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Determınatıon of some basıc propertıes of tradıtıonal malatya cheese

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Abstract

Malatya cheese is generally produced and consumed in Malatya province of Turkey.The starter culture is not used in the production of this cheese. It is traditionally made from raw cow or sheep milk or a mixture of them. This study aims to determine some characteristics parameters (the antioxidant activity, mineral composition, chemical, biochemical and textural properties) of Malatya cheese and therefore, 25 samples purchased from retail markets in Malatyawere analysed. The antioxidant capacity of the water-soluble extracts was detected using DPPH (2,2-diphenyl-1-picrylhydrazyl) and ABTS (2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)) methods, mineral composition of samples prepared by dry ash method were determined using Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES). This samples were generally different from each other according to the chemical, biochemical and textural properties; however, some interesting similarities were identified. Besides, the mineral compositions and antioxidant activities in cheese samples were determined higher than expected. In conclusions, the production method and ripening conditions may play a decisive effect on some basic properties of the cheeses investigated.

Keywords: malatya cheese; mineral content; total phenolics; antioxidant activity; texture profile analysis (TPA).

Practical Application: Malatya cheese is a kind of traditional Turkish cheese manufactured from raw or pasteurized milk by scalding of curd in hot whey.

1 Introduction

Malatya cheese is traditionally produced from raw sheep's or cow's milk in the Malatya province of Turkey. If sheep or cow's milk is not available, their mixtures were used for the manufacturing of cheeses. Malatya cheese has an elastic and compact texture, salty taste and is manufactured in farms on asmall scale and in villages. Nowadays, Malatya cheese has two general production methods: traditional and industrial. In industrial production, the cheese is made from pasteurized milk using starter culture in large enterprises (Hayaloglu & Brechany, 2007), however, there is no standard production method.

In the traditional method, milk was not pasteurized and the starter culture was not used (Hayaloglu et al., 2014). The raw milk is filtered through a cloth filter, heated to 32 °C and then coagulated for 45 min using commercial rennet. Subsequently, the curd is cut into small cubes, stirred for about 30 min and left to drain for 30 min without pressing. The curd was pressed with a wooden block for 2 h, scalded at 85 or 90 °C for 3-5 min using whey. Then, curds were re-pressed between the same wooden blocks for 3 min and quickly cooled to room temperature. The cooled blocks were immersed in brine and matured in plastic or metal packaging at 6-8 °C for at least 60 days (Hayaloglu et al., 2008).

There are only a few studies related to Malatya cheese. The effect of milk pasteurization and scalding temperature on proteolysis and peptide profiles of Malatya cheese was determined by Hayaloglu et al. (2010) and volatile profiles were investigated by Hayaloglu & Brechany (2007). The effects of different enzyme concentrations on chemical, physical and biochemical properties of Malatya cheese were determined by Hayaloglu et al. (2014). The effect of some production parameters on functional and ripening properties of Malatya cheese was investigated by Karatekin (2014). To the authors' knowledge, no previous study was determined to chemical, biochemical, physical, mineral content, and antioxidant activity of Malatya cheese obtained from retail markets. Thus, this study aims to elucidate some characteristics of cheeses produced by the traditional method collected from Malatya retail markets.

2 Materials and methods

2.1 Materials

In this study, 25 different Malatya cheese produced in Malatya were obtained from the retail market and used as material. 300-400 g samples were taken to sterile jars, brought to the laboratory under refrigerator conditions, homogenized and stored in the refrigerator (4 ± 2 °C) until the analysis was completed.

2.2 Methods

Chemical analysis

For pH measurements, a pH meter (Hanna Instrument pH 211; Microprocessor pH meter, Germany) was used. The samples were analyzed for protein content using micro Kjeldahl digestion and distillation units (Association of Official

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Analytical Chemists, 1990). Titratable acidity (as a lactic acid percentage), dry matter, and fat content (Gerber method) were detected according to methods described by Case et al. (1985). The salt content was detected according to the Mohr method (Nielsen, 2003). The ash content was determined by dry ashing the cheeses in an ash oven at 550 °C for 16 h (International Dairy Federation, 1992). The L*, a*, and b* values of cheese samples were determined with Konica Minolta Chroma Meter CR-400 (Osaka, Japan). The L* value represents lightness value varying between 0 and 100, b* value represents the blue (-) to yellow (+) component and a* represents the green (–) to red (+) component (Akarca et al., 2015).

Biochemical analysis

Water-soluble extracts of the cheese samples were prepared as previously described (Kuchroo & Fox, 1982). These extracts were used in the determination of total phenolic compounds (TPC), antioxidant activity, water soluble nitrogen (WSN), 12% trichloroacetic acid soluble nitrogen (TCA-SN), and 5% phosphotungstic acid soluble nitrogen (PTA-SN). The lipolysis ratio was measured as ADV (Acid Degree Value) according to methods described by Case et al. (1985). WSN %, TCA-SN %, and PTA-SN % contents of cheese were analyzed as previously described (Butikofer et al., 1993).

Total Phenolic Compounds (TPC)

TPC content of water-soluble extracts of the cheese samples were determined using the Folin Ciocalteu method (Yemis et al., 2008). For this, 150 µL of a sample and 3 mL of Na_2CO_3 (2%) were taken in a test tube, and 150 µL of Folin-Ciocalteu's reagent (1:1, v/v in water) was added to the tube. Then the mixture was thoroughly mixed with vortex and was kept at room temperature in the dark. After 45 minutes, the absorbance was read at 765 nm in the spectrophotometer (UV Mini-1240, Shimadzu, Japan). The results are explained as gallic acid equivalent (mg GAE/kg).

