DETERMINATION OF THE COLOR AND SENSORY CHARACTERISTICS OF ALBUMIN CHEESE ENRICHED WITH BEETROOT

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Abstract: Albumin cheese (Urda) is a traditional Macedonian cheese produced from whey, consumed by various age groups. Albumin cheeses focusing on functional properties have been developed over the last decade, but there are still no reported results on enriching albumin cheeses with organic beetroot powder. For this purpose, four samples of albumin cheese were produced: the control sample (ACK) of albumin cheese from whey, and enriched albumin cheese samples AC1, AC2, and AC3 with 2.5%, 5.00%, and 7.5% organic beetroot powder, respectively. The color of the enriched products was determined based on the added percentage of beetroot and the changes occurring during storage for 21 days at a temperature of 4°C, as well as the sensory acceptability, one of the most important parameters when creating a new product. The addition of beetroot powder to the Urda resulted in statistically significant differences ($p < 0.05$) in color between the control sample and the beetroot-enriched samples. The L^* parameter value decreased as the amount of beetroot powder increased. Even the lowest added amount of beetroot powder (2.5%) in the AC2 sample caused a statistically significant difference ($p < 0.05$) in the a^* parameter throughout the entire storage period of the albumin cheese. The results for the b^* parameter indicated a decrease in yellow color in the enriched samples and an intensification of blue color with the increasing percentage of added beetroot powder. Based on the results from sensory evaluation, it can be concluded that albumin cheese with 5% organic beetroot powder produces a product with excellent sensory quality, with a weighted average score of 4.58.
Keywords: Albumin cheese, beetroot, enriched product, sensory analysis, color.

1. INTRODUCTION

The production of whey cheeses (albumin cheeses) has a long history as a sustainable way to utilize whey (Bintsis & Papademas, 2023), which is rich in high-quality whey proteins, lactose, vitamins, and minerals (Kalevska et al., 2018). Albumin cheeses focusing on functional properties have been developed in the last decade (Bintsis & Papademas, 2023) in response to the growing demand for functional food, which has been steadily increasing (Akan, 2021).

Many plants contain pigments responsible for their natural color (Singh et al., 2023), among which is red beetroot *(Beta vulgaris L. species),* botanically classified as a biennial plant of the Chenopodiaceae family (Varshney & Mishra, 2022). In fact, the red color of beetroot is a result of the presence of betalains (Ravichandran et al., 2013). Depending on the pigmentation, betalains are classified into two structural groups: red-violet (betacyanins) and yellow (betaxanthins) (Ravichandran et al., 2013; Ben Haj Koubaier et al., 2014). Due to their water solubility, coloring properties, and antioxidant activities, betalains are increasingly added to various food products (Sadowska-Bartosz & Bartosz, 2021; Calva-Estrada et al., 2022). In addition to the wide application of beetroot in its fresh state, it is also used as a component for nutritional enrichment of products (Mudgal et al., 2022).

The application of betalains as a natural colorant in the food industry is intensifying, as they are non-toxic, non-poisonous, and possess anti-allergenic, antioxidant, and anticancer properties (Dias et al., 2020). According to Calva-Estrada et al., (2022), the use of betalains as antioxidant agents seems to meet the growing demand for functional foods, and should not be overlooked due to their pigmentation and sensory impact on the food in which they are added. The addition of natural color to dairy products makes them more appealing, particularly to children, thus increasing their demand and improving the health condition of children (Salman et al., 2024).
In recent years, research has focused on sensory acceptability and color stability during storage in new innovative dairy products enriched with beetroot (Adjei et al., 2024; Dabija et al., 2019; Junqueira-Goncalves et al., 2011; Evstigneeva et al., 2017). The available scientific literature has not yet determined the effect of added organic beetroot powder on the sensory characteristics of albumin cheese. The main objective of this study is to create a new innovative product - albumin cheese (Urda) from cow's whey, enriched with organic beetroot powder at

concentrations of 2.5%, 5%, and 7.5%, and to monitor the change in color during storage at intervals of 1, 7, 14, and 21 days, as well as the sensory acceptability of the new types of albumin cheese.

