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Investigation of the Effects of Blueberry Powder on the Ripening of Turkish White Cheese

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ABSTRACT

This study aims to enrich Turkish white cheese with blueberry powder, owing to its exceptional bioactive properties, to enhance its functionality. Five cheese samples were prepared by adding different concentrations [0 (control), 0.5, 1, 1.5, 2%] of blueberry powder to the cheese curd. The cheese samples were ripened in vacuum packages for 90 days at 7±1°C. The pH, dry matter, salt, fat, total protein, titration acidity, water-soluble nitrogen, ripening index, electrophoretic casein fractions, color and sensory analyses were performed on the 3rd, 30th, 60th, and 90th days of ripening period. The data obtained were compared in terms of cheese types and ripening times. The addition of blueberry powder to cheese curd and the storage time affected the pH values significantly (p<0.05). Similarly, the addition of blueberry increased the titratable acidity values of white cheese and the differences in acidity between cheese samples were found to be significant (p<0.05). The highest decrease in the amount of α_{S1}-casein was recorded in C2 (1% blueberry added cheese) samples and the least decrease was in the control group cheeses. Color analysis indicated that the *L* value was reduced with increasing concentrations of blueberry addition because of darkening. In conclusion, blueberry added Turkish white cheese could be produced as an alternative dairy product with acceptable sensory properties.

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Introduction

Turkish White cheese is a brined (or pickled) cheese variety with a soft or semi-hard texture and a salty, acidic taste. Considering its texture, taste and production methods, Turkish White cheese is comparable to some other cheese varieties such as Feta and Domiati (1). Some aspects of this cheese are reviewed, including milk supply, use of starters and enzymes, manufacturing technology, chemical composition and microflora, chemical and biochemical changes during ripening. These cheeses are generally rich in proteins and some minerals however, their bioactive properties are limited. Therefore, it is important to improve its bioactivity (i.e., antimicrobial activity, antioxidant activity, phenolic content) and functionality using ingredients with high bioactivity. A variety of ingredients including nuts, almonds, walnuts, peanuts, nuts, cereals, sugar, and sugary products, fruits and vegetables and their juice, concentrate, puree, paste, products such as honey, cocoa, coffee, chocolate, spices edible parts of plants have been added to cheese. When 10% pineapple is added to Queso de pina cheese, the resulting composition is 60.77% moisture, 19.26% fat, 12.88% total protein, 1.46% salt and pH 6.34 (2). Choi et al. (3) reported that pH values were between 5.24 and 5.39, and fat values between 31.72% and 33.52%, as a result of their study by adding fruit flavors to Gouda type cheeses. Yerlikaya and Karagözlü (4) found that the addition of caper fruit to cheese caused significant improvements in terms of salt, lactic acid, and mineral substances, in line with their analysis of some physicochemical and functional properties of white cheese with caper fruit. It has also been determined that the addition of caper fruit has a positive effect on some physicochemical properties of cheese and differentiates some quality properties. Da Silva et al. (5) investigated the antimicrobial activity of extracts obtained from dried fruit and leaves of blueberry (*Vaccinium corymbosum*) and discovered that leaf extracts were more effective than fruit extracts. In this research, whether the extract of blueberry fruit is dry or wet, it was determined that it has a very good antimicrobial activity regardless of fruit or leaf.

Blueberry is a medicinal plant that is widely used against many health problems. Blueberry are

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used in a variety of food products, particularly in Europe and America, including cake, jam, molasses, marmalade, fruit juice, ice cream, fruit yoghurt, fruit muffins, and wine. Blueberry leaves are used to make tea, and its roots, fruits, flowers, and leaves are used in the production of medicine. It is known with different names such as tea currant, cranberry, and blueberry in different locations. Blueberries have a high-water content (6) hence prone to microbial spoilage and chemical degradation. Therefore, it is sometimes used in dried and ground form, for instance, as a sweetener for diabetics. However, traditional drying methods may harm its bioactive and physical properties due to heat treatment. Freeze-drying can be used as an alternative method to maintain its bioactive properties and color, but it is an expensive method with high-cost setup. As a solution, the development of a method that is both inexpensive and do not damage the components is being considered. One way is the spray drying method which relatively affordable however, due to the high temperature, this method may produce undesirable results (7). In this regard, vacuum drying may offer an efficient method for drying of blueberries.

Fruit and fruit-flavored cheese varieties can provide both the nutritional value of cheese and bioactive properties of the fruit that is contained. Hence, they could present a healthy option for the consumers. The aim of this study is to add blueberry powder dried by vacuum oven, to preserve the bioactive components and maintain the color, into cheese to increase the bioactvitiy and functionality of cheese. Also, it was aimed to develop an alternative cheese with fruity flavor and aroma with an attracting appearance for consumers that avoid eating cheese due to its odor and taste.

