matter.[30] They are sufficient to produce a viscous, spoonable product.

Antioxidant activity

The Duncan's multiple range test analysis demonstrated that the addition of steamed purple sweet potato significantly affected the antioxidant activity of yoghurt. Each treatment exhibited significantly different antioxidant values. The

Table 2. Pearson correlation matrix (r) among physicochemical parameters of yoghurt with steamed purple sweet potato (n = 25)

		pH	Lactic Acid	Viscosity
pH	Pearson Correlation	1	-0.941**	-0.846**
	Sig. (1-tailed)		0	0
	N	25	25	25
Lactic Acid	Pearson Correlation	-0.941**	1	0.818**
	Sig. (1-tailed)	0		0
	N	25	25	25
Viscosity	Pearson Correlation	-0.846**	0.818**	1
	Sig. (1-tailed)	0	0	
	N	25	25	25

** Correlation is significant at the 0.01 level (1-tailed)

control sample (P0), without purple sweet potato addition, recorded the lowest antioxidant activity at 31.20% (Table 1), reflecting the baseline level contributed by the yoghurt matrix alone, without the influence of bioactive compounds from the sweet potato.

Incremental additions of steamed purple sweet potato in treatments P1 through P4 consistently increased antioxidant activity, with respective values of 48.40% (P1), 60.60% (P2), 70.60% (P3), and reaching a maximum of 83.00% in P4. This progressive enhancement is closely associated with the presence of antioxidant compounds, such as anthocyanins, in purple sweet potato, which are known to scavenge free radicals.[33] The mildly acidic yoghurt matrix (pH 4.5-4.8) stabilises the flavylium cation form of anthocyanins, preserving their hydrogen-donating capacity. At the same time, proteolytic release of peptides during fermentation provides additional electron donors, thereby elevating DPPH scavenging.[11] Moreover, anthocyanins help reduce inflammation and enhance immune responses against pathogens.[34]

According to Lestari et al.,[35] yoghurt enriched with purple sweet potato displays higher antioxidant activity than the tuber alone. Therefore, it can be concluded that incorporating steamed purple sweet potato into yoghurt significantly enhances its antioxidant potential, suggesting that natural ingredients such as purple sweet potato can effectively enrich yoghurt's functional value beyond its basic nutritional profile.

Pearson's correlation analysis across treatments (n = 25) revealed strong and significant relationships: pH versus titratable acidity (r = -0.941, P < 0.001), pH versus viscosity (r = -0.846, P < 0.001), and titratable acidity versus viscosity (r = 0.818, P < 0.001). These coefficients confirm that incremental addition of steamed purple sweet potato simultaneously lowers pH, raises lactic acid content, and thickens the gel, thereby strengthening the physicochemical evidence (Table 2).

Color measurement (L*a*b*)

The chemical structure of anthocyanins is highly influenced by pH, resulting in variations in color stability. Changes in pH can alter the molecular form of anthocyanins, thereby shifting the color expression from red to purple to blue, depending on the medium's acidity or alkalinity. Anthocyanins are more stable at low pH[36]; thus, their use as colorants in the food industry is not recommended under alkaline conditions.

The L* color parameter indicates the lightness of a product, with L* values ranging from 0 (black) to 100 (white).[37] Based on Duncan's multiple-range test results, the addition of steamed purple sweet potato significantly affected the lightness (L*) of yogurt. Treatments P4 and P3 were grouped in a different subset from P0, indicating that the addition of purple sweet potato significantly decreased the L* value compared to the control. Treatments P1 and P2 were intermediate between these groups, suggesting that at moderate concentrations, the influence

Table 3. Mean values of ANOVA results for the color of yoghurt with the addition of steamed purple sweet potato

Color Parameters	Experimental Treatments				
	P0	P1	P2	P3	P4
L*	89.21 ± 2.59[a]	84.73 ± 3.55[ab]	81.47 ± 4.43[bc]	78.41 ± 3.21[c]	76.69 ± 3.75[c]
a*	-3.51 ± 0.45[a]	-3.43 ± 1.38[a]	-7.48 ± 1.42[b]	-10.18 ± 1.93[c]	-12.01 ± 1.86[c]
b*	8.35 ± 1.01[a]	3.36 ± 1.54[b]	-0.12 ± 1.40[c]	-2.37 ± 1.48[d]	-3.83 ± 1.63[d]

P0 (control, without addition of purple sweet potato), P1 (addition 2% purple sweet potato), P2 (addition 4% purple sweet potato), P3 (addition 6% purple sweet potato), P4 (addition 8% purple sweet potato). Data are mean ± SD (n = 5). Based on ANOVA results, superscript letters[a-e] in the same row indicate significant differences (P < 0.05)

on lightness was still significant but less than at higher concentrations. The highest L* value was observed in the control treatment (P0, without purple sweet potato) at 89.21, while the lowest L* value was found in P4 (with 8% purple sweet potato) at 76.69 (Table 3). This indicates that increasing the addition of steamed purple sweet potato results in a darker yogurt color.