2. MATERIALS AND METHODS

Materials

For the production of albumin cheese (Urda), whey was used, obtained during the production of white brined cheese under industrial conditions at the "Mavrovo" dairy, located in the village of Izhishte, Kičevo, Republic of North Macedonia. For the enrichment of albumin cheese, organic beetroot powder from the producer "We are one", Serbia, was used.

Methods

Production of Albumin Cheese

The production process of albumin cheese involves heating the whey to 92°C, followed by coagulation and the separation of whey proteins on the surface. The whey is then drained, cooled to 15°C, and the albumin cheese is salted with 1.5% NaCl. Four variants of albumin cheese were produced:

- Control sample ACK: albumin cheese (Urda) from whey without the addition of beetroot powder.
- Sample AC1: albumin cheese (Urda) from whey enriched with 2.5% organic beetroot powder.
- Sample AC2: albumin cheese (Urda) from whey enriched with 5% organic beetroot powder.
- Sample AC3: albumin cheese (Urda) from whey enriched with 7.5% organic beetroot powder.

Color Determination

The color of the tested samples with different amounts (0%, 2.5%, 5%, 7.5%) of beetroot powder was determined using computer image processing (Lukinac Čačić, 2012; Nakov et al., 2019). The procedure for color determination was carried out in several steps:

- Digitalization of the samples;
- Processing and analysis of the digital images using a computer program;
- Conversion of the results from the RGB model to the CIE *L*a*b** model.

The analyses were repeated every seven days from the day of the production of the albumin cheese until the 21st day.

Sensory Analysis

The sensory evaluation of the enriched albumin cheese (Urda) samples was conducted on the first day after production using a five-point scoring system, adapted from Radovanovic and Popov-Raljic (2000/2001), by 13 evaluators of different genders and age categories. The following sensory attributes were assessed: appearance, color, taste, odor, and consistency. For each of the examined characteristics, a weighting coefficient was assigned. The evaluated properties were rated on a scale from 1 to 5. The score for each property was multiplied by its respective weighting coefficient, and the sum of these values was expressed as a percentage (%), representing the percentage of the maximum possible quality. This value, when divided by the sum of the weighting coefficients ($\Sigma = 20$), gives the weighted average value, which represents the overall quality score of the examined albumin cheeses. The categorization of the overall quality score was based on the German standard for sensory evaluation (Deutsche Landwirtschafts-Gesellschaft-DLG), according to which the tested products are categorized into several groups: products with excellent quality (score of 4.5 out of 5.00), products with very good quality (3.5 to 4.5), products with good quality (2.5 to 3.5), and products that do not meet the quality requirements (< 2.5) (Nakov et al., 2018).

For the graphical representation of the results and the determination of statistical differences, ANOVA (analysis of variance) and Fisher's LSD test for least significant differences with a 95% confidence factor ($p < 0.05$) were used through the XLSTAT 2019 and Microsoft Office Excel 2019 programs.

3. RESULTS AND DISCUSSION

The results from Table 1 show the changes in the color of albumin cheese (Urda) with different amounts of beetroot powder (0, 2.5%, 5.00%, and 7.5%), as well as the changes that occur during storage over a 21-day period. The *L** parameter indicates the lightness of a product. The closer the values for this parameter are to 0, the darker the analyzed samples appear. The results indicate that the value of this parameter decreases as the amount of beetroot powder increases (from 87.48 to 58.27 on the first day, from 85.45 to 56.34 on the seventh day, from 82.73 to 54.48 on the fourteenth day, and from 77.99 to 52.59 on the twenty-first day). In other words, the addition of beetroot powder results in a darker final product. The observed difference in the *L** parameter value between samples with different amounts of added beetroot powder during storage is statistically significant at the level ($p < 0.05$).

On the other hand, no statistically significant difference ($p < 0.05$) was found when monitoring the changes in the *L** parameter during the prolonged storage of Urda cheese with different amounts of beetroot powder. According to Adjei et al., (2024), the *L** values for yogurt samples were statistically different ($p < 0.05$) compared to other

samples with added beetroot puree at concentrations of 2%, 2.03%, and 8%. According to Salman et al., (2024), the *L** parameter value decreases during prolonged storage from day 0 to day 12 (from 74.13 to 69.63) for yogurt enriched with 5% beetroot juice.

