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Fermented milks with the addition of flour from cultivated rosehip

Ферментирали млека с добавка на брашно от култивирана шипка

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ABSTRACT

Yogurt is a traditional product in the Republic of Bulgaria that contains the lactic acid bacteria *Lactobacillus delbrueckii* sp. *bulgaricus* and *Streptococcus thermophilus*. In this study, three types of yogurt were produced - according to the classical technology (control sample) without the addition of rosehip flour, yogurt with 2% rosehip flour, and a sample with 2% encapsulated rosehip flour. The samples obtained were stored for 14 days. The yogurt samples were analysed for sensory, chemical, microbiological, and textural properties on the 1st and 14th day of storage. The results show that the type of sample and the storage period significantly influence parameters such as active acidity, dry matter, ascorbic acid content, fibres, protein and fatty acid composition. In the samples with added rose hip flour were observed double the higher values of antioxidant activity and phenolic content. The samples with directly added rosehip flour showed better sensory properties than the reference sample and the sample with encapsulated rosehip flour. The addition of rosehip flour improved the coagulation and consistency of the yogurt. On the 14th day of storage, the highest value for water-holding capacity was recorded for yogurt with directly added rosehip flour.

Keywords: omega-3, omega-6, vitamin C, antioxidants, functional, dietary fibers

АБСТРАКТ

Киселото мляко е традиционен продукт за Република България съдържащ млечнокиселите бактерии *Lactobacillus delbrueckii* sp. *bulgaricus* и *Streptococcus thermophilus*. В това проучване са произведени три вида кисели млека - по класическа технология (контрола) без добавено шипково брашно, кисело мляко с 2% брашно от шипка и проба с 2% енкапсулирано брашно от шипка. Получените проби са съхранявани в продължение на 14 дни. След коагулация пробите са анализирани по сензорни, химични, микробиологични и текстурни характеристики на 1ви и 14ти ден от съхранението. Получените резултати показват, че видът на пробата и периодът на съхранение оказват съществено влияние върху показателите активна киселинност, сухо вещество, съдържание на аскорбинова киселина, хранителни фибри, протеини и мастнокиселинен състав. Наблюдават се двойно по-високи стойности на антиоксидантна активност и фенолното съдържание в пробите с добавено шипково брашно. Пробите с директно вложено шипково брашно показват подобрени сензорни характеристики в сравнение с контролата и пробата с капсулирано шипково брашно. Коагулацията и консистенцията на киселото мляко се подобряват от вложеното шипково брашно. Най-висока стойност на капацитет на задържане се наблюдава при киселото мляко с директно вложено брашно от шипка в 14ти ден от съхранение.

Ключови думи: омега-3, омега-6, витамин С, антиоксиданти, функционален, хранителни влакнини

INTRODUCTION

Fermented dairy products are rich in nutrients (carbohydrates, lipids, proteins, vitamins minerals) and play a significant role in the development of the human organism (Foroutan et al., 2019).

Interest in fermented milk is constantly growing as consumers see it as a healthy food with a higher bioavailability of nutrients and minerals (Gahruie et al., 2015).

Fermented milk (yogurt) is obtained from pasteurized milk followed by fermentation with a starter culture of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* (Buttriss, 2003). According to FAO/WHO, the term "yogurt" is used for dairy products that have undergone lactic acid fermentation with the yogurt microflora and/or other lactic acid microorganisms in a total amount of not less than 10^7 cfu/g in the final product.

In the production of fermented dairy products with functional properties, various types of plant raw materials (berries, vegetables, fruits, seeds and spices), which are rich in polyphenols, biologically active substances (BAS) and dietary fibres are used (Kang et al., 2018; Shori et al., 2018). Suitable bioactive ingredients in milk and dairy products include carotenoids and phytosterols, phenolic compounds, vitamins, mineral elements, essential and glyceride oils and extracts, essential fatty acids, and plant fibres (dietary fibres).

Among the various types of herbs and plant products, rosehip fruits (*Rosa canina* L.) have a high BAS content. The genus *Rosa* includes more than 200 species and 40,000 cultivars widely distributed across temperate to subtropical zones of Europe, Asia, the Middle East and North America (Murathan et al., 2016). Three types of cultivated rosehip are included in the list of varieties in Bulgaria: "Vebecina-115", "Plovdiv-1," and "Nectar," the first two of which have industrial importance.

Rosehip fruits contain the whole complex of vitamins, organic acids, flavonoids, carotenoids, macro- and microelements and certain lipids that are necessary for humans and recognized as functional compounds (Al-Yafeai et al., 2018; Liaudanskas et al., 2021).

Fermented milks can be fortified with minerals and vitamins, especially vitamin C and B. Vitamin C (ascorbic acid) helps to enhance the human immune system but is also an antioxidant that can extend the shelf life of milk. The recommended daily dose of ascorbic acid for women is between 80 and 100 mg/day, and for men is 100 and 120 mg/day. One of the ways to supply the human body with vitamin C is to make products that are enriched with it. Adding fruits (fresh or dried) to fermented dairy products is a suitable method as there is a synergy between these products and their bioactive ingredients (Guiné and De Lemos, 2020).

According to Ivanova et al. (2023a), the vitamin C content in dried fruit of the cultivated rosehip type “Plovdiv-1” is 153.8 mg/100 g, and it can be a suitable raw material for the fortification of dairy products.

Znamirowska et al. (2021) added different quantities of *Rosa spinosissima* extracts to fermented milk and observed an increase in antioxidant activity and good microbial activity.

The production of new fortified dairy products can significantly affect the quality and properties of the bioactive compounds delivered to the human body with the additive. The study and analysis of these changes are of practical importance for optimizing processes and improving the quality of fermented milk (Cușmenco and Bulgaru, 2020).

The food industry is constantly developing and introducing new fortified/enriched products with improved health properties. One method of increasing the shelf life and effectiveness of added biologically active substances in food is encapsulation. In this method, the biologically active substance is encapsulated or "closed" by an edible coating (Nedovic et al., 2011).

This study aims to evaluate the influence of the cultivated rosehip variety "Plovdiv-1", which is added directly as flour and in encapsulated form, on the sensory, chemical, microbiological and antioxidant properties of fermented milk during storage.

MATERIALS AND METHODS

Materials

Raw cow's milk (solid non-fat 9.60±0.33%, protein 3.33±0.08%, fat 3.6±0.10%, density 1.0315±0.0005 g/cm^3 at 20 °C, freezing point -0.580±0.030 °C, titratable acidity 0.171±0.009% lactic acid) was used in the present study. It complied with the sensory, chemical and microbiological indicators described as requirements in the European Union Regulation No. 853/2004.

Starter culture YOFLEX® containing the specific thermophilic strains (*Lactobacillus delbrueckii* sp. *bulgaricus* and *Streptococcus thermophilus*) for yogurt type "Direct vat set" (DVS) was donated by CHR Hansen, Denmark.

Dried fruits of the "Plovdiv-1" cultivated rosehip with previously studied composition (Ivanova et al., 2023a) were purchased from a private producer in the Gotse Delchev region, Bulgaria. The rosehip fruits were ground in a laboratory mill (model PRO 02; 2600 rpm) to 1-2 mm after the seeds had been separated from the fleshy part (husks). Before being added to the milk, the rosehip flour was heat–treated at a temperature of 75 °C for 15 minutes.