Antioxidant activity

DPPH radical scavenging activity

The inhibition of DPPH was determined as described previously (Brand-Williams et al., 1995). Firstly, 100 mL of water-soluble extracts and 2.4 mL of DPPH solution prepared daily were added to a test tube. The mixture was incubated in darkness at room temperature. After 30 min, the absorbance was read at 520 nm in a spectrophotometer. The results were expressed as: Inhibition of DPPH (%) = $[1 - (A/A_0)] \times 100$, where A_0 is the absorbance of the blank and A is the absorbance of the test.

TEAC test

7.0 mM ABTS radical solution containing 2.45 mM potassium persulfate was prepared and was left in darkness at room temperature for at least 12-16 hours to form an $ABTS^{\bullet+}$ radical solution. Then, this radical solution was diluted with 80% ethanol to give 0.700 ± 0.2 absorbances at 734 nm and 2.97 mL of the diluted radical solution transferred to a test tube and 30 µL of water-soluble extracts were added to the tube. The mixture left for 6 min in the dark and the absorbance was read at 734 nm in a spectrophotometer. The same processes were repeated for Trolox and antioxidant activity value was expressed as mmol/g Trolox equivalent (Kirca & Özkan, 2007).

Texture Profile Analysis (TPA)

TPA analysis of the cheese samples was carried out at 25 °C using a texture analyzer equipped with a 50 kg load cell and a cylindrical probe (25.4 mm in diameters). TPA was determined by compressed twice using a probe to make 10-mm penetration with a speed of 1 mm/s. Hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness, and resilience were carried out from TPA by using software (Kahyaoglu et al., 2005).

Mineral analysis

By adding 5 ml of nitric acid to the ash obtained in the ash determination, the ash was thoroughly dissolved on the heating plate and then the dissolved ash-acid mixture was filtered with Whatman no: 41. Subsequently, the solution was diluted with 1 N HNO_3 and completed in 50 ml with 1 N HNO_3. The Ca, Mg, K, P, Zn, Fe, Mn and Cu concentrations of the cheese samples were determined by ICP-OES (Thermo Scientific ICAP 6300 DUO, England) at 317.93, 279.55, 766.49, 177.50, 213.86, 259.94, 257.61, and 324.75 nm, respectively. Also, blank samples were prepared by subjecting to the above procedures (International Dairy Federation, 1992).

Statistical analysis

SPSS for Windows statistical software (SPSS, 1999) was used for all statistical analysis in this study. All data are showed as mean ± standard deviation of means. Correlations between the chemical, biochemical, textural and antioxidant properties and mineral content were determined using Pearson correlation method with SPSS package program.

3 Results and discussions

3.1 Chemical and biochemical properties

The dry matter (DM), ash, pH, titratable acidity (lactic acid), salt, protein, fat, and color properties of the cheese samples were presented in Table 1. It was determined that % dry matter, % fat, % ash, % protein, % salt, % lactic acid (l.a) and pH content of Malatya cheese samples varied between 49.01 to 64.09, 24.50 to 31.00, 4.77 to 10.54, 16.59 to 23.54, 2.46 to 6.14, 0.13 to 0.73 and 5.50 to 6.76, respectively. The pH, titratable acidity (%), salt (%), total protein (%), and lower fat (%) values were similar to results of Hayaloglu et al. (2014). Salt (%) and protein (%) values were higher than the values determined by Hayaloglu & Brechany (2007). The differences in protein and salt contents between the cheeses might be related to the type of milk, heat treatment, and production methods.

Color values were determined as CEILAB color space L*, a*, and b*. There was no significant difference between cheese samples in terms of L*, a*, and b* values. The L* values of samples were determined between 88.08 and 93.21. The parameter L* of the samples generally indicates lightness. It was determined that

Table 1. Some chemical parameters of malatya cheeses.

