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ORIGINAL ARTICLE

Use of corn oil in the production of Turkish white cheese

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Abstract The use of corn oil in white cheese production instead of milk fat was investigated and its effects on the quality parameters of cheese were studied. It was demonstrated that the use of corn oil significantly affected the levels of dry matter, fat in dry matter, protein, salt in dry matter and titratable acidity and pH value of samples ($p<0.05$). The water-soluble nitrogen based ripening indices of cheeses increased throughout the ripening period. However, there were not large quantitative differences among the peptide profiles of all the cheese samples. The polyunsaturated fatty acids (PUFA), the polyunsaturated to saturated fatty acid ratios (PUFA/SFA) and total *cis* fatty acid contents were found to be higher whilst the saturated fatty acid and *trans* fatty acid content were found to be lower than those of the control cheese ($p<0.05$). It was found that the use of corn oil instead of milk fat in cheese production decreased the cholesterol content of the cheese samples ($p<0.05$). The sensory scores of corn oil cheese were almost similar to the control cheese. The results indicated that corn oil utilization in cheese production has commercial potential in overcoming the defects related to fat reduction.

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Introduction

White cheese as a brined type cheese is very popular dairy product in Turkey and it is a rich source of nutritive compounds and has a high content of milk fat (Arslan et al. 2010a). Milk fat is composed of saturated fats and cholesterol to complicate the matters for health-conscious consumers and people suffering from coronary heart diseases and/or diabetes (Patel et al. 2010). Many epidomiological studies have shown a positive correlation between total cholesterol (TC) level, especially low density lipoprotein (LDL) cholesterol level and cardiovascular heart disease (CHD) (Ney 1991; Dhaka et al. 2011). The level of TC and LDL cholesterol in blood serum is affected by the consumption of fatty foods in the diet (Ney 1991). Therefore, consumers, from the standpoint of their health, are against foods containing high fat level and prefer the ones having low calorie and cholesterol contents.

Fat plays a major role in texture and flavor of the food products (Eswarapragada et al. 2010). Commercialization of low-fat cheese production has significantly increased. However, technological aspects associated with processing of low-fat cheese include problems related to the texture, flavor, melting ability and shelf life (Mistry 2001). Therefore, vegetable oils have been proposed in order to improve the flavor and texture of low-fat cheeses (Bachmann 2001).

Vegetable oils are free of cholesterol and have a high content of unsaturated fatty acids. Hovewer, some vegetable oils have only limited applications in their original forms because of their specific chemical composition (Javidipour and Tuncturk 2007).

Corn oil is an excellent source of essential fatty acids. It contains approximately 60 % polyunsaturated fatty acids contributed predominantly by linoleic (C-18:2) and usually less than 1.5 % linolenic (C-18:3) fatty acids. Corn oil belongs to the group of oils with high levels of linoleic and oleic fatty acids. In spite of this high level of unsaturation, corn oil has a good oxidative flavor stability (O'Brien 1998).

Moreover, in recent years, cheese products wherein the milk fat is replaced with vegetable oils have gained increased popularity (Lobato-Calleros et al. 1997; Bachmann 2001; Karvonen et al. 2002; Kesenkas et al. 2009; Arslan et al. 2010a; Dinkci et al. 2011). The use of vegetable oils can give the cheese a consistency that makes it more suitable for certain applications (Bachmann 2001). Karvonen et al. (2002) have investigated the effects of rapeseed oil-based cheese consumption (milk fat substitued by rapeseed oil) on serum LDL cholesterol and total cholesterol. Compared with the control cheese, the mean total cholesterol concentration was lowered by 5 % and LDL cholesterol concentration was reduced by 6.4 % after 4 weeks of cheese consumption.

However, no research has been carried out on direct incorporation of corn oil in white cheese and other type of cheeses. In this research, the utility of corn oil in white cheese production instead of milk fat and its effects on the quality parameters of the resultant product were studied. The physicochemical, chemical, sensory and rheological properties of the functional Turkish white cheese samples were also determined during the ripening period.