Table 1. Changes in the color of albumin cheese enriched with different amounts (2.5%, 5.0%, and 7.5%) of beetroot powder during a 21-day storage period.

Parameters	Amounts of beetroot powder (%)	Time of storage (days)			
		1	7	14	21
*L**	0	$87.48\pm0.98^{a,A}$	$85.45\pm0.38^{a,A}$	$82.73\pm0.93^{a,A}$	$77.99\pm1.49^{a,A}$
	2.5	$65.54\pm2.43^{b,A}$	$62.82\pm0.93^{b,A}$	$61.58\pm1.51^{b,A}$	$61.52\pm0.18^{b,A}$
	5	$59.38\pm0.81^{c,A}$	$56.68\pm1.95^{c,A}$	$56.44\pm1.06^{c,A}$	$56.43\pm1.41^{c,A}$
	7.5	$58.27\pm1.97^{d,A}$	$56.34\pm1.45^{d,A}$	$54.48\pm3.38^{d,A}$	$52.59\pm0.86^{d,A}$
*a**	0	$0.53\pm0.02^{c,C}$	$0.62\pm0.05^{c,B}$	$0.76\pm0.02^{c,A}$	$1.15\pm0.31^{c,A}$
	2.5	$48.05\pm0.30^{b,C}$	$54.83\pm2.19^{b,B}$	$59.47\pm0.55^{b,A}$	$59.73\pm0.07^{b,A}$
	5	$59.40\pm1.06^{a,C}$	$60.29\pm0.33^{a,B}$	$63.63\pm3.14^{a,A}$	$65.78\pm1.06^{a,A}$
	7.5	$60.51\pm0.58^{a,C}$	$60.93\pm0,69^{a,B}$	$64.93\pm2.40^{a,C}$	$66.92\pm0.17^{a,C}$
*b**	0	$-0.29\pm0.02^{a,A}$	$0.49\pm0.08^{a,B}$	$4.66\pm0.0^{4a,C}$	$6.63\pm0.25^{a,C}$
	2.5	$-3.08\pm0.22^{b,A}$	$-4.43\pm0.42^{b,B}$	$-8.35\pm1.15^{b,C}$	$-10.18\pm0.24^{b,C}$
	5	$-5.72\pm0.80^{c,A}$	$-8.37\pm0.29^{c,B}$	$-11.10\pm0.80^{c,C}$	$-13.27\pm2.72^{c,C}$
	7.5	$-6.29\pm0.19^{d,A}$	$-12.51\pm0.54^{d,B}$	$-13.71\pm0.47^{d,C}$	$-14.29\pm0.02^{d,C}$

The presented values are the mean ± standard deviation from three consecutive measurements. Lowercase letters in the index indicate a Statistically significant difference ($p < 0.05$) between samples with different amounts of added beetroot powder; uppercase letters in the index indicate a statistically significant difference ($p < 0.05$) between storage days of the Urda cheese.

Source: Authors research

The *a** parameter characterizes the red (positive values) or green (negative values) color. The results from Table 1 show that in all the samples with added beetroot powder (AC1, AC2, and AC3), the values are positive, meaning that the red color prevails. Furthermore, even the lowest added amount of beetroot powder (2.5%) in the AC2 sample causes a statistically significant difference ($p < 0.05$) in terms of the *a** parameter, from 0.53 to 48.05; from 0.62 to 54.83; from 0.76 to 59.47; and from 1.15 to 59.47 on the first, seventh, fourteenth, and twenty-first days of storage, respectively. A statistically significant ($p < 0.05$) increase in the *a** parameter values is observed throughout the entire storage period of albumin cheese. A positive increase in the *a** parameter value was also determined by Salman et al., (2024). An increase in the *a** parameter value from -6.94 for the control to -6.29 for yogurt enriched with 2% beetroot powder was observed by Dabija et al., (2019).