Materials and Methods

The white cheese used in this study; was produced in a laboratory environment. The fresh cow milk (4% fat, pH of 6.5, and dry matter of 13.12%) was obtained from Bulancak district of Giresun province was used in the production of cheese samples. The commercial rennet obtained from Intermak Makina product Inc. (8000 mcu/ml) was used as coagulant. Blueberries were collected form Giresun plateaus, and after they were slightly crushed, they were spread on plates in thin layers and dried in a vacuum oven (50°C, 24 h) and ground into powder using a coffee grinder. The blueberry powder concentrations were determined based on preliminary sensory trials. Following production, cheese samples were packed using a vacuum packing machine (Cas Cvp-260, Czech Republic). The packaging material is made of 360 µm thick polyethylene plastic, which is suitable for the product and has very low oxygen and odor permeability.

Cheesemaking

The cow milk was pasteurized at 75°C for 30 s and cooled to 34°C for rennet addition. Rennet was added (3 mL/15 L milk) and kept for 90 minutes to reach cutting maturity. Then, the curd was cut, and whey was removed. Blueberry powder was added to the curd [0% (CC), 0.5 % (C1), 1.0 % (C2), 1.5 % (C3), and 2.0 % (C4)] and homogenized before pressing the curd. After the addition of blueberries, the curds were left in the press overnight. Following the completion of the pressing process, the samples were removed from the pressing cloth and salted with 4% salt (w/w %). To ensure that the salt spreads homogeneously during the salting process, each surface was salted separately. The cheese samples were vacuum-packed and ripened at 7±1°C for 90 days. Two replicates of cheese samples were prepared for each cheese type.

Chemical and Biochemical Analysis

To determine the dry matter content, the cheese samples were dried in a laboratory oven at 105 °C until a constant weight was obtained. The total nitrogen (VELP Scientifica, Italy) concentration of the samples was determined according to Kurt et al. (8). Fat content was determined by the Gerber method. Salt content was determined according to the Mohr method, while pH was measured with a digital pH meter (Starter 3100, USA) as described by Case et al. (9). Water-soluble nitrogen (WSN) and ripening index (WSN/TN) values were calculated using methods developed by Kamaly et al. (10) and Butikofer et al. (11), respectively. Electrophoretic analysis of protein patterns was performed by the method of Celik and Tarakci (12), as previously described by Creamer (13), with some modifications.

Color Analysis

Color measurements were performed using a colorimeter (Minolta Chroma Meter, CR-400, and Osaka, Japan). The L^*, a^*, and b^* color measurements were determined according to the

CIE Lab color system. Three readings were taken for each sample and arithmetic means were calculated.

Sensory Analysis

Sensory evaluation of blueberry-added white cheese was performed by a panel of ten semi-trained graduate students experienced in the sensory evaluation of cheeses. Before evaluation, each cheese was cut into 20 g cubes, left at room temperature (25°C) for 2 hours, and randomly served to the panelists. Overall sensory quality was assessed using a hedonic scale method (1-10 points), with 1 being unacceptable and 10 being very good for color and appearance, smell, structure and texture, taste, and flavor. The panelists were given a glass of water to rinse their mouths between cheese samples. Panelists were also asked to report any flaws in color and appearance, texture, odor, taste, and overall acceptability.

Statistical Analysis

All analyses were performed in duplicate. Minitab 16.0 Statistical Software (Minitab Inc.) was used for all statistical calculations, and the results are presented as mean ± standard deviation. Analysis of variance (ANOVA) was used to determine significance, followed by Tukey's multiple range tests. The significance level of $p<0.05$ was used for statistical differences.

Results and Discussion

Chemical Analysis Results

Table 1 shows the results of the chemical values of the cheeses produced with blueberry addition. The lowest dry matter value was determined with 43.82±0.71% in the C2 sample on the 30th day of ripening; and the highest dry matter value was found in the C3 sample on the 30th day of ripening with the rate of 47.68±0.85%. The effect of cheese type on dry matter values was found to be statistically significant ($p<0.05$), but no significant ($p>0.05$) increase was observed in dry matter values during the ripening period. This could be explained by the blueberry powder being added to the samples at different rates. Similar values were obtained by Davide et al. (2) in queso de pina cheeses with pineapple, Uraz and Şimşek (14) in white cheeses, Yerlikaya and Karagözlü (4) in white cheeses with caper, and Sağun et al. (15) in the brined herb cheese. The effect of blueberry powder on the fat content of cheeses was significant ($p<0.05$), while the differences between ripening periods were insignificant ($p>0.05$). The lowest fat rate was determined as 24.00±0.50% in 2% blueberry cheese on the 3rd day of ripening. During ripening, except C2, a decrease in fat content was observed.

