Scientific Papers. Series D. Animal Science. Vol. LXIX, No. 1, 2026
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

SUSTAINABLE UTILIZATION OF ROSE PROCESSING BY-PRODUCT IN THE PRODUCTION OF WHITE BRINED CHEESE

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Abstract

This study examines the incorporation of distilled Rosa damascena extract into traditional Bulgarian white brined cheese as a potential natural preservative. Cheese was produced from cow's milk and ripened in brine containing three concentrations of rose extract (0, 33.3, and 66.6 mg/kg) to assess its influence on physicochemical stability, microbial safety, and sensory quality. Standard analytical methods - including pH and titratable acidity measurement, salt and moisture analysis, Kjeldahl nitrogen fractionation, microbiological enumeration, and instrumental color and texture profiling - were applied before and after a 30-day ripening period and throughout refrigerated storage at the 1st, 3rd, and 6th month. The rose extract demonstrated antimicrobial and antioxidant activity, supporting controlled microbial growth and inducing subtle structural changes likely related to interactions with casein. Sensory evaluation indicated acceptable consumer perception across all samples. Overall, the findings show that integrating distilled rose extract into the brining process can enhance cheese quality while promoting sustainable practices through the valorization of aromatic plant by-products.

Key words*: antioxidant, rose, waste, White Brined cheese.*

INTRODUCTION

The increasing demand for sustainable food production has intensified interest in the valorization of agro-industrial by-products (Silva et al., 2025). The rose processing industry, particularly in regions known for essential oil production, generates substantial quantities of by-products rich in bioactive compounds, including polyphenols, flavonoids, and natural antioxidants (Kolev et al., 2025; Khezerlou et al., 2025; Mileva et al., 2021). Despite their potential functional value, these by-products are often underutilized or discarded, posing environmental and economic challenges (McCarthy et al., 2019).

White brined cheese is one of the most widely consumed varieties of cheese worldwide, valued for its mild flavor, high moisture content, and unique textural properties (Hayaloglu, 2017). Incorporating natural functional ingredients derived from plant by-products offers a promising strategy to enhance the nutritional profile, oxidative stability, and shelf life of such cheeses (Ritota & Pamela Manzi, 2020). The sustainable utilization of rose processing by-products in white brined cheese production aligns with circular economy principles by reducing waste while adding value to traditional dairy products.

The aim of the present study was valorisation of rose distillation by-products for improving the quality of traditional White Brined cheese.

MATERIALS AND METHODS

Cow milk – with the following composition: fat content 3.38 ± 0.10%; protein 3.26 ± 0.10%; pH 6.56 ± 0.10; solid-non-fat 8.64 ± 0.20%; Titratable acidity 17 ± 2°T, density 1.029 ± 0.025 g/mL; freezing point -0.568 ± 0.020°C; no added water. Starter culture - a combination of DVS cultures was used: White classic 1-01 (with composition *Lactobacillus delbrueckii* subsp. *bulgaricus*, *Lactococcus lactis* subsp. *cremoris*, *Lactococcus lactis* subsp. *lactis*, *Streptococcus thermophilus*) and LB 144-12 (with composition *Streptococcus thermophilus*,

Lactobacillus delbrueckii subsp. *bulgaricus*) from the company Novonesis Group.

Distilled rose flower extract - the extract was analyzed by Kolev et al. (2025) and the used quantity was according to a previous experiment (Vlahova-Vangelova et al., 2025).

Calcium dichloride - with a concentration of 33-35%, purchased from Biokom Trendafilov EOOD, Bulgaria.

Rennet enzyme – chymosin CHY-MAX® Supreme from Novozymes A/S, part of Novonesis Group in amount 35 mL/100 L milk.

Sensory analysis - was done by 7 trained specialists taste and aroma (10 points), consistency at 18-20°C (10 points), cut surface, structure and color (10 points), brine (10 points), appearance of the pieces (10 points) and packaging and labelling (10 points) adapted from BDS 15612-83.

White Brined Cheese production process - A whole raw cow's milk was received by a local farmer and was checked to ensure it meets quality requirements. The milk must arrive between +4°C and <10°C. After acceptance, the milk was submitted to standardization, adjusting the casein-to-fat ratio to approximately 0.70 ± 0.20. The standardized milk was pasteurized at 72-74°C for 10 min, followed by cooling to 36 ± 2°C. At this stage, a direct-vat-set (DVS) starter culture was added, consisting of White Classic and LB 144-12, dosed at 1.5 g and 20 g per 100 L of milk, respectively. Then, calcium chloride (37%), previously diluted 1:10 in potable water, was added at a concentration of 50 mL per 100 L. Immediately afterward, chymosin (rennet enzyme) also diluted 1:10 was introduced at 35 mL per 500 L of milk. The milk was left to coagulate for 60 min at 34 ± 2°C. Once a firm curd has formed, it was cut vertically and horizontally into 2 cm cubes. The curd was allowed to rest for 15 min, followed by gentle turning to promote whey expulsion. This operation was repeated 5 times until reached the desired curd density. The curd was formed and a whey was separated. Then it was self-pressed and additionally drained over night at 20 ± 2°C. The drained curd was cut into blocks (approximately 123 × 123 mm) and placed into containers when active acidity reaches 5.2 ± 0.2 (or 170°T). Then it was submitted to pre-ripening process and dry salting with amount of salt 30 g/kg cheese at 20°C for 24 h. Cheese acidity reached pH 5.0 or 180-200°T. Next, the cheese was immersed in brine composed of water, salt, and lactic acid. The brine had a salt concentration of 5-6% and acidity of pH (4.0-4.5) reached by addition of lactic acid. Three different batches of white brined cheese were produced - with 0 mg/kg rose petals extract in brine (0WBC - control sample), with 33 mg/kg rose petals extract in brine (33WBC) and with 66 mg/kg rose petals extract in brine (66WBC). The cheese was submitted to ripening at 12°C for 30 days in brine. Finally, the matured cheese was packaged under vacuum, and stored at 2-4°C, for up to 6 months. The obtained cheese is presented on Figure 1.