The *b** parameter provides information about the blue (negative values) or yellow (positive values) color. The results indicate a statistically significant ($p < 0.05$) decrease in the values for this parameter in the AC3 sample with 7.5% beetroot powder from -0.29 to -6.29 on the first day, from 0.49 to -12.51 on the seventh day, from 4.66 to -13.71 on the fourteenth day, and from 6.63 to -14.29 on the twenty-first day of storage, compared to the control sample. The results for the *b** parameter show a decrease in yellow color and an intensification of the blue color as the percentage of added beetroot powder increases. On the other hand, only in the control sample does the yellow color intensify as storage time increases, while in the samples with beetroot powder, the blue color intensifies.

An increase in the positive values for *b**, meaning an increase in yellow color depending on the added amount of beetroot puree in yogurt, was also determined by Adjei et al., (2024). Salman et al., (2024) found that the values for the *b** parameter increase with the extended storage period of yogurt. This contrasts with our results, where the decrease in the *a** parameter values and the increase in the *b** parameter values could suggest the degradation of betalains. The degradation of betalains leads to the formation of yellow-colored compounds, which is reflected by an increase in the *b** parameter (Flores-Mancha et al., 2021).

From the presented data, we can conclude that albumin cheese (Urda) positively influences the preservation of betalains during a 21-day storage period. However, to confirm this, further analysis is needed to determine the betalain content at all the intended analysis periods.

Table 2. Results from the sensory analysis of albumin cheese enriched with different amounts of beetroot powder.

Показател на квалитет	CV	Score ACK	Score AC1	Score AC2	Score AC3
Appearance	4	4.750	4.375	4.875	3.875
Color	5	5.000	4.750	4.750	4.000
Taste	5	4.750	4.500	4.500	3.875
Aroma	5	4.375	4.125	4.375	3.875
Texture	3	4.500	4.250	4.250	3.775
Overall acceptance	Σ20				
Weighted average grade		4.72	4.44	4.58	3.88
% of totally quality		94.38	88.88	91.63	77.75

Source: Authors research

The results of the sensory evaluation of all albumin cheese (Urda) samples: ACK, AC1, AC2, AC3 with (0%, 2.5%, 5%, and 7.5% beetroot powder) are presented, where the sensory quality was evaluated based on the following attributes: appearance, color, taste, odor, and consistency. The addition of 5% beetroot powder improved the appearance and consistency of the AC2 sample, which received the highest ratings of 4.875 and 4.375, respectively, compared to the other samples with added beetroot powder. The sample with 8% beetroot powder received the lowest ratings for all evaluated sensory quality parameters compared to the other tested samples. The presented results indicate that the addition of 5% beetroot powder positively affects the overall acceptability, with the highest rating of 4.58, compared to the other two samples with 2.5% and 7.5% beetroot powder, though it remains lower than the overall acceptability rating for the ACK sample (4.72), which contained no added beetroot powder.
According to the German sensory evaluation standard, the ACK and AC2 samples were rated with an average weighted score of 4.72 and 4.58, respectively, and are classified in the category of products with excellent quality. The AC1 and AC3 samples were categorized in the group of products with very good quality, with a weighted average score of 4.44 and 3.88, respectively.

4. CONCLUSION

Enriching Urda with organic beetroot powder is a viable option for creating new enriched products. The addition of 5% organic beetroot powder improves the sensory quality of albumin cheese from the AC2 sample, categorizing it as a product of excellent quality with a weighted average score of 4.58. The addition of beetroot powder to albumin cheese (Urda) contributes to statistically significant differences ($p < 0.05$) in color between the samples. The value of the L^* parameter decreases with an increase in the amount of added beetroot powder ($p < 0.05$), resulting in a darker color of the final product. Monitoring the color change during the 21-day storage period may help determine the stability of betalains, which have anti-allergenic, antioxidant, and anticancer properties. Even the smallest added amount of beetroot powder (2.5%) causes a statistically significant difference ($p < 0.05$) in terms of the a^* parameter throughout the entire storage period. The results for the b^* parameter indicate a decrease in yellow color in the enriched samples and an intensification of blue color with the increase in the percentage of added beetroot powder, suggesting the stability of the added betalains throughout the 21-day storage period. However, to confirm this conclusion, further research on the betalain content in the enriched samples is necessary, which will be one of the objectives of future research.

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