Medium viscosity sodium alginate was purchased from Sigma Aldrich, Bulgaria.

The alginate beads were made with calcium dichloride (37%) purchased from Biokom Trendafilov" Ltd., Bulgaria.

Methods

Preparation of the alginate beads

The alginate beads were prepared as follows: 8 g of rosehip flour, 4 g of alginate and 5 g of sugar in 100 cm^3 of distilled water. The mixture was heated to 70 °C for 10 minutes, stirred for 2 minutes in IKA® T-18 Digital Ultra turrax® laboratory homogenizer (Staufen, Germany) at 10,000 rpm, and then cooled to room temperature. Finally, small alginate beads were formed by pouring them with a syringe into a 2% solution of calcium dichloride ($CaCl_2$), prepared from a 37% ($CaCl_2$) stock solution. Then, they were washed with distilled water and added to the yogurt formulation.

Preparation of fermented milks

A classical technology for the production of yogurt using the set-type method was applied. Three batches of yogurt were produced, each comprising three samples. The raw milk samples were pasteurized to 92 ± 2 °C and kept at this temperature for 20 minutes. After cooling to 42 ± 2 °C, three samples were prepared: S1 - reference sample (without added rosehip flour), S2 – sample with 2% rosehip flour, and S3 – sample with 2% encapsulated rosehip flour (Figure 1). The samples were inoculated with the DVS yogurt starter culture added in the amount recommended by the manufacturer, packaged in plastic packaging with lids and incubated at 42 ± 2 °C to allow fermentation to take place for 4 hours. The samples were cooled to 4 ± 2 °C and stored at this temperature for 14 days.

Chemical analysis

The titratable acidity was determined according to the titrimetric method (BNS 1111-80). The active acidity was measured potentiometrically using a pH meter 7110 WTW (Germany). The dry matter was analyzed by the gravimetric method (ISO 5534:2004). The total protein content was determined according to Kjeldahl method (ISO 8968-1:2014) using a BÜCHI® Kjeldahl MultiKjel with titrator and SpeedDigester K-365 Kjel line (Flawil, Switzerland). The fat content was determined using the volumetric Gerber method (ISO 19662:2018). Dietary fibre content was determined using gravimetric method (AOAC, 2000). The vitamin C content was determined using the titrimetric 2,6-dichlorophenolindophenol method (Hughes, 1983). The content of polar metabolites and fatty acid composition was determined by GC/MS mass spectrometry (Ivanova et al., 2023b). Retention times for the respective metabolites were compared with a reference library according to the Golm Metabolome Database (GMD) (Hummel et al., 2010) and the libraries of the National Institute of Standards and Technology (NIST 08) (Manion et al., 2015).

S1

S2

S3

Figure 1. Different types of fermented milks: S1 - reference sample (without added rosehip flour), S2 – sample with 2% rosehip flour; S3 – sample with 2% encapsulated rosehip flour

Syneresis and water-holding capacity

Syneresis is determined by spreading 50 cm^3 of unstirred milk evenly on Whatman filter paper No. 1 in a funnel at 4 °C. After five hours, the serum volume was measured and multiplied by two (Sidira et al., 2017).

Water-holding capacity was determined by centrifuging 10 g of the yogurt samples at 4000 rpm for 30 min in a model ST 802 A centrifuge. After centrifugation, the supernatant was weighed, and the water-holding capacity (WHC, %) was determined according to equation (1):

$$WHC = \frac{(Y - WE).100}{Y} \quad (1)$$

where:

WHC is water holding capacity, %;

Y is the mass of the milk sample, g;

WE is a mass of supernatant, g;

100 – to represent as percent.

Antioxidant activity

DPPH method - 250 mm^3 of yogurt supernatant was mixed vigorously with 3 cm^3 of DPPH and stored in the dark at room temperature for 30 min. A reference sample was prepared in a like manner, but 250 mm^3 of distilled water was added instead of milk extract. Measure the absorbance at 517 nm using a UV/Vis spectrophotometer, and the results are expressed as mmol TE/100 cm^3 (Amirdivani and Baba, 2011). FRAP method - FRAP analysis was performed according to the method of Benzie and Strain (1996) with some modifications. The supernatant obtained by the method described above was mixed with 50 mL of acetate buffer, 5 cm^3 of 2,4,6-tripyridyl-s-triazine (TPTZ) solution and 5 cm^3 of $FeCl_3$. The resulting mixture was incubated at 37 °C for 15 min. Then, the coloured product was measured with a spectrophotometer at a wavelength of 593 nm. The results are expressed in mMTE/cm^3.

Sensory analysis

The sensory evaluation of the samples was carried out on the first and last day of storage. Yogurt samples were subjected to sensory evaluation by 20 trained evaluators. Each panelist was asked to rate the three samples in terms of colour, taste, aroma, aftertaste and texture using a 9-point hedonic scale ranging from 1 (extremely dislike) to 9 (extremely like). All samples were placed in 50 cm^3 white plastic cups with randomised codes and served to the panelists in a random order.

Microbiological analysis

The preparation of yogurts for microbiological analysis was carried out according to BNS EN ISO 6887-5:2020 procedure. The number of *Lactobacillus* ssp. was determined according to BNS EN ISO 9232:2005. *Streptococcus* ssp. was analysed according to BNS EN ISO 7889:2005 procedure. The number of viable microorganisms was calculated using selective synthetic nutrient media of MRS (Merck) and M17 (Merck), respectively. Samples for yeasts and moulds were inoculated in YCG (Merck) according to Standard BNS EN ISO 6611:2006.

Textural analysis

The texture profile of yogurt samples was analysed using a Stable Micro Systems XT2A texture analyzer equipped with a cylindrical sensor (φ = 5 mm, area: 19.630 mm^2). The measurements were carried out on the 1^{st} and 14^{th} day of storage at 6 °C. The compression speed was 1 mm/s, and the deformations in the two cycles were 15 mm, as the relaxation time between the cycles was 5 s. The texture profile was assessed on the basis of hardness (N), adhesiveness (N · mm), cohesiveness, and gumminess (N). The hardness (N) represents the maximum force required to deform the sample at the first compression. Cohesiveness represents the internal bond strength of the sample expressed as the energy ratio of the second compression to the first. Adhesiveness (N · mm) is the force required to separate the working body from the sample and has a negative value. Gumminess (N) is a product of hardness and cohesiveness and indicates the energy required to bring the structure of the sample into a ready-to-eat state.

Statistical analysis

A statistical analysis was performed to determine statistical differences between the samples. For this purpose, a one-way ANOVA analysis was performed. Samples were treated as statistically different if $P<0.05$. The multiple comparison test was performed using the LSD method. The number of replicates per analysed sample was four (n = 4).

RESULTS AND DISCUSSION

Chemical analyses

Yogurt samples showed differences compared to the control depending on how the rosehip flour was added (directly added flour and indirectly with encapsulated rosehip flour) (Table 1).