Figure 1. White Brined Cheese matured in brine with rose petals extract (Source: author's own photograph)

Physicochemical analysis - fat content was measured using the Gerber volumetric technique (BDS ISO 19662:2019); dry matter - assessed with a KERN DBS moisture analyser; salt content - determined by the Mohr titration method following BDS 8274-82; ash content - evaluated according to BDS 6154:1974; active and titratable acidity - active acidity was quantified potentiometrically using a 7110 WTW (Germany) pH meter, while titratable acidity was established following the procedure described in BDS 1111-80.

Texture analysis - The texture parameters: hardness, cohesiveness, elasticity, gumminess, chewiness were obtained by analysis of cheese slices (15 mm thick and 60 mm in diameter) using a TX-700 analyzer equipped with a 25 kg strain gauge (Lamy Rheology, Champagne au Mont d'Or, France). A double compression method with a ½ spherical probe (30 mm in diameter) to compress 70% of the initial height at a compression rate of 1 mm/s and a 5-s delay between compressions was applied. The data

were processed using Rheotex software version 2.55 (Lamy Rheology, Champagne au Mont d'Or, France). The results from the measurements were calculated as described by Estevez et al. (2005).

Color - using the chroma meter cr-410, to evaluate the color of the surface and the cut surface;

Protein content and maturity level - Total nitrogen (TN), protein, non-casein nitrogen (NCN), non-protein nitrogen (NPN), and water-soluble nitrogen (WSN) were quantified following BDS EN ISO 8968-1:2014. Biogenic amines content was determined according to the following procedure: aqueous standard solutions of cadaverine, putrescine, tyramine, and histamine (Sigma, St. Louis, MO) were derivatized using the same procedure as for cheese samples. Biogenic amines were quantified according to Eerola et al. (1993) by HPLC-DAD using an ELITE LaChrom system (Hitachi) with a Purospher STAR C18 column (4.6 × 150 mm, 5 µm). Dansylated amines were detected at 254 nm, and quantification was performed using external standards.

Total phenolic content - Determined using a modified Folin-Ciocalteu assay (Pimentel-González et al., 2014). One milliliter of sample was combined with 5 ml diluted Folin-Ciocalteu reagent (1:10). After 6 min, 4 ml of 20% Na_2CO_3 was added, followed by 2 h incubation at room temperature (25 ± 0.5°C). Absorbance at 760 nm was read using a UV-Vis spectrophotometer. Results are expressed as mg gallic acid equivalents per gram of cheese.

Antioxidant activity - DPPH assay (Amirdivani et al., 2011): 250 µL cheese extract was vigorously mixed with 3 ml DPPH and stored in the dark at room temperature (25 ± 0.5°C) for 30 min. A control was prepared similarly, substituting the extract with 250 µL distilled water. Absorbance was measured at 517 nm, and activity expressed as mmol TE/100 ml. FRAP assay (Benzie and Strain, 1996): Supernatant was mixed with 50 ml acetate buffer, 5 ml TPTZ solution, and 5 ml $FeCl_3$, then incubated at 37 °C for 15 min. Absorbance of the coloured complex was measured at 593 nm. Results were expressed as mM TE/ml.

Microbiological analyses - The tested cheese samples are prepared according to ISO 6887-5:2020. Cheese samples were analyzed for the viable counts of different microbial groups: lactococci and lactobacilli were enumerated according to ISO 15214:1998, *Enterobacteriaceae* according to ISO 21528-2:2017, yeasts and molds were enumerated according to ISO 21527-1:2008, coagulase-positive *Staphylococcus aureus* according to ISO 6888-1:2021, and *E. coli* according to ISO 16649-2:2001/Amd 1:2017, while *Listeria monocytogenes* was detected according to ISO 11290-1:2017, and *Salmonella* spp. were detected by presence/ absence testing following ISO 6579-1:2017.

Statistical analysis - Data are presented as mean ± standard deviation (n = 4). Each experiment included four replicates, comprising two independent technological replicates and two analytical measurements per replicate. Statistical evaluation was performed using one-way analysis of variance (ANOVA). Differences between sample means were assessed using the least significant difference (LSD) post hoc test. Statistical significance was considered at $p < 0.05$.