Table 1. Changes in dry matter, fat, titratable acidity, pH, salt and ash content values during the ripening of cheese samples

	Cheese Types	Ripening Times (Days)			
		3	30	60	90
Dry Matter (%)	CC	$44.59\pm0.74^{a,B}$	$45.39\pm0.00^{a,B}$	$45.78\pm0.04^{a,A}$	$44.61\pm1.46^{a,B}$
	C1	$45.72\pm0.75^{a,B}$	$44.47\pm0.79^{a,B}$	$46.23\pm0.47^{a,A}$	$44.00\pm1.08^{a,B}$
	C2	$45.24\pm0.21^{a,B}$	$43.82\pm0.71^{a,B}$	$45.83\pm0.98^{a,A}$	$46.35\pm0.22^{a,A}$
	C3	$44.92\pm0.57^{a,B}$	$47.68\pm0.85^{a,A}$	$46.87\pm0.41^{a,A}$	$46.94\pm0.11^{a,A}$
	C4	$44.82\pm0.21^{a,B}$	$45.30\pm0.38^{a,B}$	$45.37\pm1.12^{a,B}$	$44.96\pm0.83^{a,B}$
Fat (%)	CC	$25.75\pm0.35^{a,A}$	$25.50\pm0.00^{a,A}$	$25.50\pm0.00^{b,A}$	$25.25\pm0.35^{a,A}$
	C1	$25.75\pm0.60^{b,A}$	$25.00\pm0.50^{a,A}$	$25.25\pm0.50^{b,A}$	$24.00\pm0.55^{b,A}$
	C2	$24.00\pm0.50^{b,A}$	$25.00\pm0.50^{a,A}$	$26.00\pm0.50^{a,A}$	$25.00\pm0.55^{a,A}$
	C3	$25.25\pm0.35^{a,A}$	$25.00\pm0.50^{a,A}$	$26.25\pm0.50^{a,A}$	$25.25\pm0.35^{a,A}$
	C4	$25.50\pm0.35^{a,A}$	$25.00\pm0.41^{a,A}$	$24.00\pm0.41^{b,A}$	$24.50\pm0.35^{a,A}$
Titratable acidity (Lactic acid, %)	CC	$0.40\pm0.06^{cd,C}$	$0.69\pm0.01^{cd,B}$	$0.82\pm0.01^{c,A}$	$0.85\pm0.06^{cd,A}$
	C1	$0.39\pm0.01^{a,C}$	$0.82\pm0.02^{ab,B}$	$0.94\pm0.02^{ab,A}$	$1.10\pm0.03^{a,A}$
	C2	$0.40\pm0.03^{ab,C}$	$0.85\pm0.06^{a,B}$	$0.90\pm0.04^{b,A}$	$0.95\pm0.06^{ab,A}$
	C3	$0.40\pm0.03^{bc,C}$	$0.72\pm0.03^{bc,B}$	$1.00\pm0.06^{a,A}$	$0.88\pm0.05^{bc,A}$
	C4	$0.45\pm0.04^{a,C}$	$0.70\pm0.06^{d,B}$	$0.73\pm0.01^{d,A}$	$0.75\pm0.04^{d,A}$
pH	CC	$4.73\pm0.02^{b,A}$	$4.77\pm0.01^{b,B}$	$4.81\pm0.00^{b,B}$	$4.79\pm0.01^{b,B}$

	Cheese Types	Ripening Times (Days)			
		3	30	60	90
	C1	6.48±0.03^{a,A}	5.48±0.01^{a,B}	5.52±0.01^{a,B}	5.42±0.02^{a,B}
	C2	5.93±0.02^{a,A}	5.41±0.02^{a,B}	5.49±0.03^{a,B}	5.64±0.02^{a,B}
	C3	635±0.07^{a,A}	5.68±0.04^{a,B}	5.43±0.01^{a,B}	5.51±0.01^{a,B}
	C4	4.68±0.02^{b,A}	4.60±0.01^{b,B}	4.68±0.01^{b,B}	4.62±0.00^{b,B}
Salt (%)	CC	2.44±0.11^{a,A}	2.92±0.08^{a,B}	2.83±0.04^{a,B}	2.77±0.04^{a,B}
	C1	2.81±0.71^{a,A}	2.39±0.00^{a,B}	2.60±0.04^{a,B}	2.46±0.33^{a,B}
	C2	3.63±0.38^{a,A}	2.69±0.00^{a,B}	3.06±0.11^{a,B}	2.19±0.04^{a,B}
	C3	3.31±0.11^{a,A}	2.36±0.12^{a,B}	2.60±0.04^{a,B}	2.51±0.00^{a,B}
	C4	3.36±0.33^{a,A}	2.66±0.87^{a,B}	2.39±0.00^{a,B}	2.34±0.08^{a,B}
Ash (%)	CC	3.27±0.18^{b,A}	3.61±0.06^{b,C}	3.31±0.03^{b,C}	3.18±0.08^{b,B}
	C1	4.03±0.06^{a,A}	3.70±0.02^{a,C}	3.99±0.07^{a,C}	3.96±0.01^{a,B}
	C2	4.67±0.07^{a,A}	3.32±0.09^{a,C}	3.28±0.04^{a,C}	4.23±0.00^{a,B}
	C3	3.96±0.04^{a,A}	3.53±0.13^{a,C}	3.89±0.02^{a,C}	4.00±0.02^{a,B}
	C4	2.92±0.16^{c,A}	3.24±0.06^{c,C}	3.78±0.03^{c,C}	3.75±0.01^{c,B}

a–d indicate differences (p<0.05) between columns.
A–C indicate differences (p<0.05) between rows.
Mean values ± standard deviation of two trials.