Materials and methods

Milk, culture, rennet and alternative agent

The cow's milk used in the production cheese was obtained from Bahcivan Cheese Factory (Luleburgaz, Turkey). A freeze-dried mixture of *Lactococcus lactis* subsp. *cremoris* and *Lactococcus lactis* subsp. *lactis* were used as starter culture (Ezal MA16, Rhodia Food, Sassenage, France). Fermentation-produced chymosin (Maxiren®, DSM Food Specialties, Istanbul, Turkey) was used as the coagulant enzyme. Corn oil was obtained from a local market (Luleburgaz, Turkey). The cholesterol standard was from Sigma (Diesenhofen, Germany). Fatty acid standards were obtained from Supelco (Bellefonte, Philadelphia, USA). The other chemicals were from Merck Chemical Co. (Darmstadt, Germany).

White cheese production

Cheese production was carried out in Bahcivan Cheese Factory (Luleburgaz, Turkey). Approximately 180 L of cow's milk was used for each batch. Skim milk was mixed with corn oil (10 %) and homogenized (50 °C, 150 Bar). This blend and cream (35 % milk fat) was used to obtain required fat ratios in cheesemilk. The full fat cheese was produced from cheesemilk containing 3 % milk fat (obtained by mixing cream and skim milk). The other cheese samples were manufactured by partial or total substitution of milk fat with corn oil blend. The full fat cheese (A) was used as control cheese. B cheese was produced from cheesemilk prepared by mixing skim milk, cream, and corn oil blend to obtain 1 % milk fat and 1 % corn oil on milk basis. Similarly, C cheese was produced from the milk containing 1 and 1.5 % milk fat and corn oil, respectively. D and E samples were produced from cheesemilk prepared by mixing skim milk and corn oil blend to obtain 1 % or 1.5 % of corn oil on milk basis, respectively. The oil ratio was determined by pre-experimental study by sensorial evaluation to prevent any oily off-flavour defect in cheese samples. White cheese production was carried out according to Topcu and Saldamli (2006). Briefly, after pasteurization (72 °C, 15 sec), milk was cooled to 32 °C. $CaCl_2$ (0.015 % w/v) and freeze-dried lactic culture (5 U for 180 L milk) were added to cheesemilk. After 15 min, chymosin was added at a level sufficient to coagulate the milk in 60 min. The curd was cut into 1 cm^3 and allowed to rest in the whey for 20 min. The whey was drained and pressure (20–30 kg weights for approximately 100 L of cheese milk) was applied at room temperature (21 °C) until whey drainage had stopped (pH 5.2–5.3). The raw cheese mass was divided into blocks of about 7×7×7 cm. It was salted in brine (16 %) for about 5 h at room temperature (until pH 4.8–4.9). Salted cheese blocks were placed in plastic containers filled with 6 % brine solution to cover the surface of the cheese blocks. Cheese samples in brine were stored for 90 days at 4–6 °C. Before analysis, the cheese samples were selected randomly, well homogenized and then analyzed on the 1, 30, 60, and 90 days of ripening.

Chemical analysis

Cheese samples were analyzed for moisture by the gravimetric method (Turkish Standards (TS) 1987), fat content by the Van-Gulik method (Turkish Standards (TS) 1978), and total nitrogen content by the Kjeldahl method (AOAC 1990). Titratable acidity (lactic acid %), pH and salt levels of cheese samples were determined according to Turkish Standard TS 591 (Turkish Standards (TS) 1989). The pH in cheese was analysed using a pH meter (Hanna 8521, Hanna Inc., Singapore).

Water soluble extract (WSE) and trichloroacetic acid soluble nitrogen (TCA-SN) fraction of the cheese sample was prepared as described by Kuchroo and Fox (1982) and Topcu and Saldamli (2006), respectively. The water soluble

nitrogen (WSN) and TCA-SN were determined by Kjeldahl method (AOAC 1990). The water soluble nitrogen was expressed as a percentage of total nitrogen. The soluble nitrogen in TCA was expressed as a percentage of total nitrogen. Peptide profiles of the WSE were detected by reverse phase- high performance liquid chromatography (RP-HPLC) system, essentially as described by Topcu and Saldamli (2006).