RESULTS AND DISCUSSIONS

The results obtained from the physicochemical analysis are presented in Table 1.

Table 1. Physicochemical analysis of White Brined Cheese matured in brine with rose petals extract

Indicator	Sample	Ripening period		Storage period		
		1 day	60 days	1 month	3 months	6 months
Titratable acidity, °T	0WBC	224±2	223±2	264±2	238±2	218±1
	33WBC		235±2	240±	172±1	206±1
	66WBC		220±2	258±2	184±2	212±1
pH	0WBC	4.84±0.02	4.74± 0.05	4.80± 0.12	4.54± 0.40	4.57±0.12
	33WBC		4.70± 0.04	4.55± 0.12	4.72± 0.25	4.61±0.13
	66WBC		4.76± 0.05	4.60± 0.14	4.58± 0.14	4.64±0.22
Fat, %	0WBC	17.75±0.12	17.25± 0.75	19.50± 0.15	21.50± 1.22	19.50± 1.56
	33WBC		17.50± 0.69	18.50± 1.12	20.50± 2.00	22.00± 2.02
	66WBC		17.50± 0.45	19.00± 1.25	19.00± 1.48	19.75± 2.45
Dry matter, %	0WBC	46.62±2.22	42.49± 3.10	45.47± 2.02	49.30± 2.13	45.50± 2.12
	33WBC		45.96± 3.11	41.90± 2.55	50.15± 2.75	50.37± 2.08
	66WBC		47.36± 2.42	44.07± 2.46	48.07± 2.69	46.60± 2.33
Salt, %	0WBC	3.28±0.04	4.74± 0.05	3.51± 0.04	3.16± 0.10	3.51±0.05
	33WBC		4.39± 0.04	3.28± 0.06	3.63± 0.12	3.28±0.06
	66WBC		3.92± 0.05	3.29± 0.07	3.28± 0.07	3.16±0.08
Ash, %	0WBC	4.45±0.06	4.41± 0.05	3.87± 0.20	3.82± 0.07	3.86±0.06
	33WBC		4.73± 0.06	3.78± 0.11	3.93± 0.13	3.74±0.09
	66WBC		4.08± 0.07	3.93± 0.12	3.47± 0.14	3.88±0.14
Protein, %	0WBC	17.47±2.10	17.71± 1.23	18.79± 2.12	20.5± 1.12	18.46± 1.23
	33WBC		18.12± 2.22	18.98± 1.15	19.38± 1.05	19.05± 1.05
	66WBC		17.77± 1.05	18.97± 1.55	18.78± 2.00	20.11± 1.45

The physicochemical changes observed in Table 1 are typical for the ripening of white brined cheese and correlate with results reported in similar studies (Öner et al., 2006). The evolution of pH and titratable acidity follows normal trends associated with lactic fermentation and proteolysis, comparable to those described for Feta-type and white brined cheeses (Hayaloglu, 2017). Cheeses containing rose extract showed slightly higher acidity. This is in agreement which reports on cheeses enriched with plant extracts, where phenolic compounds were shown to influence acidification dynamics (Ritota & Manzi, 2020).
The increase in fat, protein, and dry matter content during ripening and storage is due to moisture loss, in line with findings reported by Pimentel-González et al. (2014) and other studies on brined cheeses. Similar data were found in cheeses supplemented with different herbal or antioxidant extracts, without negative influence on technological quality. Salt and ash contents remained within the typical ranges reported for white brined cheeses. This indicated that rose extract addition did not affect salt diffusion or mineral balance.
Table 2 represents the degree of ripeness and the presence of biogenic amine in the end of the storage period.

Table 2. Degree of ripeness and presence of biogenic amines in White Brined Cheese matured in brine with rose petals extract

Indicator	Sample	Ripening period		Storage period		
		1 day	60 days	1 month	3 months	6 months
NCN/TN, %	0WBC	5.07± 0.12	6.57± 0.12	5.22± 0.17	6.38± 0.14	6.18± 0.15
	33WBC		5.33± 0.14	4.08± 0.15	5.10± 0.14	5.32± 0.14
	66WBC		6.06± 0.15	4.46± 0.14	5.86± 0.15	6.15± 0.16
NPN/TN, %	0WBC	4.06± 0.14	4.82± 0.02	4.33± 0.15	4.94± 0.15	5.44± 0.17
	33WBC		3.83± 0.25	3.11± 0.16	3.87± 0.20	4.24± 0.21
	66WBC		4.53± 0.33	2.90± 0.15	4.46± 0.16	5.12± 0.09
WSN/TN, %	0WBC	4.24± 0.15	4.25± 0.25	3.33± 0.14	3.17± 0.16	3.39± 0.15
	33WBC		3.87± 0.26	2.15± 0.14	3.29± 0.19	3.22± 0.15
	66WBC		4.24± 0.26	2.22± 0.09	3.26± 0.14	3.68± 0.14
Putrescine, mg.kg^{-1}	0WBC	-				24.0±2.4
	33WBC	-				18.5±1.9
	66WBC	-				22.0±2.2
Cadaverine, mg.kg^{-1}	0WBC	-				19.0±1.9
	33WBC	-				14.5±1.5
	66WBC	-				17.0±1.7
Histamine, mg.kg^{-1}	0WBC	-				15.0±1.5
	33WBC	-				11.5±1.2
	66WBC	-				14.0±1.4
Tyramine, mg.kg^{-1}	0WBC	-				85.0±8.5
	33WBC	-				64.0±6.4
	66WBC	-				78.0±7.8

Values below 10 mg.kg^{-1} are below the limit of quantification (LOQ), i.e. they are outside the accuracy of the standard line.