Cheese is a fermented dairy product hence, controlled production of lactic and other acids from lactose by lactic acid bacteria is an essential step during the manufacturing and ripening. Titratable acidity in cheese is composed of lactic acid, formic acid, acetic acid, butyric acid (a lactose fermentation product), free fatty acids formed by lipolysis, and free amino acids formed by proteolysis. The differences between the samples and storage time were found to be significant (p<0.05). The acidity of the cheese increases over time due to the high acidity of the fruit added to the cheese. The results obtained are higher than the titration acidity values of Tarakçı and Küçüköner (16) herb-added cheese sample, and Uraz and Şimşek (14) White cheese sample.

The effect of storage time on the pH data of cheese samples was found significant (p<0.05). The highest value was detected in the C1 sample on the 3rd day, and the lowest was in the C3 sample on the 30th day. The pH values of the CC and C4 samples are slightly lower than the other samples. Tarakçı et al. (17) herby cheeses, Da Silva et al. (18) fruit added cheese samples, Çakır-Yılmaz (19) spice added cheese samples were found to have similar pH values.

The effect of cheese type on salt content was found statistically significant (p<0.05). On the 90th day of the storage period, a decrease in salt values was observed in general. In the dry salting method, the cheese absorbs the salt over time. Therefore, as the storage time increases, the salt value decreases. Salt values of this study are comparable to those found in the Van herby cheese study by Tunçtürk et al. (20), freshly produced circassian cheese samples by Uysal et al. (21), and local herb-added cheeses study by Agboola and Radovanovic-Tesic (22). Davide et al. (2) added pineapple to queso de pina cheeses and determined a higher salt content. Ash rates were found to be between 2.75% and 4.67%. The effect of cheese type on the ash concentrations was found significant (p<0.05). The change in ash rates were found to be similar to the changes in salt rates.

Changes in the Protein, WSN, WSN/TN of Cheeses during Ripening

Cheese texture is formed by casein-casein, casein-water, and casein-fat interfaces, state of ionic or bound (to the casein matrix) calcium, state of bulk or bound (to casein) water, and the degree of proteolysis. The distribution and binding capability of water affect the structure, for example, the casein matrix becomes porous and tortuous (23). It was determined that the protein ratios of white cheeses produced with different amounts of blueberry fruit were between 14.88% and 17.69%. The results suggested that the fruit added to the cheese did not affect the protein values. Agboola and Radovanovic-Tesic (22) herb cheese, Tarakçı et al. (24) herbed cheese, Tunçtürk et al. (20) in kashar cheese, Tarakçı and Deveci (25) in spicy white cheese, Davide et al. (2) queso de pina cheese with pineapple and Yerlikaya and Karagözlü (4) cheese with capers determined similar ripening values. One method for determining the rate of proteolysis in cheeses is to measure the rate of water-soluble nitrogen (WSN). It has been reported that the acidity in cheese is primarily a result of lactic acid, acetic acid, butyric acid, formic acid however, free amino acids, alkaline and neutral compounds formed by proteolysis, as well as lipolysis degradation products, can cause a decrease in titratable acidity (26, 27).

Water soluble nitrogen (WSN) amount is a ripening parameter (28). It has been determined that the water-soluble nitrogen ratios of the cheeses were between 0.17-0.51%. Statistical differences between samples were found to be significant (p<0.05). This deviation is estimated to be due to errors that occurred during the instrumental analysis.

The ripening index is calculated by proportioning the total WSN to the total nitrogen amount. According to the results obtained from the study, it was noted that the differences between the samples were significant (p<0.05). According to the data given in the Table 2, the highest degree of ripening value was observed on the 90th day for the C1 sample, and the lowest degree of ripening value was observed on the 3rd day for the C4 sample. The ripening index results of the cheese samples obtained were similar to those of Gezmiş and Tarakçı (29) spice-added circassian cheese, Koçak et al. (30) kashar cheese samples, and Tarakçı and Küçüköner (16) herb cheese samples.