The levels of lypolysis of the white cheese, expressed as acid degree value (ADV), were determined according to the modified Deeth and Fitz-Gerald method (Deeth and Fitz-Gerald 1976; Arslan et al. 2010a).

Fatty acid analysis

Total lipids were extracted according to the modified method of Folch et al. (Folch et al. 1957; Arslan et al. 2010a). Fatty acid methyl esters (FAMEs) were obtained according to the International Dairy Federation Standard (IDF) (IDF 1999). Analysis of FAMEs was performed on a gas-liquid chromatography (GC), Hewlett Packard 5890 series II (Hewlett-Packard, Avondale, Pennsylvania, USA), equipped with a flame-ionization dedector and a DB- 23 capillary column (60 m×0.25 mm i.d., 0.25 μm film thickness, J&W Scientific, Folson, California, USA). The injection volume was 1 μL. The temperature of GC oven was programmed to 140 °C for 5 min then 3 °C/min to 220 °C and held for 19 min at this temparature. The injector and detector temperatures were 250 °C. Nitrogen was used as the carrier gas and the flow rate was 2.3 mL/min (Arslan et al. 2010a). Results were expressed as a percentage (% wt/wt) of all fatty acids detected with a chain length between 4 and 22 carbon atoms.

Determination of cholesterol

The cholesterol contents of cheese samples were determined by RP-HPLC (Arslan et al. 2010a). The cholesterol was quantified by ThermoFinnigan HPLC system (ThermoFinnigan Inc., San Francisco, USA). The analysis was performed isocratically at 0.7 mL/min flow rate using a Luna C18 analytical column (5 μm, 250×4.6 mm, Phenomenex, Torrance, California, USA). Mobile phase was prepared using a mixture of acetonitrile and 2 propanol (70:30, *v*/*v*). The absorbance of the eluate was monitored at 205 nm.

Texture analysis

TA plus Texture Analyzer (Ametek Lloyd Inst.Ltd., Hampshire, United Kingdom) equipped with a cylinder probe (10 mm diameter) was used for instrumental texture profile analysis (TPA). Hardness, springiness, chewiness, and gumminess properties of cheeses were evaluated and the samples were taken from at least 2 cm deep in the cheese blocks. After cutting, the samples were immediately covered airtightly and allowed to equilibrate to room temperature (20± 2 °C) for 30 min prior to testing. The samples were compressed by 33 % from the initial sample's height, using two consecutive compression cycles at a speed of 0.5 mm/s (Romeih et al. 2002; Topcu and Saldamli 2006).

Sensory analysis

Sensory properties of cheeses were evaluated using a scoring test by five panelists who are the members of Food Engineering Department (Hacettepe University, Ankara, Turkey). Cheese samples were graded for external appearance, interior appearance, structure, odour, taste and overall acceptability using a score from 1 to 5. Cheese samples were evaluated according to the Turkish Standard for white cheese (Turkish Standard (TS) 1989).

Statistical analysis

The experimental design was conducted to evaluate the influence of the 5 treatments (A, B, C, D, or E), and 4 ripening periods (1, 30, 60, or 90 days) on the physicochemical characteristics of cheese. Each of the combined factors (4 ripening periods×5 treatments) had 2 replications for the chemical parameters and 3 replications for the mechanical parameters. The effects of ripening period and different treatment on the chemical, sensory, physicochemical, and textural properties of samples were assessed using ANOVA by the general linear model procedure of the SPSS 11.0 statistical package programme. Significant means were compared using Duncan test on the level of $p<0.05$.

Results and discussion

Composition of cheese

The composition of cheese samples at 1, 30, 60 and 90 days of ripening are given in Table 1. The chemical composition of the cheese samples showed changes over the ripening period. Corn oil substitution significantly affected the levels of dry matter, fat in dry matter, protein, salt in dry matter and titratable acidity, and pH values of cheeses ($p<0.05$).