The obtained results (NCN/TN, NPN/TN, and WSN/TN) show the extent of proteolysis occurring during ripening and storage of white brined cheese. The control sample (0WBC) presented showed progressive protein breakdown and accumulation of soluble nitrogen compounds demonstrated by the increase in NCN/TN and NPN/TN values. This indicates a slight evolution in cheese maturation. However, the results remain higher compared to those of other authors (Hayaloglu et al., 2002).
The relatively stable WSN/TN values observed during ripening may be attributed to the limited proteolysis typical for brined cheeses, where low pH, high salt concentration, and refrigerated storage conditions restrict enzymatic activity. Additionally, phenolic compounds from the rose extract may interact with casein or inhibit proteolytic enzymes, reducing the formation of water-soluble nitrogen fractions. This may be associated with interactions between phenolic compounds from the rose extract and casein fractions or microbial enzymes, as reported for cheeses supplemented with plant-derived bioactive compounds (Salik and Çakmakçi, 2024).
Biogenic amine accumulation in the studied white brined cheese after six months of storage remained low in all samples, with cheeses supplemented with rose petal extract generally showing lower concentrations compared to the control. The detected histamine levels (11.5-15.0 mg·kg^{-1}) were considerably below the commonly accepted safety threshold of 50-100 mg·kg^{-1} for fermented foods and below levels considered potentially hazardous by the EFSA Panel on Biological Hazards (2011), while regulatory limits established by the European Commission apply mainly to fish products. These values are lower than those reported for traditional and long-ripened cheeses, where concentrations may exceed 50 mg·kg^{-1} (Novella-Rodríguez et al., 2002; Natrella et al., 2024). Tyramine was the predominant amine (64.0-85.0 mg·kg^{-1}), which is typical for lactic acid fermentation, and the observed concentrations remained below those reported for long-ripened hard cheeses (>400 mg·kg^{-1}) (Spano et al., 2010; Ruiz-Capillas and Herrero, 2019) and under the safety threshold for healthy individuals (Linares et al., 2012). Putrescine (18.5-24.0 mg·kg^{-1}) and cadaverine

(14.5-19.0 mg·kg⁻¹) were also present at relatively low levels consistent with properly manufactured white brined cheeses (Andiç et al., 2010; Buňková, 2025), indicating limited proteolytic degradation and good hygienic practices (Alvarez & Moreno-Arribas, 2014; Doeun et al., 2017). The total biogenic amine content (108.5-143.0 mg·kg⁻¹) remained markedly below levels associated with defective fermentation (>500-1000 mg·kg⁻¹) (Ruiz-Capillas & Herrero, 2019), and the reduced accumulation observed in treated samples may be attributed to the antimicrobial activity of polyphenolic compounds present in plant extracts (Ritota & Manzi, 2020; Wang et al., 2021; Zhang et al., 2017).

The microbiological dynamics in the ripening and storage processes of the productc are presented in Figures 2 and 3.

From the results presented in Figure 2, it can be seen that in the initial stage of ripening of the White Brined Cheese, no significant difference was observed in the values of lactobacilli (8.2-8.3 log CFU/g) among all samples. These results are in accordance with the data presented by other studies, which show that rose petal extract does not have an inhibitory effect on the starter

culture in dairy products (Dimitrova et al., 2019). In the present study, at the end of ripening (60 days), an increase in the count of lactobacilli was observed in all samples (8.9 log CFU/g), which can be associated with the active phase of development of lactic acid microflora during ripening (Özer, 2014).

In the current investigation, all experimental variants showed a gradual decrease in the lactobacilli count during the storage period of 1, 3, and 6 months (Figure 2).

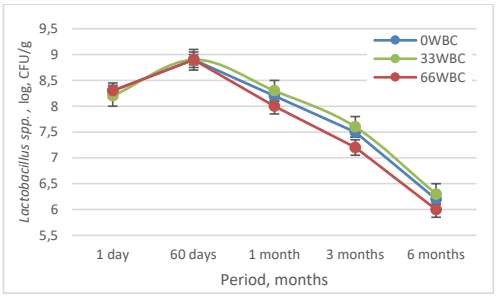

Figure 2. Dynamics of lactobacilli in White Brined Cheese matured in brine with rose petals extract

At the end of storage (6 months), the values reached 6.2 log CFU/g for the control sample (0WBC), 6.3 log CFU/g for 33WBC, and 6.0 log CFU/g for 66WBC, respectively.