Table 2. Changes in the protein, WSN, WSN/TN during the ripening of white cheeses

	Cheese Types	Ripening Times (Days) 3	30	60	90
Protein (%)	CC	15.18±0.13^{a,B}	15.72±0.38^{a,B}	15.90±0.13^{a,AB}	15.81±0.25^{a,A}
	C1	15.63±0.76^{a,B}	15.56±0.00^{a,B}	16.61±0.38^{a,AB}	15.99±0.50^{a,A}
	C2	15.99±0.00^{a,B}	14.92±0.51^{a,B}	15.72±0.63^{a,AB}	16.52±1.26^{a,A}
	C3	14.88±0.71^{a,B}	15.99±0.51^{a,B}	15.54±0.13^{a,AB}	17.69±0.63^{a,A}
	C4	15.98±0.24^{a,B}	16.17±0.51^{a,B}	17.40±0.38^{a,AB}	16.45±0.00^{a,A}
WSN (%)	CC	0.19±0.00^{b,C}	0.28±0.01^{b,B}	0.35±0.01^{b,A}	0.31±0.01^{b,A}
	C1	0.19±0.00^{b,C}	0.40±0.00^{a,B}	0.49±0.02^{a,A}	0.51±0.01^{a,A}
	C2	0.21±0.01^{a,C}	0.37±0.00^{a,B}	0.44±0.01^{a,A}	0.41±0.02^{a,A}
	C3	0.20±0.00^{a,C}	0.37±0.00^{a,B}	0.47±0.01^{a,A}	0.50±0.00^{a,A}
	C4	0.17±0.01^{c,C}	0.20±0.00^{c,B}	0.26±0.01^{c,A}	0.27±0.00^{c,A}
WSN/TN (%)	CC	7.90±0.03^{c,C}	11.46±0.01^{d,B}	14.18±0.09^{d,A}	12.62±0.10^{d,A}
	C1	7.64±0.39^{d,C}	17.40±0.00^{a,B}	18.93±1.16^{b,A}	20.23±0.87^{a,A}
	C2	8.20±0.37^{b,C}	15.83±0.54^{c,B}	18.04±0.52^{c,A}	15.67±0.61^{c,A}
	C3	8.69±0.19^{a,C}	14.73±0.47^{b,B}	19.33±0.59^{a,A}	18.06±0.81^{b,A}
	C4	6.75±0.36^{e,C}	7.75±0.21^{e,B}	8.92±0.70^{e,A}	11.12±0.02^{e,A}

a–d indicate differences (p<0.05) between rows.
A–C indicate differences (p<0.05) between columns.
Mean values ± standard deviation of two trials.

Casein Fractions in Cheese Samples

Proteins in cheese are broken down by proteolytic and other degrading enzymes. As a result, large and small peptides, amino acids, and smaller organic molecules are formed and this hydrolysis is monitored by different methods (31). One of these methods is the gel electrophoresis method, which detects coarse peptides. At the same time, gel electrophoresis method has been seen as a suitable method for tracking straight chains in casein micelles in the early stages of cheese ripening (32). The images of the gel electrophoresis determination showing the ripening time of the cheeses produced by the Urea-PAGE electrophoresis method are given in Figure 1.

Electrophoretic properties of the blueberry cheese samples and the casein fractions of the control cheese sample were observed in the bands on the 3rd, 30th, 60th, and 90th days of ripening, respectively. When the casein fractions in the gels are examined, it can be seen from the figures that β-casein and αs1-casein densities decrease during the ripening period. The highest decrease in the amount of αS1-casein was recorded for C2 (1% blueberry added) cheeses and the least decrease was seen in the control group cheeses. Considering β-casein, the C2 (1% blueberry added) cheese sample again showed the highest decrease, and the cheeses from the control group showed the least decrease. In general, the lowest values were found on the 3rd day and the highest values were found in the cheese samples at 90th day. The differences between the samples were found to be significant ($p<0.05$). Similarly, Gezmiş and Tarakci (29) spice-added circassian cheese, Tarakçı et al. (23) herbed cheese, and Tunçtürk et al. (20) herbed cheese, Tarakçı and Deveci (25) spice-added white cheese samples determined a decrease in the ratios of αS1-casein and β-casein throughout the period.