The active acidity decreased in all samples during storage. The yogurt enriched with the direct addition of rosehip flour had the lowest pH values. The lactic acid bacteria digested the lactose and converted it into lactic acid, increasing the titratable acidity and decreasing the pH of the samples during storage (Arioui et al., 2016). Compared to the reference sample, the decrease in pH from the first to the last day of storage was more limited. In the milk with encapsulated rosehip flour the decrease in acidity was lower, and the pH values were close to those of the control. This was due to the low pH value, which is characteristic of rosehip. Similar reductions in pH values were reported in other studies when the milk was fortified with wine grape pomace supplements (Tseng and Zhao, 2013).

Simultaneously with a decrease in pH during milk storage, a significant increase ($P<0.05$) in titratable acidity was observed. In the samples with direct application of the rosehip flour, it increased faster during the storage period, which is probably due to the presence of lactic acid as well as some organic acids in rosehip, such as ascorbic and citric acid (Demir et al., 2014).

The dry matter of the yogurt samples varied depending on the method of adding rosehip flour. In the reference sample, the dry matter had the lowest values. These values were higher in the yogurts with the addition of rosehip flour, especially in the case where it was in encapsulated form. This can be explained by the presence of covering materials on them (Mousa et al., 2014). The amount of dry matter varied within small limits of 4%, due to the small amount of added rosehip flour (2%). In a study by Sahingil and Hayaloglu (2022), the dry matter varied by at least 12%, which is due to the large differences in the added rosehip syrup (from 5 to 20%).

The ascorbic acid content in the tested yogurts varied with a difference of 1.45 mg/100 g (Table 1). The data showed that the rosehip-enriched yogurts significantly increased their concentration compared to the control sample (*P*<0.05). This was due to the higher vitamin C content of rosehip flour (153.8 ± 13.1 mg/100 g) (Ivanova et al., 2023a). The concentration of vitamin C can be influenced during the storage period by various factors such as temperature, form of vitamin C and many others (Lešková, 2006).

In the present study, the concentration of ascorbic acid did not change significantly during the storage period, which is evidence of its preservation and stability. Ascorbic acid content has a direct influence on the pH, taste, texture and sensory properties of fermented milk (Tamime and Robinson, 2000). Znamirowska et al. (2021) obtained similar results for fermented milk with the addition of rosehip, acerola and ascorbic acid powder.

High-fibre foods are known to promote satiety and the health of the gastrointestinal tract (Solomon, 2021). The amount of dietary fiber in the samples fortified with rosehip flour was significantly higher than in the control (*P*<0.05). The amount of dietary fibres in the sample with directly added rosehip flour was significantly higher than the control (*P*>0.05). The differences between the two samples enriched with rosehip flour can probably be explained by the uneven distribution of dietary fibres in the rosehip capsules due to the coarseness of the particles.

Table 1. Physicochemical composition of yogurts

Variable	Storage time, day	Yogurt sample		
		S1	S2	S3
Dry matter, %	1	14.31 ± 0.11^{aA}	16.07 ± 0.15^{bA}	17.23 ± 0.12^{cA}
	14	14.26 ± 0.14^{aA}	16.46 ± 0.13^{bA}	17.28 ± 0.16^{cA}
Fat, %	1	3.08 ± 0.18^{aA}	3.05 ± 0.22^{aA}	3.01 ± 0.15^{aA}
	14	2.99 ± 0.12^{aA}	3.03 ± 0.12^{aA}	3.00 ± 0.26^{aA}
Protein, %	1	2.91 ± 0.16^{aA}	2.86 ± 0.14^{aA}	2.33 ± 0.14^{bA}
	14	3.09 ± 0.15^{aA}	2.98 ± 0.15^{aA}	2.55 ± 0.13^{bA}
Dietary fibres, %	1	0.05 ± 0.11^{aA}	0.31 ± 0.12^{bA}	0.12 ± 0.11^{cA}
	14	0.05 ± 0.10^{aA}	0.32 ± 0.10^{bA}	0.13 ± 0.12^{cA}
Ascorbic acid, mg/100g	1	0.32 ± 0.12^{aA}	3.85 ± 0.13^{bA}	2.62 ± 0.19^{cA}
	14	0.30 ± 0.14^{aA}	3.82 ± 0.15^{bA}	2.40 ± 0.18^{cA}

S1 – control sample (without the addition of rosehip flour), S2 – sample with 2% rosehip flour, S3 – sample with 2% encapsulated rosehip flour. Values are means ± standard deviation.
a–c letters point out differences (*P* < 0.05) between yogurt samples
A–B letters point out differences (*P* < 0.05) between storage days

Table 2. Fatty acid composition of yogurt samples

Variable	Storage time, day	Yogurt sample		
		S1	S2	S3
Short and Medium-chain fatty acids				
Caproic acid, 6:0	1	10.16 ± 1.80^{aA}	6.50 ± 1.68^{bA}	8.13 ± 1.62^{cA}
	14	10.97 ± 1.87^{aA}	7.09 ± 1.82^{bA}	8.54 ± 1.72^{cA}
Caprylic acid, 8:0	1	0.80 ± 0.25^{aA}	0.51 ± 0.23^{aA}	0.64 ± 0.23^{aA}
	14	0.87 ± 0.26^{aA}	0.56 ± 0.25^{aA}	0.68 ± 0.24^{aA}
Capric acid, 10:0	1	2.38 ± 0.19^{aA}	1.52 ± 0.18^{bA}	1.90 ± 0.17^{cA}
	14	2.56 ± 0.20^{aA}	1.66 ± 0.19^{bA}	2.00 ± 0.18^{cA}
Lauric acid, 12:0	1	2.77 ± 0.16^{aA}	1.77 ± 0.15^{bA}	2.22 ± 0.14^{cA}
	14	2.99 ± 0.17^{aA}	1.93 ± 0.16^{bA}	2.33 ± 0.15^{cA}
Long-chain fatty acids				
Tridecanoic acid, 13:0	1	0.26 ± 0.02^{aA}	0.17 ± 0.02^{bA}	0.21 ± 0.02^{bA}
	14	0.28 ± 0.02^{aA}	0.18 ± 0.02^{bA}	0.22 ± 0.02^{bA}
Myristic acid, 14:0	1	9.76 ± 0.30^{aA}	8.24 ± 0.28^{bA}	7.80 ± 0.27^{bA}
	14	10.53 ± 0.31^{aB}	8.99 ± 0.29^{bB}	8.20 ± 0.29^{bA}
Pentadecanoic acid, 15:0	1	1.13 ± 0.07^{aA}	0.72 ± 0.07^{bA}	0.90 ± 0.06^{cA}
	14	1.22 ± 0.07^{aA}	0.79 ± 0.07^{bA}	0.95 ± 0.07^{cA}
Palmitic acid, 16:0	1	32.40 ± 1.12^{aA}	28.64 ± 1.05^{bA}	27.92 ± 1.01^{bA}
	14	34.96 ± 1.16^{aA}	31.21 ± 1.13^{bB}	29.32 ± 1.07^{bA}
Heptadecanoic acid, 17:0	1	0.79 ± 0.03^{aA}	0.51 ± 0.03^{bA}	0.63 ± 0.03^{cA}
	14	0.85 ± 0.03^{aB}	0.55 ± 0.03^{bA}	0.67 ± 0.03^{cA}
Stearic acid, 18:0	1	14.14 ± 0.42^{aA}	15.05 ± 0.39^{bA}	16.31 ± 0.38^{cA}
	14	15.25 ± 0.44^{aB}	17.12 ± 0.40^{bB}	16.40 ± 0.42^{cA}
Arachidonic acid, 20:0	1	0.14 ± 0.02^{aA}	0.09 ± 0.02^{bA}	0.12 ± 0.02^{cA}
	14	0.16 ± 0.03^{aB}	0.10 ± 0.02^{bA}	0.12 ± 0.02^{abA}
Behenic acid, 22:0	1	0.11 ± 0.01^{aA}	0.07 ± 0.01^{bA}	0.09 ± 0.01^{bA}
	14	0.12 ± 0.01^{aA}	0.07 ± 0.01^{bA}	0.09 ± 0.01^{bA}
Lignoceric acid, 24:0	1	0.07 ± 0.01^{aA}	0.05 ± 0.01^{aA}	0.06 ± 0.01^{aA}
	14	0.08 ± 0.01^{aA}	0.05 ± 0.01^{aA}	0.06 ± 0.01^{abA}