The sample with a lower concentration of the extract (33WBC) followed the dynamics of the control sample (0WBC) without significant deviations. In the sample 66WBC, a less pronounced, but earlier occurring population reduction was observed during the storage period, which suggests a possible dose-dependent effect of the extract.

Figure 3 shows the dynamics of lactococci in studied samples (0WBC, 33WBC and 66WBC). According to the findings, there were no statistically significant changes between the control sample and the samples with added extract on the first day of ripening. The count of lactococci was relatively high and comparable among all samples ranging between 8.9-9.0 log CFU/g. This suggests that rose petal extract does not affect the initial microbial population in White Brined Cheeses.

After 60 days of ripening and the first month of storage, high levels of lactococci were also observed in all samples. The samples 33WBC and 66WBC were characterized by slightly lower values compared to the control sample (0WBC), but the differences were minimal and within the standard deviations.

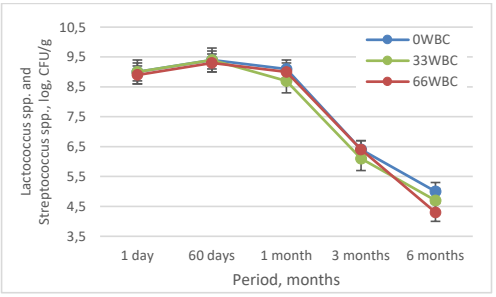

Figure 3. Dynamics of lactococci in White Brined Cheese matured in brine with rose petals extract

During prolonged storage (3 and 6 months), a significant decrease in the count of lactococci was observed in all samples. The samples matured in brine with rose petals extract (33WBC and 66WBC) showed a more pronounced decrease in lactococci count compared to the control (0WBC), with the values reaching about 4.3-4.7 log CFU/g at 6

months, while in the control they were slightly higher (about 5.0 log CFU/g). This is probably due to the antimicrobial effect of the rose petal extract during a longer storage period, which may be due to the presence of phenolic compounds and other bioactive substances in the plant extract. The results obtained indicate that the addition of rose petal extract in the studied concentrations does not significantly affect the development and survival of lactic acid microflora during ripening and storage of the White Brined Cheese.

The microbiological analysis of White Brined Cheese showed that all main sanitary-hygienic and pathogenic indicators remained within the acceptable limits or below the detection limits (Table 3). Regarding coliforms, *E. coli*, and *Staphylococcus aureus*, in all samples after 6 months of storage, the values remained below 10 CFU/g sample, indicating microbiological safety and a low level of secondary contamination. Similar low values have been reported in other studies of traditional White Brine cheeses (Makarijoski, 2023; Plessas et al., 2021).

Table 3. Microbiological analysis for basic sanitary and hygienic indicators of White Brined Cheese matured in brine with rose petals extract

Indicator	Sample	Ripening period		Storage period		
		1 day	60 days	1 month	3 months	6 months
Coliforms, log CFU/g	0WBC	-				Under 1
	33WBC	-				Under 1
	66WBC	-				Under 1
E. coli, log CFU/g	0WBC	-				Under 1
	33WBC	-				Under 1
	66WBC	-				Under 1
Salmonella subsp. presence/absence	0WBC	-				nd
	33WBC	-				nd
	66WBC	-				nd
L. monocytogenes, presence/absence	0WBC	-				nd
	33WBC	-				nd
	66WBC	-				nd
Staphylococcus aureus, log CFU/g	0WBC	-				Under 1
	33WBC	-				Under 1
	66WBC	-				Under 1
Molds/yeasts, log CFU/g	0WBC	-	3.5	-		2.4
	33WBC	-	4.5	-		2.4
	66WBC	-	4.0	-		2.3

"-" – not determined; nd – not detected

In the preset study, during ripening and storage periods in none of the examined variants of White Brined Cheeses was detected the presence of *Salmonella* subsp. and *Listeria monocytogenes* which is in accordance with the requirements of Commission Regulation (EC) No 2073/2005 (Commission Regulation, 2005).

A more significant difference was observed among the samples in the count of yeasts and molds. At 60 days of ripening, the control sample was characterized by yeast and mold values 3.5 log CFU/g, while the samples matured in brine with rose petals extract demonstrated significantly higher values (4.5 log CFU/g at 33WBC and 4.0 log CFU/g at 66WBC, respectively). However, at the end of the 6-month storage period, the count of yeasts and molds in the fortified samples decreased to levels similar to the control (2.4 log CFU/g for 33WBC and 2.3 log CFU/g for 66WBC vs. 2.4 log CFU/g for 0WBC). In a previous study on the antimicrobial activity of rose petal extract against some strains of molds and yeasts, it was found that the extract exhibits antifungal effects, making it suitable for application in food products (Kolev et al., 2025).