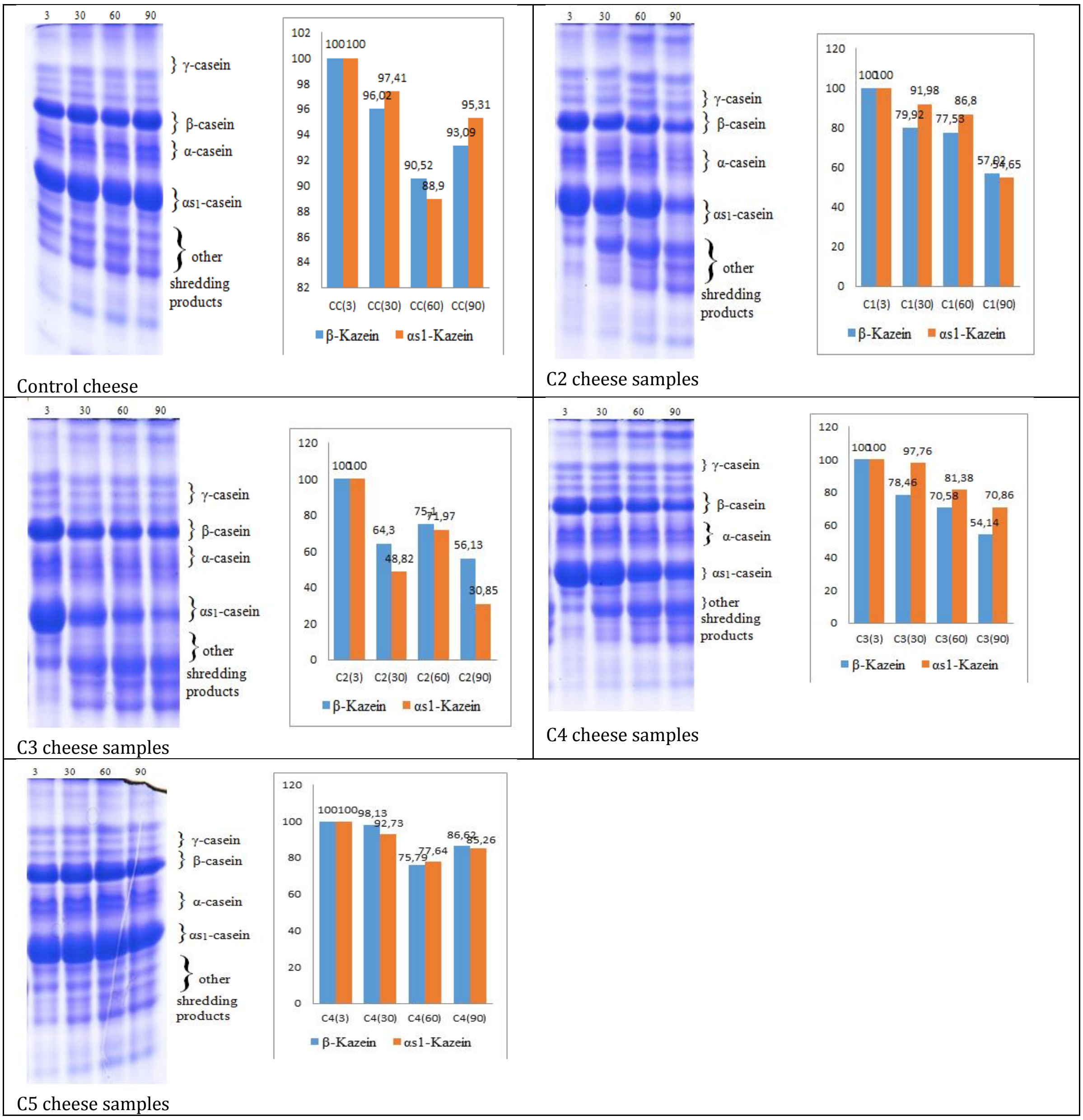

Figure 1. The images showing the ripening by the Urea-PAGE electrophoresis. C5?

Changes in the Color Values of Cheese Samples

L, *a*, and *b* color data are represented by a three-dimensional coordinate system. In this system, the *L* color value represents the color tone going from brightness (100) to darkness (0) on the vertical axis, while +a refers to red, -a to green, +b to yellow, and -b to blue. The *L* color value of the white cheese samples we produced is presented in Table 3. It has been determined that *L* color values are between 68.84 and 92.50. In line with the data we obtained, the differences between the samples were found to be significant ($p<0.05$). The *L* value was higher in the control group samples than in the blueberry cheese samples. As the fruit ratio of cheese increases, the *L* value decreases due to the dark purple color of blueberry. When the data in the table were examined, it was found that the C4 samples in 60th and 90th days had the lowest *L* values, and the CC cheese samples of 3rd day had the highest *L* value. The high deviation values in some of the measurements are estimated to be due to errors that occurred during the instrumental analysis. The results we obtained are similar to the values in the studies of Çakır-Yılmaz (19) on spice-added kashar cheese, Gezmiş and Tarakçı (29) on traditional spicy circassian cheese, and Tarakçı and Bayram (33) on fruit powder-added kashar cheese while Aydın and Tarakçı (34) determined higher *L* values for the kashar cheese with dried herbs.