Continued. Table 2

Variable	Storage time, day	Yogurt sample		
		S1	S2	S3
Monounsaturated fatty acids				
Myristoleic acid, 14:1	1	0.46 ± 0.04^{aA}	0.51 ± 0.04^{aA}	0.65 ± 0.04^{bA}
	14	0.36 ± 0.04^{aB}	0.62 ± 0.04^{bB}	0.49 ± 0.04^{cB}
Palmitoleic acid, 16:1	1	1.50 ± 0.07^{aA}	1.89 ± 0.07^{A}	1.98 ± 0.06^{A}
	14	1.18 ± 0.07^{aB}	1.28 ± 0.07^{B}	1.89 ± 0.07^{A}
cis-10 Heptadecenoic acid, 17:1	1	0.16 ± 0.02^{aA}	0.20 ± 0.02^{A}	0.18 ± 0.02^{A}
	14	0.12 ± 0.02^{aA}	0.19 ± 0.02^{A}	0.17 ± 0.02^{A}
Oleic acid, 18:1 9n	1	19.43 ± 0.55^{aA}	28.50 ± 0.51^{A}	25.82 ± 0.50^{A}
	14	15.33 ± 0.57^{aB}	24.08 ± 0.56^{B}	23.15 ± 0.52^{B}
Polyunsaturated fatty acids				
Linoleic acid, 18:2n6c	1	2.33 ± 0.09^{aA}	3.36 ± 0.08^{bA}	2.95 ± 0.08^{cA}
	14	1.24 ± 0.09^{aB}	2.51 ± 0.09^{bB}	2.38 ± 0.09^{bB}
γ-Linolenic acid, 18:3n6	1	0.08 ± 0.00^{aA}	0.13 ± 0.00^{bA}	0.09 ± 0.00^{cA}
	14	0.07 ± 0.00^{aA}	0.12 ± 0.00^{bA}	0.09 ± 0.00^{cA}
Linolenic acid, 18:3n3	1	0.39 ± 0.04^{aA}	0.55 ± 0.04^{bA}	0.45 ± 0.04^{cA}
	14	0.31 ± 0.04^{aA}	0.52 ± 0.04^{bA}	0.43 ± 0.04^{cA}
Eicosadienoic acid, 20:2n6	1	0.08 ± 0.01^{aA}	0.14 ± 0.02^{bA}	0.12 ± 0.02^{bA}
	14	0.06 ± 0.01^{aA}	0.13 ± 0.01^{bA}	0.10 ± 0.01^{cA}
Eicosatrienoic acid, 20:3n3	1	0.25 ± 0.01^{aA}	0.32 ± 0.01^{bA}	0.28 ± 0.01^{cA}
	14	0.20 ± 0.01^{aA}	0.30 ± 0.01^{bA}	0.27 ± 0.01^{cA}
Arachidonic acid, 20:4n6	1	0.22 ± 0.02^{aA}	0.27 ± 0.01^{bA}	0.24 ± 0.01^{cA}
	14	0.17 ± 0.02^{aB}	0.26 ± 0.02^{bA}	0.23 ± 0.02^{bA}

S1 – reference sample (without added rosehip flour), S2 – sample with 2% rosehip flour, S3 – sample with 2% encapsulated rosehip flour.
Values are average ± standard deviation.
a–b letters point out differences (*P* < 0.05) between yogurt samples
A–B letters point out differences (*P* < 0.05) between storage days

The proteins in the control sample were significantly higher (*P*<0.05) than those enriched with rosehip flour samples. In a study by Gurbuz and Demirci (2023), probiotic yogurt fortified with rosehip flour showed a reverse trend in the results obtained, with the control having the lowest protein content. In this case, there was no significant (*P*>0.05) difference between the reference sample and the sample with directly added rosehip flour. A significant difference (*P*<0.05) with the sample where the rosehip flour was added in encapsulated form was probably due to a possible interaction between the alginate and the protein matrix. Similar results have been reported in other scientific studies where other gelling hydrocolloids, such as pectin, showed reduced protein content due to the interaction between these two substances (Ivanova et al., 2020).