The a* color parameter measures the intensity of red (+) or green (-) hues in yogurt.[37] According to Duncan's multiple-range test, the a* value decreased with increasing steamed purple sweet potato concentration. Treatment P4 showed the lowest a* value (-12.012), followed by P3 (-10.13), P2 (-7.48), P0 (-3.51), and P1 (-3.42). All treatments yielded negative a* values, indicating that the yogurt color tended toward green or bluish-purple. This coloration results from anthocyanin pigments present in purple sweet potatoes; the higher the concentration added, the more intense the purple coloration becomes.

The b* value measures the color brightness on the blue-yellow spectrum, where positive values indicate a yellowish hue and negative values indicate a bluish hue.[37] In this study, the addition of steamed purple sweet potato significantly affected the b* value. According to Duncan's multiple-range test, treatment P0 (without purple sweet potato) had the highest b* value of 8.35, indicating the brightest color. Conversely, the treatment with the highest purple sweet potato concentration (P4) showed the lowest b* value of -3.83, indicating a darker, bluish hue. Higher L* values (lighter colour) in PSP-flour yoghurts compared with PSP-flour yoghurts[31] are attributed to limited thermal degradation of anthocyanins during 6 min steaming compared with prolonged drum-drying.

Sensory evaluation
Aroma

The organoleptic test showed that adding steamed purple sweet potato significantly increased the aroma intensity of yogurt. For the sweet potato aroma attribute, treatment P0 had the lowest score (1.40), while P4 had the highest score (4.12) (Table 4). Based on Duncan's multiple range test, there was no significant difference between treatments P2 (3.84) and P4 (4.13), as both were grouped in the same subset (subset 3) with a significance value of p = 0.214. This suggests that these concentrations were sufficient to produce a distinctive sweet potato aroma acceptable to the panelists. The observed increase is suspected to be due to volatile compounds formed during fermentation.[38]

Meanwhile, the highest sour aroma attribute was observed in treatment P3 (4.92), and the lowest in P0 (3.24). The addition of steamed purple sweet potato served as a carbohydrate source, supporting lactic acid bacteria metabolism and thereby enhancing the production of organic acids and volatile compounds that contribute to aroma.[38] However, further increases in concentration did not always have a significant effect once the optimum fermentation point was reached.

Color

Color is a critical parameter in organoleptic evaluation, as it provides an initial impression of product quality and appeal. Based on Duncan's

Table 4. Mean values of ANOVA results for the organoleptic evaluation of yoghurt with the addition of steamed purple sweet potato

Sensory Evaluation		Experimental Treatments				
		P0	P1	P2	P3	P4
Aroma	Sweet potato	1.40 ± 0.50[a]	2.60 ± 0.71[b]	3.84 ± 0.85[c]	4.08 ± 0.86[c]	4.13 ± 0.80[c]
	Sour	3.24 ± 0.72[a]	4.28 ± 0.54[bc]	4.04 ± 0.79[b]	4.92 ± 0.57[d]	4.46 ± 0.78[c]
Color		1.32 ± 0.48[a]	3.08 ± 0.28[b]	4.08 ± 0.28[c]	4.84 ± 0.55[d]	5.54 ± 0.51[e]
Texture		3.32 ± 0.69[a]	4.00 ± 0.58[b]	4.48 ± 0.71[c]	4.76 ± 0.72[c]	4.50 ± 0.51[c]
Taste	Sour	4.00 ± 0.65	4.12 ± 0.60	4.20 ± 0.71	4.48 ± 0.51	4.33 ± 0.56
	Sweet	4.04 ± 0.68	3.68 ± 0.69	3.96 ± 0.79	3.44 ± 0.58	3.88 ± 0.68
Overall Acceptability		4.04 ± 0.93[a]	4.36 ± 0.70[abc]	4.76 ± 0.66[bc]	4.32 ± 0.85[ab]	4.79 ± 0.66[c]