Table 3. Changes color values during the ripening of white cheeses

	Cheese Types	Ripening Times (Days)			
		3	30	60	90
L color value	CC	92.50±0.66^{a,A}	91.60±0.24^{a,A}	91.56±0.11^{a,A}	90.62±0.57^{a,A}
	C1	84.50±3.27^{b,A}	83.29±0.50^{b,A}	85.45±0.61^{b,A}	87.24±1.41^{b,A}
	C2	77.35±0.64^{c,A}	75.66±4.89^{c,A}	77.34±1.03^{c,A}	81.85±7.02^{c,A}
	C3	73.65±3.35^{d,A}	72.68±5.07^{d,A}	70.54±0.31^{d,A}	72.68±5.07^{d,A}
	C4	75.56±4.40^{d,A}	72.61±1.32^{d,A}	68.84±2.47^{d,A}	68.84±2.47^{d,A}
a color value	CC	-4.04±0.02^{e,A}	-4.44±0.16^{e,A}	-4.23±0.16^{e,A}	-4.63±0.15^{e,A}
	C1	-1.25±0.77^{d,A}	-2.73±0.01^{d,A}	-2.61±0.08^{d,A}	-2.29±0.27^{d,A}
	C2	0.46±0.52^{c,A}	0.13±1.33^{c,A}	-0.46±0.29^{c,A}	0.24±0.15^{c,A}
	C3	0.76±0.59^{b,A}	1.03±0.95^{b,A}	1.55±0.31^{b,A}	1.65±0.45^{b,A}
	C4	2.59±0.26^{a,A}	2.83±0.37^{a,A}	3.34±0.22^{a,A}	3.63±0.30^{a,A}
b color value	CC	16.58±0.96^{a,B}	18.94±0.81^{a,A}	18.30±0.07^{a,A}	16.20±0.76^{a,B}
	C1	10.59±0.89^{b,B}	16.32±0.49^{b,A}	16.96±0.36^{b,A}	11.78±0.01^{b,B}
	C2	9.08±1.21^{c,B}	13.61±0.70^{c,A}	13.28±0.96^{c,A}	11.78±0.01^{c,B}
	C3	6.13±1.15^{d,B}	9.97±2.88^{d,A}	9.22±0.41^{d,A}	8.93±2.23^{d,B}
	C4	6.64±1.02^{d,B}	9.19±1.70^{d,A}	8.29±0.52^{d,A}	7.10±1.77^{d,B}

a–d indicate differences ($p<0.05$) between columns.
A–C indicate differences ($p<0.05$) between rows.
Mean values ± standard deviation of two trials.

It has been determined that *a* color values are between -4.63 and 3.63. It was determined that the differences between the samples were significant ($p<0.05$). The highest and the lowest values were for C4 and C1 samples on the 90th day, respectively. In general, *a* value increased as the amount of fruit powder added to the cheese increased. Based on these findings, it is concluded that adding blueberry fruit to cheese increases its color value. While *a* color value of the cheeses was close to green in the control group samples, the blueberry added cheese samples were more red. The color difference in control cheeses is thought to be due to the milk from which the cheeses are made and the diet of the animal. It is found that the color of blueberry enhances the redness of cheeses. When these results we obtained are compared with other results; Gezmiş and Tarakçı (29) spicy circassian cheese, Tarakçı et al. (24), white cheese, Tarakçı and Deveci (25) spicy white cheese, Tarakçı and Bayram (33) fruity kashar cheese, Çakır-Yılmaz (19) spice added kashar cheese, and Aydın and Tarakçı (34) herb-added kashar cheeses is found to be similar to the values in their studies. While the *b* color values of the cheeses in the control group samples were close to yellow, the values in the blueberry cheese samples were bluer.

Sensory Scores in the Cheese Samples

The sensory scores for the cheese samples during storage are presented in Table 4. The lowest and highest color and appearance scores belonged to C2 sample (5.40) at 90th day and C4 sample (9.20) on the 30th day, respectively. The findings of this study revealed that the differences between the samples were significant (p<0.05). Considering color and appearance, C4 sample is found to be the most popular while the least liked cheese was C2. The color and appearance scores got higher as storage proceeded. Similar patterns were observed in the studies by Gezmiş and Tarakçı (29) spicy Circassian cheese, Tarakçı et al. (24) white cheese, Tarakçı and Deveci (25) spicy white cheese, Tarakçı and Bayram (33) fruity kashar cheese.