Table 3. Composition of polar metabolites in yogurts

Variable	Storage time, day	Yogurt sample		
		S1	S2	S3
Amino acids, g/100 g				
Alanine	1	0.19 ± 0.09aA	0.22 ± 0.10aA	0.24 ± 0.11aA
	14	0.16 ± 0.07aA	0.20 ± 0.09aA	0.18 ± 0.08aA
Glycine	1	0.05 ± 0.02aA	0.05 ± 0.03aA	0.06 ± 0.03aA
	14	0.04 ± 0.02aA	0.05 ± 0.02aA	0.05 ± 0.02aA
Valine	1	0.14 ± 0.07aA	0.16 ± 0.07aA	0.18 ± 0.08aA
	14	0.12 ± 0.06aA	0.15 ± 0.07aA	0.13 ± 0.06aA
Leucine	1	0.27 ± 0.13aA	0.31 ± 0.14aA	0.34 ± 0.15aA
	14	0.26 ± 0.12aA	0.29 ± 0.13aA	0.26 ± 0.12aA
Isoleucine	1	0.12 ± 0.06aA	0.13 ± 0.06aA	0.15 ± 0.07aA
	14	0.10 ± 0.05aA	0.12 ± 0.06aA	0.11 ± 0.05aA
Proline	1	0.30 ± 0.14aA	0.34 ± 0.15aA	0.23 ± 0.11aA
	14	0.25 ± 0.11aA	0.32 ± 0.14aA	0.18 ± 0.08aA
Uracil	1	0.22 ± 0.10aA	0.25 ± 0.11aA	0.27 ± 0.13aA
	14	0.21 ± 0.10aA	0.23 ± 0.11aA	0.21 ± 0.10aA
Serine	1	0.19 ± 0.09aA	0.21 ± 0.10aA	0.13 ± 0.06aA
	14	0.16 ± 0.07aA	0.20 ± 0.09aA	0.10 ± 0.05aA
Threonine	1	0.16 ± 0.07aA	0.18 ± 0.08aA	0.20 ± 0.09aA
	14	0.13 ± 0.06aA	0.17 ± 0.08aA	0.15 ± 0.07aA
Aspartic acid	1	0.24 ± 0.11aA	0.27 ±0.12aA	0.30 ± 0.14aA
	14	0.23 ± 0.10aA	0.25 ± 0.12aA	0.23 ± 0.10aA
Methionine	1	0.10 ± 0.05aA	0.11 ± 0.05aA	0.12 ± 0.06aA
	14	0.08 ± 0.04aA	0.10 ± 0.05aA	0.09 ± 0.04aA
Pyroglutamic acid	1	0.39 ± 0.18aA	0.44 ± 0.20aA	0.49 ± 0.22aA
	14	0.33 ± 0.15aA	0.41 ± 0.19aA	0.37 ± 0.17aA
Creatinine	1	0.26 ± 0.12aA	0.29 ± 0.13aA	0.32 ± 0.15aA
	14	0.22 ± 0.10aA	0.27 ± 0.13aA	0.24 ± 0.11aA
Glutamic acid	1	0.21 ± 0.10aA	0.24 ± 0.11aA	0.26 ± 0.12aA
	14	0.18 ± 0.08aA	0.22 ± 0.10aA	0.20 ± 0.09aA
Phenylalanine	1	0.08 ± 0.06aA	0.10 ± 0.04aA	0.11 ± 0.05aA
	14	0.07 ± 0.03aA	0.09 ± 0.04aA	0.08 ± 0.04aA

Continued. Table 3

Variable	Storage time, day	Yogurt sample		
		S1	S2	S3
Lysine	1	0.08 ± 0.04^{aA}	0.09 ± 0.04^{aA}	0.09 ± 0.04^{aA}
	14	0.07 ± 0.03^{aA}	0.08 ± 0.04^{aA}	0.08 ± 0.04^{aA}
Tyrosine	1	0.03 ± 0.02^{aA}	0.03 ± 0.02^{aA}	0.04 ± 0.02^{aA}
	14	0.02 ± 0.01^{aA}	0.03 ± 0.02^{aA}	0.03 ± 0.01^{aA}
Monosaccharides, g/100 g				
Galactose	1	0.52 ± 0.20^{aA}	0.88 ± 0.19^{bA}	1.44 ± 0.51^{cA}
	14	0.67 ± 0.13^{aB}	2.03 ± 0.41^{bB}	1.73 ± 0.35^{cB}
Glucose	1	0.11 ± 0.03^{aA}	1.16 ± 0.36^{bA}	0.72 ± 0.26^{cA}
	14	0.23 ± 0.05^{aB}	0.91 ± 0.18^{bB}	0.46 ± 0.09^{cB}
Disaccharides, g/100g				
Lactose	1	3.63 ± 0.89^{aA}	5.21 ± 1.28^{bA}	4.28 ± 1.05^{cA}
	14	3.05 ± 0.75^{aB}	4.82 ± 1.18^{bB}	3.79 ± 0.93^{cB}
Sugar alcohols, mg/100 g				
Myo-inositol	1	8.39 ± 2.06^{aA}	8.86 ± 2.17^{aA}	7.35 ± 1.80^{aA}
	14	8.04 ± 1.97^{aA}	8.56 ± 2.10^{aA}	6.97 ± 1.71^{aA}
Organic acids, mg/100 g				
Acetic acid	1	6.98 ± 1.71^{aA}	8.56 ± 2.10^{aA}	7.77 ± 1.90^{aA}
	14	7.45 ± 1.83^{aA}	9.04 ± 2.21^{aA}	8.21 ± 2.01^{aA}
Butyric acid	1	10.94 ± 2.68^{aA}	11.03 ± 2.70^{aA}	9.34 ± 2.29^{aA}
	14	23.51 ± 5.76^{aB}	25.30 ± 6.20^{aB}	24.09 ± 5.90^{aB}
Pyruvic acid	1	2.64 ± 0.65^{aA}	4.71 ± 1.16^{aA}	3.01 ± 0.74^{aA}
	14	1.90 ± 0.47^{aA}	3.30 ± 0.81^{bA}	2.01 ± 0.49^{aA}
Lactic acid	1	599.65 ± 16.91^{aA}	798.06 ± 15.52^{bA}	713.49 ± 17.81^{cA}
	14	808.24 ± 18.02^{aB}	983.19 ± 20.88^{bB}	911.23 ± 15.25^{cB}
Oxalic acid	1	3.17 ± 0.78^{aA}	2.09 ± 0.51^{aA}	2.57 ± 0.63^{aA}
	14	2.34 ± 0.58^{aA}	2.96 ± 0.73^{aA}	2.36 ± 0.65^{aA}
Succinic acid	1	1.55 ± 0.38^{aA}	1.02 ± 0.25^{bA}	1.25 ± 0.31^{aA}
	14	1.14 ± 0.28^{aA}	1.44 ± 0.35^{bA}	1.29 ± 0.32^{aA}
Itaconic acid	1	2.30 ± 0.57^{aA}	1.52 ± 0.37^{bA}	1.87 ± 0.46^{abA}
	14	1.71 ± 0.42^{aA}	2.15 ± 0.53^{aA}	1.92 ± 0.47^{aA}

Continued. Table 3

Variable	Storage time, day	Yogurt sample		
		S1	S2	S3
Fumaric acid	1	1.09 ± 0.27^{aA}	0.71 ± 0.18^{aA}	0.88 ± 0.22^{aA}
	14	0.80 ± 0.20^{aA}	1.01 ± 0.25^{aA}	0.90 ± 0.22^{aA}
Malic acid	1	3.60 ± 0.88^{aA}	2.37 ± 0.58^{aA}	2.92 ± 0.72^{aA}
	14	2.66 ± 0.65^{aA}	3.36 ± 0.82^{aA}	2.99 ± 0.73^{aA}
Fumaric acid	1	1.30 ± 0.32^{aA}	0.86 ± 0.21^{aA}	1.05 ± 0.26^{aA}
	14	0.96 ± 0.24^{aA}	1.21 ± 0.30^{aA}	1.08 ± 0.27^{aA}
Adipic acid	1	1.84 ± 0.45^{aA}	1.21 ± 0.30^{aA}	1.49 ± 0.37^{aA}
	14	1.36 ± 0.33^{aA}	1.71 ± 0.42^{aA}	1.53 ± 0.38^{aA}
α-Hydroxyglutaric acid	1	2.01 ± 0.49^{aA}	1.32 ± 0.32^{aA}	1.63 ± 0.40^{aA}
	14	1.48 ± 0.36^{aA}	1.87 ± 0.46^{aA}	1.67 ± 0.41^{aA}
Suberic acid	1	0.85 ± 0.21^{aA}	0.56 ± 0.14^{bA}	0.69 ± 0.17^{abA}
	14	0.63 ± 0.15^{aA}	0.79 ± 0.19^{aA}	0.70 ± 0.17^{aA}
Azelaic acid	1	1.92 ± 0.47^{aA}	1.26 ± 0.31^{aA}	1.56 ± 0.38^{aA}
	14	1.42 ± 0.35^{aA}	1.79 ± 0.44^{aA}	1.59 ± 0.39^{aA}
Isocitric acid	1	152.07 ± 9.26^{aA}	146.72 ± 10.95^{aA}	140.33 ± 8.38^{aA}
	14	158.87 ± 8.92^{aA}	150.12 ± 6.78^{aA}	144.91 ± 9.50^{aA}
Others, mg/100g				
Phosphate	1	5.01 ± 1.23^{aA}	4.05 ± 0.99^{aA}	4.50 ± 1.10^{aA}
	14	3.65 ± 0.89^{aA}	2.95 ± 0.72^{aA}	3.28 ± 0.81^{aA}
γ-Aminobutyric acid	1	1.69 ± 0.41^{aA}	1.83 ± 0.45^{aA}	1.52 ± 0.37^{aA}
	14	1.23 ± 0.30^{aA}	1.99 ± 0.49^{aA}	1.10 ± 0.27^{aA}