Table 4 represents texture analysis of White Brined Cheese matured in brine with rose petals extract

Table 4. Texture analysis of White Brined Cheese matured in brine with rose petals extract

Indicator	Sample	Ripening period		Storage period		
		1 day	60 days	1 month	3 months	6 months
Hardness, N	0WBC	11.87± 3.56	8.67± 1.65	20.35± 8.91	16.14± 2.43	11.65± 3.10
	33WBC		12.15± 2.19	14.64± 1.84	14.63± 2.29	15.31± 3.24
	66WBC		9.46± 1.89	10.23± 1.86	14.18± 4.25	10.81± 3.19
Cohesion	0WBC	0.26± 0.02	0.22± 0.02	0.23± 0.02	0.27± 0.02	0.33± 0.05
	33WBC		0.24± 0.04	0.28± 0.03	0.21± 0.03	0.26± 0.06
	66WBC		0.30± 0.07	0.34± 0.06	0.29± 0.12	0.26± 0.04
Elasticity	0WBC	0.35± 0.05	0.31± 0.06	0.35± 0.03	0.58± 0.08	3.57± 1.64
	33WBC		0.39± 0.10	0.55± 0.10	0.48± 0.06	1.81± 1.70
	66WBC		0.51± 0.11	0.63± 0.12	0.51± 0.10	3.44± 1.43
Gumminess, N	0WBC	3.05± 1.01	1.92± 0.44	4.76± 2.51	4.37± 0.60	3.75± 0.98
	33WBC		2.96± 0.72	4.17± 0.80	3.15± 0.72	3.86± 1.02
	66WBC		2.85± 0.66	3.48± 0.88	3.96± 1.12	2.71± 0.76
Chewiness, N	0WBC	1.10± 0.51	0.61± 0.26	1.64± 0.82	2.56± 0.66	11.45± 4.91
	33WBC		1.19± 0.55	2.33± 0.82	1.54± 0.51	8.24± 9.25
	66WBC		1.48± 0.61	2.27± 0.96	2.06± 0.74	8.86± 3.66

The obtained results demonstrated that the texture parameters of white brined cheese were influenced by ripening time and the addition of rose petals extract. Their represented a

combined influence of different chemical changes in cheeses. Some indices - hardness, gumminess, and chewiness increased during storage, indicating progressive structure strengthening, particularly after prolonged storage. Sample with rose extract showed comparable (66WBC) or moderated (33WBC) hardness and higher elasticity (66WBC) compared to the control. Fox and McSweeney (2017) suggested that protein matrix rearrangement and water loss led to increased firmness in brined cheeses. This was a possible explanation why the extract affected the structural stability and flexibility of the cheese matrix. It is in correlation with the results reported by (Yerlikaya et al., 2020). The demonstrated increase in moisture content (0WBC and 66WBC) decreased hardness, while an increase in fat content (33WBC) increased elasticity. Lower gumminess in extract-treated cheese with highest applied dose (66WBC) may result from reduced protein aggregation intensity. This is an indirect correlation with the values reported for hardness and cohesiveness of the sample (Alkhalaileh, 2024).

Table 5 represents the results for the determined antioxidant activity as well as the total phenolic compounds (TPC) values.

Table 5. Total phenolic content and antioxidant activity of White Brined Cheese matured in brine with rose petals extract

Indicator	Sample	Ripening period		Storage period		
		1 day	60 days	1 month	3 months	6 months
TPC (mg GAE/g)	0WBC	476.22 ±1.94	982.99 ±5.25	484.80 ±1.38	524.12± 2.71	542.28± 3.03
	33WBC	974.20 ±5.28	975.59 ±5.36	1004.66±5.72	1021.16 ±5.40	1026.70 ±5.91
	66WBC	975.42 ±5.24	985.42 ±5.68	966.91 ±5.59	1024.65 ±5.63	1021.37 ±5.62
DPPH, µmol TE/g	0WBC	8.94± 1.38	21.14 ±1.12	10.82± 0.93	6.54± 0.69	6.63±0. 70
	33WBC	117.33 ±1.97	103.05 ±1.72	126.69 ±1.17	118.97± 1.52	119.18± 1.88
	66WBC	120.26 ±1.99	115.87 ±1.56	125.13 ±2.07	124.93± 1.31	125.81± 1.93
FRAP, µmol TE/g	0WBC	13.06± 1.10	3.93 ±0.74	10.95± 0.68	13.41±0 .79	13.13± 0.71
	33WBC	8.92± 0.54	7.45 ±0.92	8.43± 0.62	9.22± 0.72	9.24± 0.51
	66WBC	4.66± 0.60	4.66± 1.07	7.80± 0.75	7.76± 0.82	6.73± 0.68

The statistical analysis revealed that both extract concentration and storage time influenced the total phenolic content of the cheese (Table 5). The effect of sample was high, while storage period also was important. Moreover, an interaction between sample and storage period was observed, indicating that changes in TPC during storage depended on the concentration of rose petal extract added to the brine.

Cheeses containing rose petal extract had considerably higher phenolic content compared with the control sample. The control cheese (0WBC) showed the lowest TPC value, while cheeses produced with 33 mg/kg and 66 mg/kg extract exhibited significantly higher values (Table 5). The analysis confirmed that both enriched samples differed from the control, whereas no difference was detected between the two extract concentrations.