Table 4. Sensory scores for the cheese samples

	Cheese Types	Ripening Times (Days)			
		3	30	60	90
Color and Appearance	CC	8.10±0.99^{b,A}	8.40±1.58^{b,A}	7.50±1.43^{b,A}	7.40±1.51^{b,A}
	C1	7.00±1.33^{c,A}	6.30±1.06^{c,A}	6.90±1.37^{c,A}	7.00±1.33^{c,A}
	C2	6.20±0.79^{d,A}	5.60±0.97^{d,A}	6.20±0.92^{d,A}	5.40±0.97^{d,A}
	C3	7.00±0.94^{ab,A}	8.70±0.82^{ab,A}	8.40±0.97^{ab,A}	8.80±0.79^{ab,A}
	C4	8.40±1.35^{a,A}	9.20±1.14^{a,A}	8.60±1.08^{a,A}	8.50±1.18^{a,A}
Odor	CC	8.60±0.97^{b,A}	7.00±1.33^{b,A}	7.50±1.43^{b,A}	7.70±1.06^{b,A}
	C1	5.70±1.06^{d,A}	5.50±0.53^{d,A}	5.80±1.03^{d,A}	5.50±0.53^{d,A}
	C2	5.50±0.97^{d,A}	5.50±0.53^{d,A}	5.50±0.71^{d,A}	5.40±0.70^{d,A}
	C3	5.80±1.03^{c,A}	7.20±1.03^{c,A}	6.00±0.82^{c,A}	6.70±1.49^{c,A}
	C4	8.60±1.51^{a,A}	8.60±1.51^{a,A}	9.10±1.20^{a,A}	8.20±1.32^{a,A}
Structure and Texture	CC	9.30±0.82^{b,A}	7.70±1.42^{b,A}	7.90±1.66^{b,A}	8.40±1.65^{b,A}
	C1	6.20±0.92^{d,A}	5.90±0.99^{d,A}	6.10±1.10^{d,A}	6.00±1.16^{d,A}
	C2	5.50±1.08^{d,A}	5.40±0.70^{d,A}	5.50±0.97^{d,A}	5.70±1.25^{d,A}
	C3	6.10±0.99^{c,A}	7.20±0.63^{c,A}	6.60±1.43^{c,A}	7.60±1.43^{c,A}
	C4	9.40±0.70^{a,A}	9.40±1.08^{a,A}	9.50±0.85^{a,A}	9.10±0.99^{a,A}
Taste and Flavor	CC	8.30±1.06^{a,A}	7.40±1.35^{a,A}	6.40±1.65^{a,A}	8.40±0.84^{a,A}
	C1	5.70±1.06^{b,A}	5.70±1.06^{b,A}	6.20±1.23^{b,A}	5.80±1.14^{b,A}
	C2	5.40±0.70^{b,A}	5.40±1.08^{b,A}	5.30±0.48^{b,A}	5.40±1.08^{b,A}
	C3	6.70±1.25^{a,A}	7.40±1.43^{a,A}	8.60±0.84^{a,A}	7.20±1.14^{a,A}
	C4	7.90±1.66^{a,A}	7.00±1.89^{a,A}	7.90±1.10^{a,A}	8.20±0.79^{a,A}
General acceptability	CC	9.00±1.05^{a,A}	7.70±1.34^{a,B}	8.10±1.29^{a,A}	8.20±0.79^{a,A}
	C1	5.40±0.70^{c,B}	5.10±0.57^{c,B}	6.40±0.84^{c,A}	6.60±0.84^{c,A}
	C2	5.70±1.06^{c,B}	5.60±0.84^{c,B}	5.90±0.57^{c,A}	6.10±0.88^{c,A}
	C3	5.50±0.71^{b,B}	7.300±0.95^{b,B}	7.40±0.52^{b,A}	7.80±0.92^{b,A}
	C4	8.50±0.85^{a,A}	8.60±0.84^{a,A}	8.80±0.79^{a,A}	9.00±0.67^{a,A}

a–d indicate differences (p<0.05) between columns.
A–C indicate differences (p<0.05) between rows.
Mean values ± standard deviation of two trials.

The C4 sample is the most liked and the C2 sample is the least liked regarding odor scores. The odor scores decreased with prolonged ripening. The structure and texture scores were the lowest with 5.40 for the C2 sample on the 30th day, and the highest score with 9.50 for the C4 sample on the 60th day. Considering structure and texture scores, it is observed that the most liked cheese sample is the C4 sample while the least liked one was C2. In general, structure and texture scores decreased over time.

The lowest taste and aroma scores were determined as 5.30 for the C2 sample on the 60th day while the highest score was 8.60 for the C3 sample on the 60th day. In general, the taste and aroma scores increased over time. It was determined that the differences between the taste and aroma scores of the samples were significant (p<0.05). Also, it was determined that the most liked sample was the C3 sample while the least liked one was C2.

Salt, pH, degree of ripening, and cheese composition are improtant factors in the development of cheese flavor and aroma. For this reason, the taste of cheeses produced and ripened differently from each other is also different (35). According to this study, the lowest general acceptability scores were determined as 5.10 for the C1 sample on day 30, and the highest score of 9.0 was for the C4 sample on day 90. When the obtained data are examined, it was observed that the differences between the samples were significant ($p<0.05$). Overall, it was determined that the most liked sample was C4, and the least liked sample was C2. The general acceptability scores showed an increasing pattern over time. Similarly, Tarakçı and Bayram (33) cheddar cheese with fruit addition, Gezmiş and Tarakçı (29) Circassian cheese with spice addition, and Tarakçı and Deveci (25) white cheese with spice addition determined increasing acceptability scores over storage time.

Conclusions

In this study, it was found that organoleptically acceptable white cheese could be produced by adding an optimized concentration of blueberry fruit powder. The addition of blueberry fruit powder affected the chemical, biochemical, and sensory properties of white cheese significantly. According to sensory evaluation and general acceptability data, cheeses with higher blueberry ratio received higher scores. The highest casein degradation was observed in 1% blueberry-added cheeses while the cheeses with 2% blueberry fruit addition were liked the most. Blueberry addition to white cheese improves its taste and offers an alternative product to consumers. This study did not cover the alteration in bioactivity of white cheeses with blueberry powder addition however, future studies should focus on the effect of blueberry addition on the phenolic content and antioxidant activity of white cheese. Also, including the cheeses' organic acid and phenolic profiles would enrich the study.

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