S1 – reference sample (without added rosehip flour), S2 – sample with 2% rosehip flour, S3 – sample with 2% encapsulated rosehip flour.
Values are average ± standard deviation.
a–c letters point out differences ($P < 0.05$) between yogurt samples
A–B letters point out differences ($P < 0.05$) between storage days

No statistical differences ($P>0.05$) were observed in the concentrations of short-, medium- and long-chain saturated fatty acids across all three samples from the 1st to 14th day of storage. These fatty acids are naturally present in milk, so their concentrations were consistent in all samples. The highest content of palmitoleic acid in the samples with added rosehip flour compared to the control could be explained by the additional presence of these fatty acids in the rosehip flour (Ivanova et al., 2023a). The same trend was observed by Rao et al. (2023) in rosehip-enriched yogurts. Mono- and polyunsaturated fatty acids contained in rose hips are dietary fats that may have health benefits (Adamczak et al., 2011). The samples with encapsulated rosehips were characterized by increased values of polyunsaturated fatty acids, particularly in omega-6 and omega-3 fatty acids such as linoleic acid, γ-linolenic acid, linolenic acid, and arachidonic acid. Similar values were reported by Kulaitienė et al. (2020).

According to Settachaimongkon et al. (2014), different types of fermented milk with different starter cultures can be distinguished by their metabolic profiles. The studied fermented milks used the same type of starter culture and the same technology. It means that the addition of biologically active substances determined the differences in the metabolic composition of the three types of yogurts at the beginning and the end of the storage period. No difference in the amino acid composition was observed between the studied samples, regardless of the applied treatment and storage time. Similar results were obtained by enrichment of yogurt with walnuts and hazelnuts by Boycheva et al. (2012).

A clear trend was observed, showing higher concentrations of certain organic acids and glucose on the 1st day of storage in the samples with the embedded spike. This can be attributed to the physicochemical composition of the pseudofruits (Demir et al., 2014). Consequently, higher ascorbic acid and glucose contents were found in sample S2 on the 1st day. The highest lactose content was found in the sample with directly incorporated rosehip flour (S2) on both the 1st and 14th days. This probably led to its conversion to lactic acid, which was influenced by the lactic acid bacteria present in the starter culture. This was also confirmed by the highest lactic acid values measured in sample S2 on the first and last day. Lactic acid is a natural preservative that extends shelf life, flavours the yogurt and thickens the milk proteins (Dias and Braga, 2015). Fermented milk samples with rosehip flour and macrocapsules on the 1st day of storage contained higher levels of lactic and acetic acid on 1st day of storage, which contributed to improved fermentation of the fortified yogurt (Kowalski et al., 2020).

Antioxidant activity

Table 4 shows the total phenolic content and antioxidant activity of the milk samples supplemented directly with cultured rose hip flour (S2) and encapsulated rosehip flour (S3).

Antioxidant activity is one of the most important quality parameters of medicinal plants, and many *in vitro* antioxidant test methods are used for this determination. Enrichment of fermented dairy products with cultured rosehip flour increased the total phenolic content more than twice in the reference sample by more than double compared to samples S2 and S3 (with 2% rosehip flour).

The results showed differences in the antioxidant activities of the milk samples, which increased slightly during the storage period. This was due to the presence of phenolic compounds, and the partial increase could be explained by the presence of bioactive compounds in the milk, especially peptides released by microbial proteases from milk proteins, which also act as antioxidants. The highest antioxidant activity was obtained in samples where directly cultured rosehip flour was used. A similar trend was found by Dabija et al. (2018), who investigated the antioxidant stability of fermented milk enriched with herbal extracts and concluded that they could be used as functional foods with great health benefits.

Sensory analysis

Knowledge about the palatability of food plays an important role in consumer acceptance and preferences, as it reduces uncertainty about the safety of the new product and its sensory properties (Borgogno et al., 2015).

Figure 2 (A and B) shows the results of the sensory analysis of the milk after the 1st and 14th day. The sensory properties of the yogurt with directly incorporated rosehip flour (S2) were improved compared to the control (S1) and the sample with 2% encapsulated rosehip flour (S3).

The direct addition of rosehip flour at 2% in milk resulted in changes in sensory perception in consumers compared to the control. The addition of cultivated rosehip flour to fermented milk (S2) had a positive effect on its colour, consistency and coagulation. The direct addition of cultured rosehip flour in the fermented milk samples determined the taste and aroma in sample S2 as slightly sour and sweet to sample S2 compared to sample S3. Similar results for improved taste and aroma of milk with the addition of papaya were also demonstrated by Othman et al. (2019).

It was found that the panelists did not favour the milk with 2% encapsulated rosehip flour over the control and the milk with directly added rosehip flour. This was probably due to the strange feeling and taste in the mouth when chewing the capsules.

The added rosehip flour helped to maintain the consistency and coagulation of the milk. The higher dry matter and fibre content in the rosehip flour possibly improved the textural properties of the resulting fermented milk. This result is similar to Debashis et al. (2014), who reported better textural quality of fruit yogurts compared to the control.