Sample no	Dry matter (%)	Ash (%)	pH	l.a (%)	Salt (%)	Protein (%)	Fat (%)	L*	a*	b*
1	58.19	9.53	6.39	0.18	5.73	20.89	27.75	91.93	-2.80	13.06
2	61.72	10.54	6.41	0.18	5.85	21.36	29.5	90.83	-2.94	14.17
3	59.98	10.15	6.44	0.18	5.59	21.61	28	91.43	-2.90	15.23
4	59.79	9.16	6.46	0.18	5.62	21.78	27.5	90.61	-3.01	13.88
5	57.27	10.23	6.42	0.19	5.91	20.29	31	92.12	-2.87	13.43
6	50.05	5.00	5.93	0.47	2.75	19.64	26.75	93.19	-2.02	12.81
7	49.01	4.81	5.50	0.68	2.49	18.52	29.5	92.04	-1.96	12.22
8	50.85	4.77	5.55	0.73	2.60	18.78	28	92.25	-2.21	13.78
9	49.66	5.62	5.82	0.47	2.87	17.57	24.5	92.54	-2.42	13.45
10	50.06	5.09	5.78	0.47	2.46	21.13	27	92.50	-2.18	14.29
11	49.27	6.71	5.78	0.34	4.42	18.99	26.5	92.91	-1.55	12.06
12	51.92	5.45	5.99	0.35	3.07	18.66	26.75	93.21	-1.83	11.78
13	49.88	6.16	5.85	0.25	3.36	16.59	27.25	92.99	-1.91	12.72
14	53.27	6.22	6.07	0.31	3.69	18.48	25.5	92.08	-1.88	13.07
15	52.11	5.29	5.92	0.36	2.87	18.65	28.5	92.54	-1.87	12.25
16	49.60	6.24	6	0.29	3.39	18.70	24.5	92.65	-1.77	12.66
17	49.10	4.87	5.57	0.56	2.52	17.62	26	91.52	-2.18	12.63
18	50.84	5.61	5.77	0.57	3.25	18.41	26.5	93.14	-1.94	12.97
19	49.44	4.95	5.65	0.55	2.49	17.33	26.5	91.83	-1.96	13.02
20	51.85	6.04	6.20	0.37	3.51	19.77	25.75	92.23	-2.14	13.58
21	62.22	9.43	6.30	0.16	5.47	20.75	30.5	89.87	-2.95	13.99
22	64.09	8.81	6.38	0.14	4.88	23.54	29.25	88.08	-3.41	15.67
23	62.13	9.31	6.38	0.13	5.53	21.87	28.5	91.48	-2.86	14.19
24	59.54	9.31	6.43	0.16	6.14	20.55	29.25	90.62	-1.07	14.30
25	61.12	9.58	6.42	0.14	5.94	22.35	29	89.50	-1.12	15.09
Min.	49.01	4.77	5.50	0.13	2.46	16.59	24.50	88.08	-1.07	11.78
Max.	64.09	10.54	6.46	0.73	6.14	23.54	31.00	93.21	-3.41	15.67
Mean ± S.D	54.52 ± 5.32	7.15 ± 2.12	6.05 ± 0.33	0.34 ± 0.18	4.11 ± 1.39	19.78 ± 1.78	27.60 ± 1.73	91.68 ± 1.26	-2.23 ± 0.60	13.47 ± 1.01

the obtained L* values were lower than the values determined by Tarakci & Deveci (2019) in white cheeses. The lightness values of Malatya cheese samples were lower due to scalding of curd in whey at 85-90°C for 3-5 min. Likewise, Deshwal et al. (2020) determined that the lightness values of Halloumi type cheese were significantly lower due to the scalding of curd in whey at 90 °C for 30 min. The scalding of cheese curd leads to the interaction of amino acids and lactose, which forms Maillard reaction compounds that darken the cheese (Kaminarides et al., 2015).

The values of samples were detected between -1.07 and 3.41. As can be seen, the parameter a* of the samples generally has negative values, which means that the green color dominant in most of the samples. The b values of samples were ranged between 11.78 and 15.67. The parameter b* of the samples generally has positive values, which means that the yellow color dominant in most of the samples.

The lipolysis values of Malatya cheese samples ranged from 0.34 to 4.31 ADV. These values were similar to findings obtained by Tarakci & Kucukoner (2006) and Andiç et al. (2011) and lower than the value determined by Guler & Uraz (2004) for Kashar cheese. The observed differences in lipolysis values between the cheeses might be related to the type of milk, production methods, and ripening conditions. Lipolytic agents in cheese usually originate from the milk, the cheese microflora (starter, nonstarter, and adjunct microorganism) and the coagulant (in the case of rennet paste). Milk contains a potent indigenous lipase, lipoprotein lipase. Lipoprotein lipase activity is important in raw milk cheeses because the enzyme is largely inactivated by pasteurization, but 85 °C × 10 s is required to fully inactivate the enzyme (McSweeney, 2004; Andiç et al., 2011).

The WSN contains small molecules of proteins, peptides, and free amino acids, and it is generally used as an index of ripening (Guinee & Fox, 1993). The WSN values of cheeses changed from 3.75% to 28.30%. The formation of WSN compounds during ripening is an index of the rate and extent of proteolysis, which is an indicator of casein hydrolysis brought about by the action of the residual rennet and indigenous plasmin present at the beginning of ripening (Andiç et al., 2011). The WSN values were similar to those reported by Hayaloglu et al. (2014) for Malatya cheeses and were higher than those reported by Altun & Kose (2016) for Kelle cheeses. The lowest, highest, and average TCA-SN levels of Malatya cheese samples were found to be 1.40, 9.55, and 5.42%. TCA- SN level is regarded as the ripening depth index and known to be an indication of the number of amino acids and small peptides present in cheese. These peptides and amino acids are mainly formed by the action of microbial enzymes on the peptides obtained through the action of plasmin and rennet from casein (Tarakci & Kucukoner, 2006; Andiç et al., 2011). The TCA content was higher than those reported by Hayaloglu et al. (2014) for Malatya cheeses and Altun & Kose (2016) for Kelle cheeses. The PTA-SN values of cheeses changed between 0.64 and 2.10%. Tri and dipeptides and free amino acids are soluble in the PTA-SN fraction. These free amino acids and small peptides are mainly produced by the effect of starter culture and non-starter organisms on the caseins and their peptides (Tarakci, 2004; Andiç et al., 2011). Our results were lower than those reported by Tarakci et al. (2004) for Herby cheeses.

3.2 Total phenolic compounds and antioxidant activity

The TPC, DPPH inhibition, and TEAC values of water-soluble extracts for all cheeses are shown in Table 2. TPC of Malatya cheese samples was varied between 161.70 and 935.78 mg

Table 2. Some biochemical and antioxidant activity of malatya cheeses.