As the fat content distinctly decreased, the moisture content increased. The control cheese (A) had the lowest protein content compared to the other cheeses. The protein content was inversely related to the fat content of cheese milk. An increase in protein contents of cheeses lead to increases of water binding capacity resulting increase of the moisture level (Romeih et al. 2002; Kavas et al. 2004; Arslan et al. 2010b). Banks et al. (1994) found that as fat

Table 1 Changes in chemical properties and ripening indices of Turkish white cheeses during the ripening period

Parameters	Ripening period (days)	Cheese code				
		A	B	C	D	E
Moisture, %	1	61.3±0.09^{a}	66.9±0.25^{d}	64.0±0.10^{b}	65.8±0.22^{c}	66.2±0.49^{cd}
	30	63.8±0.21^{b}	63.7±0.30^{b}	61.7±0.02^{a}	68.4±0.15^{c}	63.6±0.14^{b}
	60	64.1±0.06^{b}	65.7±0.04^{d}	62.4±0.28^{a}	66.2±0.10^{e}	64.9±0.28^{c}
	90	64.8±0.33^{c}	63.5±0.08^{b}	63.8±0.08^{b}	66.9±0.35^{d}	62.2±0.21^{a}
Protein, %	1	15.2±0.19^{a}	14.9±0.04^{a}	14.7±0.36^{a}	18.2±0.00^{c}	16.3±0.27^{b}
	30	13.4±0.36^{a}	16.7±0.09^{b}	16.7±0.27^{b}	17.2±0.36^{b}	18.0±0.18^{c}
	60	13.8±0.21^{a}	15.0±0.18^{b}	15.3±0.27^{b}	17.9±0.09^{c}	16.0±0.99^{b}
	90	12.7±0.04^{a}	16.0±0.27^{c}	14.9±0.17^{b}	17.2±0.14^{d}	18.2±0.36^{e}
Salt in DM, %	1	8.7±0.46^{a}	10.2±0.18^{b}	11.0±0.56^{b}	10.6±0.40^{b}	10.1±0.23^{b}
	30	8.2±0.24^{ab}	9.3±0.15^{c}	7.7±0.30^{a}	12.0±0.50^{d}	8.9±0.16^{bc}
	60	8.3±0.42^{a}	9.8±0.07^{a}	8.8±0.83^{a}	9.8±1.19^{a}	9.4±0.31^{a}
	90	8.7±0.48^{b}	6.9±0.41^{a}	7.4±0.35^{a}	9.5±0.24^{b}	7.4±0.30^{a}
Fat in DM, %	1	47.8±1.93^{e}	39.3±0.30^{c}	44.4±1.84^{d}	24.9±0.16^{a}	32.5±0.47^{b}
	30	51.1±0.30^{e}	39.9±0.34 ^{c}	43.1±0.02^{d}	26.9±0.13^{a}	34.3±0.13^{b}
	60	50.2±0.08^{d}	42.3±2.00^{c}	43.9±2.20^{c}	25.1±0.08^{a}	34.9±1.29^{b}
	90	52.5±0.50^{e}	41.1±0.09^{c}	45.6±0.00^{d}	25.7±0.27^{a}	35.1±1.13^{b}
Titratable acidity*	1	0.69±0.01^{a}	0.79±0.04^{a}	0.69±0.04^{a}	1.06±0.04^{b}	1.01±0.05^{b}
	30	0.99±0.03^{c}	0.83±0.03^{b}	1.03±0.04^{c}	0.73±0.04^{a}	1.12±0.01^{d}
	60	0.73±0.03^{b}	0.64±0.01^{a}	0.78±0.01^{b}	0.87±0.03^{c}	1.06±0.04^{d}
	90	0.60±0.04^{a}	0.87±0.01^{b}	0.70±0.04^{a}	0.95±0.03^{b}	1.21±0.05^{c}
pH	1	4.67±0.02^{a}	4.67±0.01^{a}	4.75±0.03^{b}	4.90±0.03^{c}	4.73±0.03^{ab}
	30	4.71±0.01^{ab}	4.68±0.01^{a}	4.70±0.01^{ab}	4.72±0.01^{b}	4.76±0.00^{c}
	60	4.54±0.02^{a}	4.55±0.01^{ab}	4.60±0.03^{b}	4.60±0.01^{b}	4.60±0.01^{b}
	90	4.53±0.00^{d}	4.35±0.00^{a}	4.43±0.01^{b}	4.52±0.01^{d}	4.49±0.00^{c}
WSN, % of TN	1	5.7±0.07^{a}	6.8±0.04^{c}	6.4±0.10^{b}	8.1±0.10^{e}	7.7±0.07^{d}
	30	8.2±0.09^{d}	6.1±0.02^{a}	7.6±0.23^{c}	6.8±0.19^{b}	7.7±0.02^{c}
	60	8.1±0.12^{a}	8.0±0.10 ^{a}	9.5±0.17^{b}	10.3±0.05^{b}	10.4±0.76^{b}
	90	9.7±0.03^{b}	9.0±0.10^{a}	9.5±0.18^{b}	10.7±0.14^{c}	10.8±0.31^{c}
TCA-SN,% of TN	1	4.0±0.11^{a}	4.9±0.14^{c}	4.2±0.10^{a}	5.3±0.05^{d}	4.5±0.13^{b}
	30	6.5±0.04^{d}	5.0±0.08^{a}	5.8±0.04^{c}	5.2±0.00^{b}	5.7±0.06^{c}
	60	5.4±0.11^{a}	5.8±0.05^{ab}	6.1±0.01^{b}	6.8±0.08^{c}	6.8±0.53^{c}
	90	7.1±0.13^{bc}	6.7±0.00^{b}	6.4±0.02^{a}	7.3±0.17^{c}	8.0±0.26^{d}
ADV**	1	0.96±0.06^{a}	0.86±0.06^{a}	0.85±0.06^{a}	0.99±0.07^{a}	1.02±0.08^{a}
	30	1.28±0.07^{a}	1.44±0.06^{ab}	1.47±0.06^{b}	1.54±0.06^{b}	1.39±0.08^{ab}
	60	1.42±0.06^{a}	1.73±0.07^{b}	1.65±0.07^{b}	1.66±0.06^{b}	1.77±0.07^{b}
	90	1.89±0.07^{a}	2.44±0.10^{bc}	2.27±0.10^{b}	2.56±0.08^{c}	2.58±1.13^{c}