Table 4. Total phenolic content and antioxidant activity of yogurt samples

Variable	Storage time, day	Yogurt sample		
		S1	S2	S3
Total Phenolic Content, mg	1	51.80 ± 1.12^{aA}	113.52 ± 2.15^{bA}	102.10 ± 1.13^{cA}
GAE/кg	14	56.72 ± 1.15^{aB}	135.26 ± 2.25^{bB}	113.20 ± 3.01^{cB}
DPPH	1	6.25 ± 0.75^{aA}	13.19 ± 1.12^{bA}	10.59 ± 1.45^{cA}
mM TE/кg	14	10.32 ± 1.40^{aB}	15.24 ± 1.04^{bB}	12.59 ± 1.02^{cB}
FRAP	1	1.32 ± 0.25^{aA}	10.59 ± 1.00^{bA}	8.56 ± 0.56^{cA}
mM TE/кg	14	1.72 ± 0.44^{aB}	12.59 ± 0.14^{bB}	9.78 ± 0.43^{cB}

S1 – reference sample (without added rosehip flour), S2 – sample with 2% rosehip flour, S3 – sample with 2% encapsulated rosehip flour.
Values are average ± standard deviation.
a–c letters point out differences ($P < 0.05$) between yogurt samples
A–B letters point out differences ($P < 0.05$) between storage days

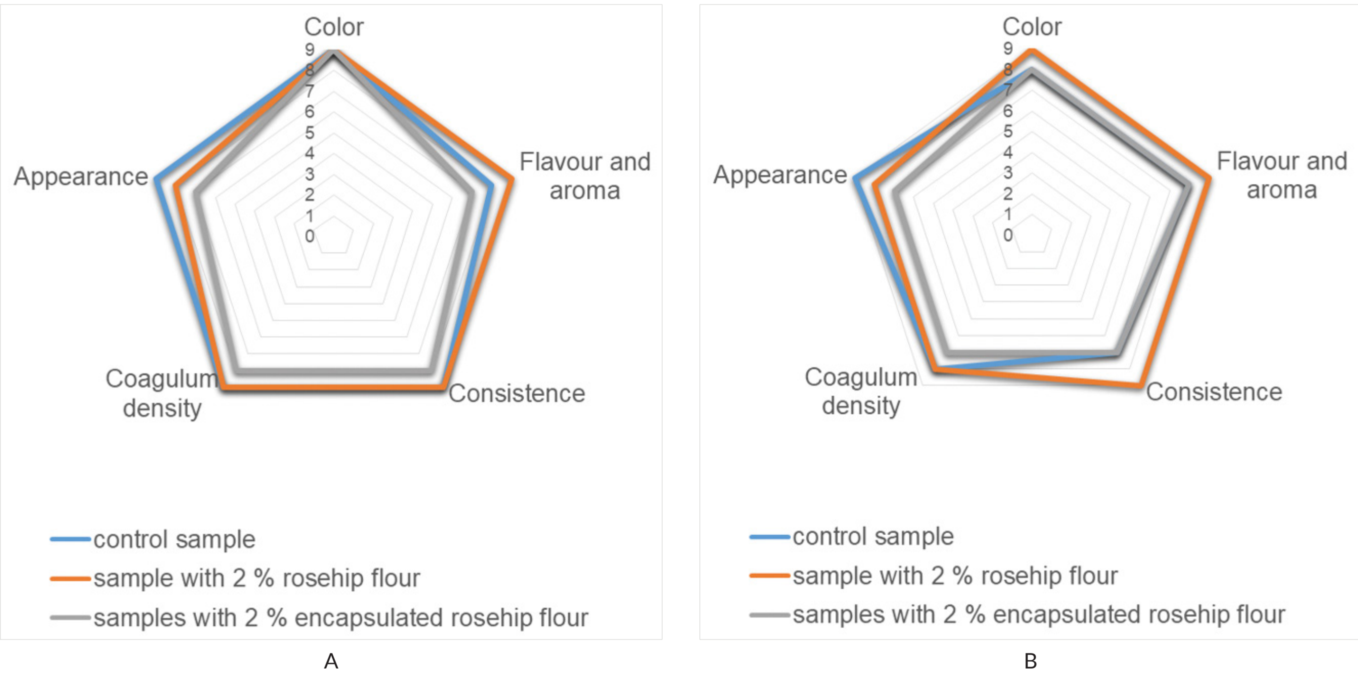

Figure 2. Sensory analysis of yogurt samples: A - 1st day of storage; B - 14th day of storage

After the 14th day of the storage period, the taste and aroma acceptability of the milk samples with directly added rosehip flour were retained. In contrast, the sample with 2% encapsulated rosehip flour (S3) was unacceptable to the panelists. The milk consistency of sample S2 was improved compared to samples S1 and S3, and was characterised by a higher density and less separated whey on the surface. Derewiaka et al. (2019) achieved similar results of improved milk consistency by adding fruit fibres.

The panelists gave the lowest scores for the appearance of sample S3, as a serum had formed on the surface of the yogurt. The overall evaluation of the sensory properties of the fortified yogurt with directly added rosehip flour on the day of production and after storage showed that the product had no sensory properties that would hinder consumption. the comparasion of the overall results showed that the control (S1) and the milk with directly added rosehip (S2) were more acceptable to the panelists, who rated them with an average of 8.8 on the 1st day of storage, and 7.8 for the sample with 2% encapsulated rosehip flour (S3). After the 14th day of storage, sample S3 received the lowest score of 7.4, while sample S2 received 8.6. Similar observations were made by other authors (Pikul and Wójtowski, 2008), who found that the evaluation of the appearance, taste and aroma of fermented milk with added fruit flour decreased during the storage period.

Microbiological analysis

It is recognized that the enrichment of fermented milk products with vitamin C improves the viability of probiotic bacteria and their sensory properties (Dave and Shah, 1997).

The amount of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* sp. *bulgaricus* was highest in the sample with directly added rosehip flour S2

The added rosehip had a stimulating effect on the growth and viability of beneficial bacteria in the yogurt. The resulting enriched yogurt product could have a positive effect on the development of good bacteria in the consumer's intestine and thus on the functional properties of this food (Cruz et al., 2013). The results of the amount of lactic acid bacteria showed that the directly added rose hip flour affected the dynamics of acid formation. It was found that after the 14th day of storage, in contrast to the control S1, in the directly S2 and indirectly S3 enriched yogurts, the number of lactic acid bacteria was significantly higher than at the beginning ($P<0.05$). Similar results were shown by Damyanova et al. (2009).

Table 5. Microbiological analysis of yogurt samples

Variable	Storage time, day	Yogurt sample		
		S1	S2	S3
Streptococcus thermophilus, log cfu/g	1	8.53 ± 0.10^{aA}	6.13 ± 0.14^{bA}	5.94 ± 0.25^{cA}
	14	8.61 ± 0.25^{aA}	9.41 ± 0.1^{6bB}	9.14 ± 0.55^{cB}
Lactobacillus delbrueckii spp. *bulgaricus* log cfu/g	1	6.58 ± 0.25^{aA}	7.03 ± 0.21^{bA}	6.68 ± 0.14^{cA}
	14	8.43 ± 0.33^{aB}	9.11 ± 0.23^{cB}	8.20 ± 0.17^{cB}
Yeasts and moulds, log cfu/g	1	<1	<1	<1
	14	<1	<1	<1

S1 – reference sample (without added rosehip flour), S2 – sample with 2% rosehip flour, S3 – sample with 2% encapsulated rosehip flour.
Values are average ± standard deviation.
a–c letters point out differences ($P < 0.05$) between yogurt samples
A–B letters point out differences ($P < 0.05$) between storage days

Textural analysis, syneresis and water-holding capacity

Syneresis is one of the biggest disadvantages of yogurt. It is caused by the contraction of the three-dimensional structure of a protein network, which leads to an accumulation of serum or whey on the surface of the yogurt (Bahrami et al., 2013).