Sample no	Lipolysis (ADV)	WSN %	TCA-SN %	%PTA-SN	TPC (mg/kg)	DPPH (% inh.)	TEAC (mmol Trolox/g)
1	2.72	6.09	1.80	1.22	217.63	4.44	2162.74
2	4.31	5.71	2.08	0.95	220.59	2.19	1979.93
3	1.79	4.72	1.90	1.02	239.11	3.13	2056.90
4	1.67	5.25	1.81	0.93	238.74	3.44	2458.63
5	2.58	6.38	1.94	0.83	252.44	3.31	2339.19
6	2.57	23.18	7.56	1.65	935.78	10.75	4308.34
7	2.49	23.70	7.65	1.75	902.44	8.49	1909.53
8	2.20	25.02	7.36	1.36	792.81	8.30	2863.17
9	2.24	28.30	9.55	1.75	750.96	10.97	3542.09
10	2.07	23.06	6.87	1.37	742.81	25.03	2136.88
11	2.16	21.61	9.45	1.43	666.52	28.24	2421.08
12	2.43	19.00	7.23	1.27	588.74	27.32	2850.54
13	2.79	21.23	9.41	2.06	559.85	7.14	1744.14
14	2.18	19.13	9.24	1.28	549.85	34.65	3295.10
15	2.33	21.17	8.72	1.46	684.67	17.48	3246.07
16	1.64	21.36	9.47	2.10	735.78	45.96	2969.71
17	1.62	20.44	6.27	1.15	825.78	15.13	2536.54
18	1.28	17.98	5.80	1.29	709.85	18.92	2780.09
19	1.85	22.12	6.14	1.36	668.00	9.78	2763.66
20	0.51	14.29	6.63	2.08	526.89	17.32	2496.50
21	0.76	3.91	1.98	0.98	219.11	7.15	1083.86
22	0.41	4.00	1.52	0.64	215.04	3.22	614.96
23	0.64	4.01	1.40	0.85	161.70	5.25	452.69
24	0.34	3.75	1.75	1.16	211.33	3.41	2106.75
25	0.45	3.79	1.84	0.75	190.22	5.81	1352.56
Min.	0.34	3.75	1.40	0.64	161.70	2.19	452.69
Max.	4.31	28.30	9.55	2.10	935.78	45.96	4308.34
Mean ± S.D	1.84 ± 0.95	14.86 ± 8.72	5.42 ± 3.19	1.31 ± 0.41	514.97 ± 264.22	13.89 ± 11.40	2341.95 ± 875.79

GAE/kg. These values were higher than those reported by Kose (2015) for Herby cheeses and similar to those reported by Kara (2019) for Herby cheeses and Canozer (2020) for Orgu cheeses. The DPPH inhibition of water-soluble extracts of Malatya cheeses was changed from 2.19 to 45.96%. The TEAC values of cheese samples were ranged from 452.69 to 4308,34 mmol Trolox/g. It is thought that the antioxidant activity of Malatya cheeses varies in such a wide range, the fact that these cheeses have different production methods and maturity. Malatya cheese is traditionally manufactured from raw milk and the curd is subjected to heat treatment at 80-90 °C by immersing the curd block in its whey or hot water (Hayaloglu et al., 2014). Therefore, it is thought that antioxidant activity varies depending on the scalding time and temperature. Hossain et al. (2020) determined that the lower heat-treated samples showed higher antioxidant activity. The heating of milk can reduce the specific order and amount of bioactive peptides of milk. It can also change the enzyme action and subsequent functional properties of cheese during ripening (Santiago-López et al., 2018). Also, Fox et al. (1994) determined that hydrolysis of casein by coagulants, plasmin, starters, and nonstarter bacterial proteinases and peptidases resulted in the formation of free amino acids and water-soluble peptides during the maturation of cheese,. The smaller peptide formation was attributed to the significant role played by lactic acid bacteria in the degeneration of primary proteolytic products from β-casein and αs1-produced by plasmin and chymosin, respectively (Singh et al., 1997).

3.3 Textural properties

Ercan (2009) reported that textural properties of foods play a major role in consumer appeal, buying decisions, and eventual consumption. For some foods, the texture is more important to consumers than color and flavor. TPA parameters of the Malatya cheeses are seen in Table 3.

Hardness is the maximum force applied to cheese in the first compression (Yasar, 2007). Hardness values of cheeses changed from 1347.82 to 29823.56 g. According to Table 3, the hardness value of cheeses varies over a wide range. Solís-Méndez et al. (2013) expressed that, the hardness and/or firmness of the cheese based on three factors: fat, moisture, and mineral content. Due to the high content of water or fat, the protein molecules separated from the cheese which increased softness. Similarly, in our study, the rate of dry matter of the first 5 and last 5 samples was found to be quite high, and accordingly, the hardness value was higher than the other samples.

Table 3. Texture profile analysis of malatya cheeses.