P0 (control, without addition of purple sweet potato), P1 (addition 2% purple sweet potato), P2 (addition 4% purple sweet potato), P3 (addition 6% purple sweet potato), P4 (addition 8% purple sweet potato). Data are mean ± SD (n = 5). Based on ANOVA results, superscript in the same row indicate significant differences ($P < 0.05$)

multiple range test results, there were significant differences ($p < 0.05$) in color parameters among treatments with the addition of steamed purple sweet potato (Table 4). The increase in color scores corresponded with the increasing concentration of steamed purple sweet potato in the yogurt, indicating that anthocyanins, the natural pigments present in purple sweet potatoes,[27] play a significant role in determining color intensity. Thus, the higher the concentration of purple sweet potato added, the stronger the yogurt's color intensity and, consequently, the higher the panelists' preference for the color. These results reinforce the role of natural colorants in enhancing the visual appeal of yogurt products.

Texture

The addition of steamed purple sweet potato significantly affected yoghurt texture, as evaluated by sensory panelists. The control treatment without purple sweet potato (P0) obtained the lowest texture score of 3.32 (Table 4). Gradual increases in purple sweet potato concentration led to higher texture scores, with the highest value recorded in treatment P3 at 4.76. This improvement indicates that higher proportions of steamed purple sweet potato in the formulation resulted in a firmer and more consistent yoghurt texture. This outcome is associated with the starch content in purple sweet potato, which reaches approximately 53%, of which about 75% is resistant starch. This component plays a crucial role in forming a stable gel structure and strengthening the milk protein matrix, thereby producing a thicker and more compact yoghurt texture.[39] These findings are consistent with a previous report,[40] which stated that the addition of purple sweet potato starch in low-fat yoghurt resulted in the highest gel firmness during storage, demonstrating its effectiveness in improving gel structure and overall yoghurt texture quality.

Taste

Taste is a complex sensory perception influenced by the interaction between gustatory and olfactory senses, and it is a key factor in food product acceptance.[41] For the sour taste attribute, the addition of steamed purple sweet potato did not show a statistically significant difference ($P > 0.05$) (Table 4). However, there was a tendency toward increased sourness. This increase is suspected to be due to amino acids produced during the fermentation of purple sweet potato, which can contribute to sour taste.[38] Conversely, for the sweet taste attribute, Duncan's multiple-range test showed a significant decrease in sweetness intensity as steamed purple sweet potato concentration increased. This decrease may be due to the dominance of sourness, which masks the perception of sweetness in the final product.

ANOVA analysis showed that the treatments had a significant effect on the panelists' overall liking of yogurt containing steamed purple sweet potato. Based on Duncan's multiple-range test, treatments P2 and P4 had higher overall liking scores than the other treatments (Table 4). This could be associated with the balanced sour-sweet taste profile produced, as well as the enhanced visual characteristics contributed by the purple sweet potato, which increased the yogurt's appeal to the panelists.

CONCLUSION

This study demonstrated that the addition of steamed purple sweet potato to yogurt significantly affected various physicochemical parameters, antioxidant activity, and sensory characteristics of the product. Increasing the concentration of purple sweet potato resulted in a decreasing pH, increased total lactic acid content and viscosity, and a darker color intensity due to the high anthocyanin content. The yogurt's antioxidant activity also consistently increased with the addition of steamed purple sweet potato, indicating enhanced functional potential. Organoleptically, the addition improved aroma, color, and texture intensity, with an optimal concentration range of 6%-8%. These findings translate into a practical formulation of 4%-6% steamed PSP for industrial low-fat yogurt, delivering a clean-label texture modifier and antioxidant claim without extra additives. The steaming step uses standard food-service steamers and can be slotted into existing fruit-preparation lines with minimal thermal load. Future studies should quantify probiotic survival during prolonged cold storage, assess *in vivo* bioaccessibility of PSP anthocyanins, and validate consumer acceptance beyond the young-adult panel evaluated here. These findings confirm that the use of steamed purple sweet potato not only enriches the nutritional and functional value of yogurt but also enhances its sensory appeal.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORS' CONTRIBUTION

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

FUNDING

None.

DATA AVAILABILITY

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

ETHICS STATEMENT

This study was approved by the Research Ethics Committee, Institut Kesehatan Helvetia (No. 027.1/EC/KEPK-IKH/06/2025).

INFORMED CONSENT

Written informed consent was obtained from the participants before enrolling in the study.

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