This defect can limit the shelf life of the milk and deteriorate its appearance. To reduce the degree of syneresis in milk, various stabilizers (pectin, gelatin, vegetable resin) and pore-forming agents with exopolysaccharide activity are added (Amatayakul et al., 2006).

The data in Table 6 shows that syneresis in is weakersample S2 (with a 2% rose) compared to the control. The highest values for syneresis were observed in the control after 14 days of storage (44.1%), and the lowest values in sample S1 (32.8%) at 1st day of storage. Syneresis is highest in samples S3 (with encapsulated rosehip flour) – from 37.2% in 1 day of storage to 40.1% after 14 days. The syneresis results were lower than those observed in other studies with yogurts enriched with carrot and grape juice (Kiros et al., 2016). This is probably due to the different acidity of these plant sources. The sample with rosehip flour (S2) was characterised by the lowest pH (4.23) and the highest content of ascorbic acid (3.85 ± 0.13 mg/100 g) compared to the control sample (pH = 4.23 and 0.32 ± 0.12 mg/100 g).

Holding capacity is an essential key parameter for the quality of fermented milk. A lower retention capacity was found in the reference sample, while the highest value was determined in the samples with the addition of rosehip flour on the 14th day of storage - 65.9%. The addition of low-moisture rosehip flour (18%) strengthens the gel structure of the yogurt. In addition, rosehip flour is rich in soluble and insoluble fibers, which have a

Table 6. The texture parameters of yogurt reference, with rosehip flour and encapsulated rosehip flour during storage

Texture parameter	Storage time, day	Yogurt sample		
		S1	S2	S3
Hardness, N	1	1.278 ± 0.056^{aA}	0.620 ± 0.092^{bA}	0.461 ± 0.043^{cA}
	14	1.331 ± 0.053^{aA}	0.635 ± 0.027^{bA}	0.449 ± 0.075^{cA}
Springiness, mm/mm	1	1.373 ± 0.074^{aA}	1.005 ± 0.065^{aA}	1.167 ± 0.102^{cA}
	14	1.639 ± 0.056^{aB}	1.086 ± 0.123^{bB}	0.952 ± 0.010^{cB}
Cohesiveness, N · mm/ N · mm	1	0.112 ± 0.006^{aA}	0.093 ± 0.009^{bA}	0.132 ± 0.010^{cA}
	14	0.155 ± 0.014^{aB}	0.155 ± 0.023^{aB}	0.065 ± 0.003^{bB}
Adhesiveness, N	1	-1.331 ± 0.227^{aA}	-0.585 ± 0.085^{bA}	-0.726 ± 0.123^{cA}
	14	-2.262 ± 0.352^{aB}	-0.517 ± 0.075^{bB}	-0.951 ± 0.085^{cB}
Water-holding capacity, %	1	59.6 ± 0.15^{aA}	62.6 ± 0.14^{bA}	60.6 ± 0.13^{cA}
	14	64.9 ± 0.13^{aB}	65.9 ± 0.13^{bB}	62.3 ± 0.17^{cB}
Syneresis, %	1	39.4 ± 0.13^{aA}	32.8 ± 0.11^{bA}	37.2 ± 0.17^{cA}
	14	44.1 ± 0.19^{aB}	33.1 ± 0.15^{bA}	40.1 ± 0.14^{cB}

S1 – reference sample (without added rosehip flour), S2 – sample with 2% rosehip flour, S3 – sample with 2% encapsulated rosehip flour.
Values are average ± standard deviation.
a–c letters point out differences ($P < 0.05$) between yogurt samples
A–B letters point out differences ($P < 0.05$) between storage days

strong hydration capacity, retain water by adsorption and influence the retention capacity (Sanchez-Zapata et al., 2011; Balthazar et al., 2016; Staffolo et al., 2017).

Analysing the texture profile of yogurt is important to evaluate its physical properties that influence its perception by consumers (Song et al., in press). Key aspects of the yogurt's texture profile include hardness (the force required to deform it), elasticity (the ability to return to shape after being stressed), adhesiveness (the energy required to detach the product from a surface) and cohesion (the internal bond and tear resistance). These factors determine the quality and acceptability of yogurt.

Table 6 shows the results of the analysis of the texture profile of yogurt with 2% rosehip flour (S2) and to 2% encapsulated rosehip (S3) compared with the reference sample (S1). The texture parameters (hardness, elasticity, adhesiveness, cohesion) were measured on the 1st and 14th day of storage at 6 °C ± 1 °C.

Hardness is the most important parameter used to evaluate yogurt texture. It measures firmness and has a direct effect on overall sensory perception (Mudgil et al., 2017). The control sample yogurt (S1) had a higher hardness than the sample with rosehip flour and encapsulated rosehip flour by approximately 51% and 64%, respectively. Samples S2 and S3 had a higher water-holding capacity than the control sample, possibly contributing to a softer but stable texture.

During 14 days of storage period, an increase in elasticity was observed for the reference yogurt (from 1.373 ± 0.074 to 1.639 ± 0.056), and a decrease in elasticity was observed for the samples with rosehip capsules (1.167 ± 0.10 N and 0.952 ± 0.010 N) and rosehip flour (1.005 ± 0.065 and 1.086 ± 0.123). The significant increase in elasticity of the yogurt reference ($P<0.05$) could be due to a stronger formation of protein bonds over time. Yogurt with rosehip flour (S2) maintained good elasticity. In contrast, the addition of encapsulated rosehip flour (S3) did not allow a comparable stabilisation of the structure and led to a weakening of the protein structure. A decrease in elasticity could lead to a decrease in consumer acceptance. The results of the cohesiveness measurements confirmed the formation of stable bonds in the protein network of the reference sample and the sample with rosehip flour. In contrast, the encapsulated flour weakens the internal stability of the protein network. It leads to the pronounced syneresis properties of the S3 sample during storage, from 37.2% in 1 day of storage to 40.1% in 14 days (Table 6).

Adhesiveness was most significant in the reference sample and increased during storage, indicating a decrease in water holding capacity during storage. Yogurt with rosehip flour (S2) showed a slightly decreased adhesiveness value during storage, indicating stability in the protein network and water-holding capacity.

CONCLUSIONS

The results of this study show new possibilities for the production of fermented milk products that are rich in fibres and polyunsaturated fatty acids and may be able to reduce blood cholesterol levels and the risk of cardiovascular disease. The high rating of the sample with directly added rosehip flour makes it the most preferred by the panelists. The higher content of beneficial microflora in the same sample would lead to a better functioning of the gastrointestinal tract, normal absorption in the intestine, and an improvement in the balance of bacterial microflora in the intestine. A strengthening of the intestinal mucosa is possible due to the higher amounts of omega-6 and omega-3 fatty acids in the samples with added rosehip flour. The results obtained for yogurt enriched with rosehip flour show that the sensory properties and antioxidant activity of the yogurt were also improved, in addition to the increase in nutritional value. Texture profile analysis showed that the control yogurt sample had the highest hardness, cohesiveness and increased elasticity during storage, indicating a stable protein structure. Encapsulation of the rosehip flour resulted in a weaker gel structure with lower elasticity and cohesiveness.

In the future, it is possible to research and identify a suitable starter culture that would optimize the fermentation process.

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