Sample no	Hardness (g)	Adhesiveness (g.s)	Resilience (%)	Cohesiveness	Springiness (%)	Gumminess	Chewiness
1	18636.42	-28.32	22.21	0.57	76.71	11562.88	7470.59
2	18033.00	-15.09	40.13	0.80	34.63	14367.17	4970.71
3	26751.01	-39.44	23.98	0.56	64.99	15631.38	10770.81
4	23017.16	-11.77	23.00	0.52	76.44	3476.00	200.48
5	26050.29	-6.60	32.73	0.70	65.14	17453.88	11379.27
6	1464.38	-3.27	38.17	0.78	46.20	1685.48	797.10
7	1464.38	-52.12	25.90	0.70	66.19	1010.25	673.06
8	1720.52	-22.62	38.56	0.79	56.52	1288.57	673.84
9	2451.46	-24.01	41.33	0.69	32.83	1332.04	230.23
10	2868.99	-20.85	30.78	0.73	60.89	2084.39	1267.38
11	4408.69	-30.04	30.73	0.68	64.59	2993.42	1851.22
12	3420.97	-34.30	34.54	0.75	58.35	2578.16	1508.29
13	4169.52	-64.93	23.50	0.63	66.04	2595.89	1663.19
14	5554.38	-35.03	34.86	0.75	60.50	4074.17	2512.56
15	4064.03	-31.24	31.55	0.75	68.67	3037.29	943.57
16	3063.16	-57.42	33.05	0.75	60.79	2290.59	834.17
17	1616.07	-38.83	24.57	0.68	57.00	1104.33	675.64
18	1503.27	-46.01	33.44	0.75	58.95	1126.62	663.70
19	1347.82	-9.35	36.47	0.77	64.52	976.15	581.97
20	4671.05	-93.20	34.13	0.72	65.92	3350.71	2208.66
21	25079.20	-47.63	38.38	0.79	70.59	19740.13	13962.14
22	19974.97	-30.11	42.53	0.79	73.51	16150.10	10655.26
23	29823.56	-28.18	34.71	0.73	62.89	16816.92	13701.66
24	18165.16	-40.49	29.65	0.71	64.59	13498.23	9051.32
25	16641.82	-16.85	35.81	0.78	64.62	12927.80	8392.51
Min.	1347.82	-3.27	22.21	0.52	32.83	976.15	200.48
Max.	29823.56	-93.20	42.53	0.80	76.71	19740.13	13962.14
Mean ± S.D	10638.45 ± 10096.86	-34.23 ± 20.10	32.57 ± 6.27	0.71 ± 0.07	61.68 ± 10.61	6926.10 ± 6659.17	4305.57 ± 4729.61

Adhesiveness is defined as the force required to separate food that adheres to the plate or mouth. It can be characterized by adhesion and moisture conditions in a foodstuff (Karatekin, 2014). The adhesiveness values of cheeses ranged from -3.27 to -93.20 g.s. Our results were lower than the value obtained by Zheng et al. (2016) for sliced cheese and were similar to findings obtained by Tarakci & Deveci (2019) for White cheese. As can be shown in Tables 2 and 3, it was determined that cheeses with a high proteolysis rate had a higher stickiness value. Likewise, it was found that the value of adhesiveness increased due to proteolysis in the study conducted by Okumus (2019) for Kashar cheese.

Resilience is expressed as the rate of cheese returning to its original shape before recompressing after the second compression. In the texture profile analysis, the time between the first and second compression is calculated as the rate of recycling in the height of the cheese (Okumus, 2019). Resilience values of cheeses ranged between 22.21 and 42.53%.

The ratio of the resistance of food to the second compression to its behavior in compression is defined as cohesiveness. It is also expressed as the power between the inner bonds that make up the product structure (Aydın, 2019). Cohesiveness values of cheeses changed between 0.52 and 0.80. These results were similar to the study obtained by Aydın (2019) for Kashar cheese, Jaster et al. (2014) for Parmesan-type cheese, and higher than the value obtained by Kaminarides et al. (2019) for ovine Halloumi cheese.

Springiness is expressed as the ratio of the cheese reinstatement to the maximum deformation after applying the first compression to the sample (Karatekin, 2014). Cheese samples are characterized as either plastic or elastic according to the springiness value (Eroglu et al., 2015). Springiness values of cheeses changed from 32.83 to 76.71%.

Gumminess is identified as the product of cohesiveness and hardness (Yildiz et al., 2015; Kose et al., 2018). It characterizes semi-solid foods with a low degree of hardness and a high degree of cohesiveness (Kose et al., 2018; Kose et al., 2019). As can be shown in Table 3, it has been determined that the value of the gumminess level varies over a very wide range. The highest gumminess values obtained for sample no. 21 (19740.13) and the lowest for the sample no.19 (976.15). Generally, gumminess has increased with an increase fat content. Similar results were obtained Salari et al. (2017). Except for fat, total solids, moisture, protein to moisture ratio can affect on texture characteristics of cheese (Salari et al., 2017).

Chewiness value is an important quality parameter that affects the acceptability of the consumer for the product. As known, generally, older people want to make less effort to chew; for this reason, they prefer cheese samples with less chewiness values. In other words, chewiness is a parameter that simulates the amount of energy required to chew the sample until it is swallowed (Eroglu et al., 2015). The average chewiness value of cheese samples was found to be 4305.57. This value was higher than the values found by Zheng et al. (2016) for sliced cheese.

3.4 Mineral composition

Table 4 shows the values of calcium, magnesium, potassium, phosphorus, iron, copper, manganese, and zinc found in traditional Malatya cheeses.

Table 4. Mineral compositions of malatya cheeses (mg/kg).