A: Control, B: 1 % milk fat plus 1 % corn oil, C: 1 % milk fat plus 1.5 % corn oil, D: Skim milk plus 1 % corn oil, E: Skim milk plus 1.5 % corn oil. *DM* Dry matter, *WSN* Water soluble nitrogen, *TCA-SN* Trichloro acetic acid soluble nitrogen, *TN* Total nitrogen

All values are mean ± SD (n=4). The values having different exponential letters in same row are significantly different (p<0.05)

*Titratable acidity expressed as % of lactic acid

**ADV, acid degree value expressed as meq KOH/100 g fat

content of Cheddar cheese decreased, moisture content increased. Similar results were reported by Rudan et al. (1999) for Mozzarella cheese and Kumar et al. (2011) for Indian cheese (paneer).

The control cheese also showed lower salt in dry matter values than the corn oil cheeses. This trend was observed throughout cheese ripening and is in close agreement with other researchers (Katsiari and Voutsinas 1994; Rudan et al.

1999; Sipahioglu et al. 1999; Romeih et al. 2002; Arslan et al. 2010a). The higher salt content in the low-fat cheeses may be linked to their higher moisture contents (Romeih et al. 2002; Kavas et al. 2004). In the study, the salt content of the cheeses varied throughout the ripening period probably due to the diffusion of NaCl between brine and cheese. The salt concentration of cheese has a great importance in cheese ripening due to its influence on the proteolytic activity of enzymes, and on the growth and activity of lactic acid bacteria. Salt content also affects the sensitivity of rennet to casein fractions (Guinee and Fox 1999).

The pH value usually decreased throughout the maturation and differences among cheese samples was significant ($p<0.05$) and fluctuated between 4.35±0.00 and 4.90±0.03 during the ripening period (Table 1). However, Rudan et al. (1999) stated that the pH value of Mozzarella cheese was not affected by variations in its fat content.

Titratable acidity of cheeses fluctuated between 0.60± 0.04 % and 1.21±0.05 % during the ripening period, due to the formation of lactic acid and the variation in the levels of dry matters. At the beginning of the ripening period, acidification of the milk by lactic acid bacteria occurs rapidly, but later, their action is limited. Because, lactose content of the white cheeses decrease during ripening (Topcu and Saldamli 2006).