This result suggests that the incorporation of rose petal extract effectively enriches the cheese with phenolic compounds, although increasing the concentration above 33 mg/kg does not result in a further significant increase.

The increase in TPC during the early stages of ripening can be attributed to several biochemical processes occurring within the cheese matrix. During cheese maturation, proteolysis and lipolysis modify the protein network and release phenolic compounds that may initially be bound to proteins or other macromolecules. In addition, diffusion of phenolic compounds from the brine into the cheese matrix continues during ripening, which can further increase the measurable phenolic content. These structural changes enhance the extractability and detectability of phenolic compounds in the cheese.

The antioxidant activity measured by the DPPH radical scavenging method showed a strong dependence on the extract concentration (Table 5). The analysis demonstrated a high effect of sample, indicating that the addition of rose petal extract markedly enhanced the radical scavenging capacity of the cheese. In contrast, the storage period did not influence DPPH activity, and the interaction between sample and storage was also not important.

These findings indicate that the antioxidant activity determined by the DPPH assay is mainly associated with the presence of phenolic compounds introduced through the rose petal extract rather than changes occurring during storage (Vlahova-Vangelova et al., 2025). The absence of significant storage effects suggests that the antioxidant compounds remain relatively stable within the cheese matrix during ripening and refrigerated storage.

Phenolic compounds are known to possess strong free radical scavenging properties due to their ability to donate hydrogen atoms or electrons to neutralize free radicals. Rose petals are particularly rich in flavonoids, phenolic acids, and anthocyanins, which are recognized for their antioxidant potential. Therefore, the higher DPPH activity observed in the extract-enriched cheeses can be directly attributed to the higher phenolic content provided by the rose petal extract (Kolev et al., 2025).

Similar trends were observed for FRAP values, which measure the reducing power of antio-xidant compounds. The FRAP assay reflects the ability of antioxidants to reduce ferric ions (Fe^{3+}) to ferrous ions (Fe^{2+}), indicating their electron-donating capacity. In general, samples enriched with rose petal extract exhibited higher FRAP values compared with the control cheese, confirming the enhanced antioxidant potential of the fortified cheeses (Table 5).

The relationship between FRAP values and phenolic content is well documented in food systems, as many phenolic compounds act as reducing agents (Vlahova-Vangelova et al., 2025). Therefore, the increased FRAP activity in cheeses containing rose petal extract is consistent with the higher levels of phenolic compounds observed in these samples. Furthermore, the relatively stable FRAP values during storage suggest that the antioxidant compounds remain stable in the cheese matrix throughout ripening and refrigerated storage.

Overall, the results demonstrate a strong relationship between total phenolic content and antioxidant activity measured by both DPPH and FRAP assays. Cheeses enriched with rose petal extract consistently exhibited higher phenolic content and stronger antioxidant activity than the control sample. This correlation indicates that phenolic compounds are the primary contributors to the antioxidant capacity of the enriched cheeses.

The stability of antioxidant activity during storage is an important technological advantage, as it suggests that functional dairy products enriched with plant extracts can maintain their bioactive properties throughout their shelf life. The cheese matrix may also provide protective effects against oxidation or degradation of phenolic compounds by limiting exposure to oxygen and light.

The results clearly demonstrate that the addition of rose petal extract to the brine significantly enhances the antioxidant properties of white brined cheese. The enriched cheeses showed higher phenolic content and improved antioxidant capacity compared with the control sample. Moreover, these bioactive compounds remained relatively stable during ripening and refrigerated storage.

Table 6. Color of the cut surface of White Brined Cheese matured in brine with rose petals extract

Indicator	Sample	Ripening period		Storage period		
		1 day	60 days	1 month	3 months	6 months
Color of the cut surface						
L*	0WBC	90.12± 0.19	90.16± 0.26	90.13± 0.14	90.86± 0.35	90.71± 0.12
	33WBC		91.16± 0.50	90.63± 0.22	90.68± 0.61	90.59± 0.16
	66WBC		90.84± 0.92	90.78± 0.25	91.61± 0.21	90.04± 0.31
a*	0WBC	-1.95± 0.11	-1.56± 0.07	-1.69± 0.15	-2.05± 0.09	-1.71± 0.07
	33WBC		-1.79± 0.10	-2.19± 0.66	-2.07± 0.16	-1.67± 0.11
	66WBC		-1.69± 0.12	-1.51± 0.14	-1.66± 0.03	-1.28± 0.08
b*	0WBC	18.09± 0.24	18.45± 0.10	18.04± 0.50	16.69± 0.63	16.70± 0.14
	33WBC		17.84± 0.24	18.60± 0.21	17.28± 0.83	16.66± 0.22
	66WBC		16.66± 0.52	16.04± 0.25	14.99± 0.28	16.89± 0.115
C*	0WBC	18.19± 0.25	18.52± 0.11	18.12± 0.51	16.82± 0.63	16.77± 0.20
	33WBC		18.03± 0.25	18.73± 0.22	17.41± 0.84	16.72± 0.24
	66WBC		16.92± 0.52	16.11± 0.25	15.08± 0.27	16.93± 0.14
h	0WBC	96.16± 0.30	94.83± 0.21	95.35± 0.42	97.00± 0.29	95.81± 0.20
	33WBC		95.68± 0.24	96.700.1 5	96.83± 0.36	95.76± 0.25
	66WBC		95.52± 0.26	95.540.2 7	96.32± 0.17	94.33± 0.19