Sample No	Ca	Mg	K	P	Fe	Cu	Mn	Zn
1	6008.85	673.97	608.54	157.92	4.30	2.01	0.68	23.35
2	7081.07	672.15	783.67	108.94	5.34	0.65	0.33	19.09
3	7069.41	766.52	720.58	126.14	4.84	0.51	0.32	20.73
4	6439.24	806.09	758.77	200.36	5.54	0.72	0.29	19.13
5	6648.72	634.59	730.40	117.41	11.68	1.89	0.33	14.40
6	5239.68	583.36	635.19	126.51	7.30	0.87	0.25	14.36
7	4784.08	587.74	628.51	109.04	9.33	1.42	0.33	16.87
8	5853.34	661.76	708.60	141.42	5.56	0.68	0.40	20.91
9	3237.89	609.87	439.92	140.46	3.91	1.30	0.40	28.54
10	4647.39	604.67	553.34	170.27	4.38	1.55	0.38	23.07
11	5336.46	582.50	749.91	111.12	4.99	1.24	0.34	30.62
12	5820.97	656.74	690.69	214.93	5.43	0.78	0.29	23.98
13	5480.10	656.33	714.88	90.25	5.28	0.65	0.25	11.88
14	5553.08	587.03	634.18	82.24	5.36	1.90	0.83	23.76
15	6972.68	684.71	922.35	233.65	4.93	1.22	0.30	21.45
16	4730.15	761.67	571.55	144.53	5.39	0.61	0.30	16.95
17	5066.74	548.44	633.64	167.68	7.56	1.25	0.24	16.81
18	4871.75	650.49	617.88	132.76	4.15	1.23	0.22	17.19
19	4809.72	653.12	699.43	84.26	4.49	2.05	1.07	14.42
20	4551.25	618.52	522.73	118.38	3.81	1.20	0.20	13.94
21	6044.11	567.93	547.30	203.41	7.06	2.30	0.29	18.52
22	5850.68	603.68	456.80	148.72	9.48	1.30	0.27	23.05
23	7052.82	632.36	751.38	214.04	4.20	0.76	0.37	19.16
24	6578.64	705.60	651.58	180.52	4.80	0.97	0.49	28.52
25	3624.58	597.35	347.23	187.31	4.10	1.81	0.60	19.78
Min.	3237.89	548.44	347.23	82.24	3.81	0.51	0.20	11.88
Max.	7081.07	806.09	922.35	233.65	11.68	2.30	1.07	30.62
Mean ± S.D	5574.14 ± 1044.82	644.29 ± 64.29	643.16 ± 123.40	148.49 ± 43.20	5.73 ± 1.97	1.23 ± 0.52	0.39 ± 0.20	20.02 ± 4.83

Calcium is responsible for many vital functions, such as blood clotting, normal cardiac rhythm maintenance, muscle contraction, hormone secretion, and enzyme activation. Dairy products are a very rich source of calcium and the majority of dietary Ca (70%) comes from these products. It is difficult to reach the recommended daily amount of calcium without consuming dairy products (Zamberlin et al., 2012). The minimum and maximum Ca values of samples ranged from 3237.89 to 7081.07 mg/kg**.** These values were higher than the value obtained by Ozlu et al. (2012) for Kashar cheeses and agreement with findings determined by Altun & Kose (2016) for Kelle cheeses. Zamberlin et al. (2012) and Šnirc et al. (2020) found that the highest calcium levels were found in hard cheeses. Likewise, in our study, it was found that cheeses with high hardness value had high calcium content.

Magnesium plays a significant role in many physiological processes, such as metabolism of nucleic acids and proteins, muscle contraction and neuromuscular transmission, regulation of blood pressure and bone growth, and a co-factor of many enzymes. On the other hand, magnesium deficiency can cause osteoporosis (Zamberlin et al., 2012). Mg concentrations of cheeses ranged from 548.44 to 806.09 mg/kg. These values were higher than the value obtained by Kose & Ocak (2019) for Herby cheeses and Cetinkaya et al. (2016) for Cami Boğazı cheeses.

Potassium is mostly present in milk (93%) in soluble form and the remaining 7% in the colloidal form. The K concentration in cheese is therefore associated with moisture (Lante et al., 2006). The average K concentrations of cheeses were found as 643.16 mg/kg. These findings were lower than the value obtained by Ocak & Kose (2015) for Herby cheese, Manuelian et al. (2017) for Cheddar cheese, and higher than the value recorded by Kirdar et al. (2015) for Kargı Tulum cheese.

The average P concentration of cheese samples was determined as 148.49 mg/kg. This value was lower than the value obtained by Canozer (2020) for Orgu cheeses, Oksuztepe et al. (2013) for Tulum and White cheeses, and Mattera et al. (2016) for Pecorino d'Abruzzo cheese.

Qin et al. (2009) reported that Fe is to be transported to cheese through the machinery and tools used in the transport, storage, and processing of milk. The minimum and maximum Fe concentrations of cheese samples ranged between 3.81 and 11.68 mg/kg. The obtained values were in agreement with the value determined by Yuzbasi et al. (2003) for Kasar cheeses and Christophoridis et al. (2019) for Greek cheeses.

Cu is an index of final product quality along with Fe because these metals play a nutritional and biological function. However, due to their unpleasant odor development and their catalytic effects on the oxidation of lipids, they may represent a problem in dairy technology, preferably limiting the proteins and membrane lipoproteins of the milk fat globule (Lante et al., 2006). The concentrations of Cu in foodstuffs may vary depending on natural plant/animal characteristics, environmental conditions and methods of cooking, processing, and food handling (Christophoridis et al., 2019). The average Cu concentration of cheese samples was determined as 1.23 mg/kg. This value was higher than the average value obtained by Ozlu et al. (2012) for Kashar cheese and lower than the average value obtained by Altun & Kose (2016) for Kelle cheese. The minimum and maximum Mn concentration of cheeses changed between 0.20 and 1.07 mg/kg. These results were similar to the value obtained by Kose & Ocak (2019). It is stated that metals such as nickel and manganese in the composition of steel containers used in the heating and boiling stages of cheese production can enter the product (Ozlu et al., 2012)

The average Zn value of cheese samples was determined as 20.02 mg/kg. This value was higher than the value obtained by Ozlu et al. (2012) for Kashar cheese and by Kose & Ocak (2019) for Herby cheese. It is thought that the variations detected in the zinc content of cheeses in different studies to be caused by milk used in cheese production and equipment and tools used in the production stage (Cetinkaya et al., 2016). This situation is also expressed by Ozlu et al. (2012). Also, it is reported that 85% of Zn in milk is exposed to casein micelles and is released from curd by becoming free in acidic pH values (Cetinkaya et al., 2016).

3.5 Correlation analysis

Table 5 and 6 shows the correlation coefficients of 32 parameters of Malatya cheese. It has been determined that there are very important correlations between variables. For instance, b, TPC, DPPH, ABTS, WSN, TCA-SN, PTA-SN, hardness, gumminess and chewiness values showed a significant negative and positive correlation with chemical, biochemical, textural and antioxidant properties and mineral content.

A significant positive correlation was found between TPC and antioxidant activity. Similarly, in many studies (Rufino et al., 2010; Augusto et al., 2014), a significant and positive correlation between TPC and antioxidant activity has been determined. TPC, DPPH and ABTS parameters showed a significant positive correlation with proteolysis (WSN, TCA-SN, PTA-SN) values. Indeed, Revilla et al.(2016), Perna et al. (2015), Erkaya & Şengül (2015), Kose (2015), and Gupta et al. (2009) found that antioxidant activity increased with the increase in water-soluble nitrogen content. In these studies, antioxidant activity was

Table 5. Correlation between the parameters.

	Dm	Ash	Fat	Protein	pH	l.a	Salt	L	a	b	Ca	Mg	K	P	Mn	Cu	Zn	Fe
DM	1,000	**0,911**	**0,661**	**0,856**	**0,886**	**-0,805**	**0,887**	**-0,807**	**-0,921**	**0,762**	**0,539**	0,213	-0,085	0,361	0,002	0,065	0,125	0,112
Ash		1,000	**0,615**	**0,754**	**0,915**	**-0,862**	**0,981**	**-0,631**	**-0,846**	**0,646**	**0,531**	0,311	-0,008	0,185	0,005	0,054	0,112	0,112
Fat			1,000	**0,545**	0,456*	-0,389	**0,589**	**-0,544**	**-0,639**	0,408	**0,558**	-0,035	0,174	0,240	-0,100	0,205	-0,095	**0,510**
Protein				1,000	**0,781**	**-0,651**	**0,732**	**-0,724**	**-0,821**	**0,769**	0,368	0,166	-0,211	0,374	-0,107	0,012	0,178	0,109
pH					1,000	**-0,919**	**0,910**	**-0,579**	**-0,790**	**0,637**	0,489	0,368	-0,070	0,287	-0,023	0,002	0,093	0,010
l.a						1,000	**-0,863**	**0,532**	**0,662**	**-0,513**	-0,462	-0,298	0,026	-0,285	0,021	-0,009	-0,142	0,014
Salt							1,000	**-0,605**	**-0,802**	**0,587**	**0,511**	0,300	-0,004	0,216	0,027	0,063	0,183	0,060
L								1,000	**0,829**	**-0,719**	-0,178	0,016	0,367	-0,252	-0,091	-0,223	-0,106	-0,236
a									1,000	**-0,816**	-0,330	-0,117	0,273	-0,316	0,019	-0,122	-0,058	-0,190
b										1,000	0,220	0,190	-0,318	0,134	0,019	-0,057	0,071	-0,047
Ca											1,000	0,423	**0,737**	0,252	-0,145	-0,284	0,016	0,199
Mg												1,000	0,388	0,160	-0,035	**-0,526**	-0,013	-0,267
K													1,000	0,048	-0,076	-0,361	-0,082	0,031
P														1,000	-0,276	-0,072	0,259	-0,143
Mn															1,000	**0,542**	0,142	-0,261
Cu																1,000	0,025	0,185
Zn																	1,000	-0,283
Fe																		1,000
TPC																		
DPPH																		
ABTS																		
WSN																		
TCASN																		
PTASN																		
ADV																		
Hardness																		
Adhesiveness																		
Resilience																		
Cohesiveness																		
Springiness																		
Gumminess																		
Chewiness																		

Table 6. Continued correlation between the parameters.