The color parameters of the cut surface of white brined cheese matured in brine with rose petals extract showed high stability throughout ripening and storage. The addition of rose petals extract to the brining solution preserved the typical color characteristics of white brined cheese, maintaining high lightness and stable hue values throughout ripening and storage, while slightly reducing yellowness and color intensity at higher extract concentrations. The lightness values (L*) remained consistently high in all samples, indicating preservation of the typical bright white appearance of the cheese. Negative a* values in all samples confirmed the characteristic slight greenish tone of white brined cheese less pronounced in the sample with the highest dose of applied rose petals extract (66WBC). This indicated a reduction in green hues, which may be associated with the presence of plant pigments and phenolic compounds from the extract. The yellowness parameter (b*) and chroma (C*)

generally decreased during storage but were found similar for both three samples. Rose petals are rich in antioxidant compounds, including phenolic and flavonoids, which may limit lipid oxidation and pigment degradation, thereby contributing to the observed color stability (Felix da Silva et al., 2015). Hue angle values remained within typical range, confirming that the dominant yellowish color, typical of white brined cheese from cow milk, was maintained regardless of treatment (Kandyliari et al., 2023).

The results for the sensory analysis are presented on Figure 4.

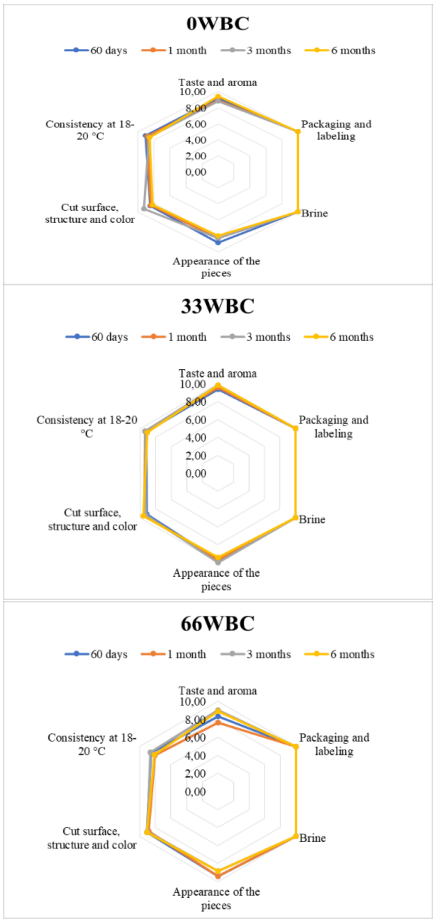

Figure 4. Sensory analysis of White Brined Cheese matured in brine with rose petals extract

It is well known that ripening significantly improves flavor development and texture due to biochemical processes such as proteolysis (Massouras et al., 2023). In white brined cheese the sensory changes are mainly due to pH decrease and protein breakdown. In the present study taste and aroma were both enhanced by the addition of rose petals extract. It is in correspondence with results of other authors who found that different herbs and plant extracts could contribute to excellent sensory scores (Hayaloglu & Farkye, 2011). According to Shahidi & Ambigaipalan (2015) some plant phenolic extracts can also improve overall sensory acceptability. The present findings are further supported by research on the incorporation of herbs and plant extracts in dairy products, which demonstrated that phenolic compounds enhance aroma and flavor while maintaining consumer acceptability (Setyawardani et al., 2023). It is evident that sample 66WBC had values closer to those of the control, while sample 33WBC has the highest score on all indicators, which indicates its preference by consumers.

CONCLUSIONS

The obtained results confirmed that the incorporation of rose petals extract preserved the physicochemical stability of white brined cheese. Low dose extract reduced proteolysis by partially inhabiting the activity of proteolytic enzymes. This resulted in a decrease in soluble nitrogen fractions and therefore a slowdown in cheese maturation. Incorporating rose could be a way to modulate the ripening speed, to adjust the texture and aroma development of the final product according to consumer preferences. The incorporation of rose petals extract did not affect the visual characteristics of white brined cheese and preserved the characteristic color profile during storage. The present study on plant-waste derived extracts in white brined cheese reported improved taste and aroma, appearance, and acceptable texture, confirming the potential of natural extracts as functional ingredients.

These findings suggest that rose petal extract can be successfully used as a natural functional ingredient in dairy products, contributing not only to improved antioxidant properties but also to the development of value-added cheeses with potential health-promoting benefits.

ACKNOWLEDGEMENTS

This research was financially supported by projects KP-06-Slovakia/7 from 13.08.2024 and APVV-SK-BG-23-0002 (grant 27A4-A-64039).

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