	TPC	DPPH	ABTS	WSN	TCASN	PTASN	ADV	Hardness	Adhesiveness	Resilience	Cohesiveness	Springiness	Gumminess	Chewiness
DM	**-0,935**	**-0,580**	**-0,687**	**-0,950**	**-0,902**	**-0,780**	-0,319	**0,921**	0,205	0,128	-0,046	0,273	**0,906**	**0,840**
Ash	**-0,946**	**-0,542**	**-0,604**	**-0,937**	**-0,859**	**-0,672**	-0,148	**0,939**	0,196	-0,051	-0,248	0,230	**0,903**	**0,817**
Fat	**-0,578**	**-0,682**	**-0,605**	**-0,643**	**-0,689**	**-0,622**	-0,042	**0,655**	0,244	0,023	0,113	0,310	**0,729**	**0,681**
Protein	**-0,743**	-0,421	**-0,611**	**-0,813**	**-0,812**	**-0,699**	-0,350	**0,775**	0,265	0,124	-0,031	0,287	**0,736**	**0,682**
pH	**-0,922**	-0,404	-0,454	**-0,913**	**-0,786**	**-0,561**	-0,258	**0,874**	0,108	0,013	-0,207	0,260	**0,816**	**0,740**
l.a	**0,885**	0,263	**0,528**	**0,826**	**0,633**	0,478	0,223	**-0,809**	-0,041	0,056	0,225	-0,310	**-0,779**	**-0,721**
Salt	**-0,939**	-0,500	**-0,580**	**-0,933**	**-0,833**	**-0,655**	-0,215	**0,910**	0,174	-0,084	-0,259	0,281	**0,863**	**0,790**
L	**0,683**	**0,506**	**0,702**	**0,729**	**0,728**	**0,687**	0,491	**-0,632**	-0,139	-0,213	-0,113	-0,307	**-0,675**	**-0,621**
a	**0,842**	**0,732**	**0,659**	**0,873**	**0,913**	**0,757**	0,336	**-0,863**	-0,277	-0,119	0,097	-0,169	**-0,843**	**-0,785**
b	**-0,674**	**-0,527**	**-0,578**	**-0,676**	**-0,696**	**-0,592**	-0,435	**0,679**	0,156	0,208	-0,012	0,110	**0,677**	**0,656**
Ca	**-0,521**	-0,348	-0,231	**-0,539**	-0,491	-0,464	0,173	**0,615**	0,168	-0,198	-0,179	0,257	**0,534**	0,474
Mg	-0,299	-0,053	0,064	-0,264	-0,220	0,008	0,077	0,285	0,013	-0,359	-0,484	0,206	0,049	-0,032
K	0,034	-0,050	0,212	0,056	0,074	-0,021	0,485	0,060	0,170	-0,321	-0,212	0,066	-0,079	-0,127
P	-0,277	-0,074	-0,252	-0,318	-0,328	-0,363	-0,373	0,316	0,111	-0,033	0,012	0,248	0,236	0,264
Mn	-0,100	0,013	0,049	0,015	-0,032	-0,141	0,024	-0,041	0,345	0,072	0,068	0,101	-0,012	0,006
Cu	-0,108	-0,046	-0,126	-0,089	-0,128	-0,226	-0,159	0,052	0,145	0,125	0,169	0,288	0,187	0,230
Zn	-0,123	0,163	-0,001	-0,020	0,024	-0,215	-0,077	0,049	0,192	0,112	-0,071	-0,096	0,076	0,069
Fe	0,004	-0,241	-0,124	-0,113	-0,170	-0,248	0,113	0,188	0,177	0,044	0,119	0,146	0,252	0,238
TPC	1,000	**0,527**	**0,680**	**0,954**	**0,861**	**0,689**	0,292	**-0,918**	-0,108	0,028	0,212	-0,360	**-0,877**	**-0,819**
DPPH		1,000	0,443	**0,556**	**0,700**	**0,505**	0,037	**-0,591**	-0,300	0,051	0,210	-0,088	**-0,544**	-0,500
ABTS			1,000	**0,679**	**0,656**	**0,540**	0,433	**-0,645**	0,117	0,054	0,018	-0,447	**-0,689**	**-0,717**
WSN				1,000	**0,937**	**0,728**	0,365	**-0,927**	-0,094	0,066	0,172	-0,396	**-0,889**	**-0,835**
TCASN					1,000	**0,803**	0,321	**-0,886**	-0,274	0,035	0,143	-0,317	**-0,837**	**-0,788**
PTASN						1,000	0,214	**-0,721**	**-0,566**	-0,131	-0,043	-0,206	**-0,699**	**-0,654**
ADV							1,000	-0,258	0,314	-0,113	-0,121	-0,450	-0,267	-0,400
Hardness								1,000	0,214	-0,067	-0,266	0,331	**0,914**	**0,881**
Adhesiveness									1,000	0,236	0,087	-0,230	0,142	0,071
Resilience										1,000	**0,826**	-0,502	0,144	0,114
Cohesiveness											1,000	-0,366	0,025	0,023
Springiness												1,000	0,224	0,307
Gumminess													1,000	**0,969**
Chewiness														1,000

attributed to these antioxidative peptide fragments released by proteolysis and the effect of starter cultures used. TPC, DPPH and ABTS parameters showed a significant negative correlation with hardness, gumminess and chewiness values. This situation is thought to be due to the high degree of proteolysis of cheese samples. Similarly, Karaman & Akalın (2013) determined that the increase in the degree of proteolysis during ripening caused a decrease in the hardness values of the cheese sample. In addition, TPC, DPPH and ABTS values was found to be negatively, positively correlated and were not significantly correlated with mineral content. Correlation analysis results revealed that TPC, DPPH and ABTS values of Malatya cheese samples could be an indicator parameter reflecting chemical, biochemical, textural and antioxidant properties and mineral content of cheese samples.

As seen in Table 1, positive and negative correlations were found between TPA parameters. While the relationship between some parameters is not important, there is a very important relationship between some parameters. For example, there is a significant positive correlation between hardness and chewiness and gummines. This may be due to the fact that chewiness consists of the product of hardness x springiness x stickiness (Kose, 2020) and gumminess consists of the product of cohesiveness x hardness of the sample (Kose et al., 2018).

4 Conclusions

Some basic characteristics of 25 different Malatya cheese samples were determined. It is estimated that the detected differences are mainly due to production methods and maturation conditions. According to correlation analysis, the samples with high contents of WSN, TCA-SN, and PTA-SN also showed higher values of TPC, DPPH, TEAC. Likewise, samples with high contents of dry matter also showed higher values of hardness, and Ca and samples with high contents of fat showed higher values of gumminess. Considering the TPA, antioxidant activity, chemical, biochemical, and mineral composition results of Malatya cheese samples, it is obtained that standard production techniques should be used in the manufacturing of this cheese to increase consumer perception and acceptability.

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