Proteolysis in cheese leads to an increase in the soluble nitrogen fractions, which is considered as an index of proteolysis (Zhang and Zhao 2010). Table 1 shows that WSN and TCA-SN of cheeses were significantly ($p<0.05$) affected by the treatment of the cheese milk. The values of WSN in the samples continuously increased throughout the ripening. The effect of ripening time and the variation of treatment on WSN fractions was found to be important in the present study ($p<0.05$). Results are in agreement with that obtained by Topcu and Saldamli (2006). It was determined that samples D and E showed the highest values WSN at the end of ripening period ($p<0.05$). WSN values of control cheese (A) and the other cheese samples (B, C, D, and E) were different during the ripening period. This might lead to the conclusion that the differences in the levels of WSN and its fractions among cheeses of different fat content could ensue from differences in rennet retention and, hence, in the level of residual rennet activity in the casein matrix. Alternatively, compositional effects (moisture and salt) might alter the activity of rennet and/or starter or non-starter proteolytic enzymes in the case of low-fat cheeses (Romeih et al. 2002; Arslan et al. 2010a).

The TCA-SN values of samples varied between 4.0± 0.11 % and 8.0±0.26 % and showed an increase during the ripening period. The effect of ripening period and discriminative treatment on TCA-SN was statistically significant ($p<0.05$). It was found that the ripening index of the cheeses containing corn oil (D, E) was higher than that of the other samples at the end of the ripening period. TCA-SN values express small molecules of peptides (lower than 20 amino acid residues) and free amino acids. TCA-SN components, which occur as a result of proteinase activity, are used to determine the proteolysis level (Javidipour and Tuncturk 2007). At the end of ripening, TCA-SN values of samples increased by 36.7–77.8 % when compared with those at the beginning of ripening (1 day).

The ADV of all groups increased markedly ($p<0.05$) throughout the ripening. The ADV value of white cheese produced by adding corn oil was higher than that of the control samples ($p<0.05$). Similar results were reported by Romeih et al. (2002), Kavas et al. (2004), Sahan et al. (2008), Arslan et al. (2010a). Nevertheless, no rancid taste and odour was detected in all cheese samples. At the end of ripening, ADV contents were 1.97, 2.84, 2.67, 2.59, 2.53 times higher than the 1 day of ripening in A, B, C, D, and E cheese samples, respectively. Statistical analysis of data showed that the differences among treatments were significant ($p<0.05$).

Determination of proteolysis level by RP-HPLC

The RP-HPLC profiles of the WSN fraction of the cheeses are given at Fig. 1. It has been found an increase total peak area during the ripening period. The retention times of three aromatic amino acids (tyrosine, phenylalanine, and tryptophan) were used to define hydrophilic and hydrophobic zones. The hydrophilic peptide (HPi) portion consisted of the peptides that eluted between tyrosine (Tyr) and tryptophan (Trp) (from 23 to 39 min). The group of hydrophobic peptides (HPo) consisted of peptides with retention times from 39 to 90 min. Most of the peptides in the cheese samples were in the hydrophobic area and the number of these peptides increased during the ripening period. At the beginning of ripening period, the ratio of the total peak area of hydrophobic to hydrophilic peptides (HPo/HPi) of cheeses, A, B, C, D and E were 3.5, 4.0, 3.6, 3.3, 3.6 respectively. On the other hand, the HPo/HPi ratios of cheeses were 3.7, 3.7, 4.1, 3.9, and 3.9 at the end of ripening period, respectively. Corn oil substitution tended to an increase of hydrophobic peptides in cheeses. However, the comparison of the chromatographic profiles of the WSN extracts of the individual cheeses at ripening period showed that the treatment had some minor influence on proteolysis since the variation of relative intensity of certain peaks was very low. These findings are in agreement with data reported by Madsen and Ardö (2001) for Danbo cheese and Romeih et al. (2002) for Feta cheese.

Textural properties

The nutritional and textural properties of products play an important role in the overall acceptability and preference

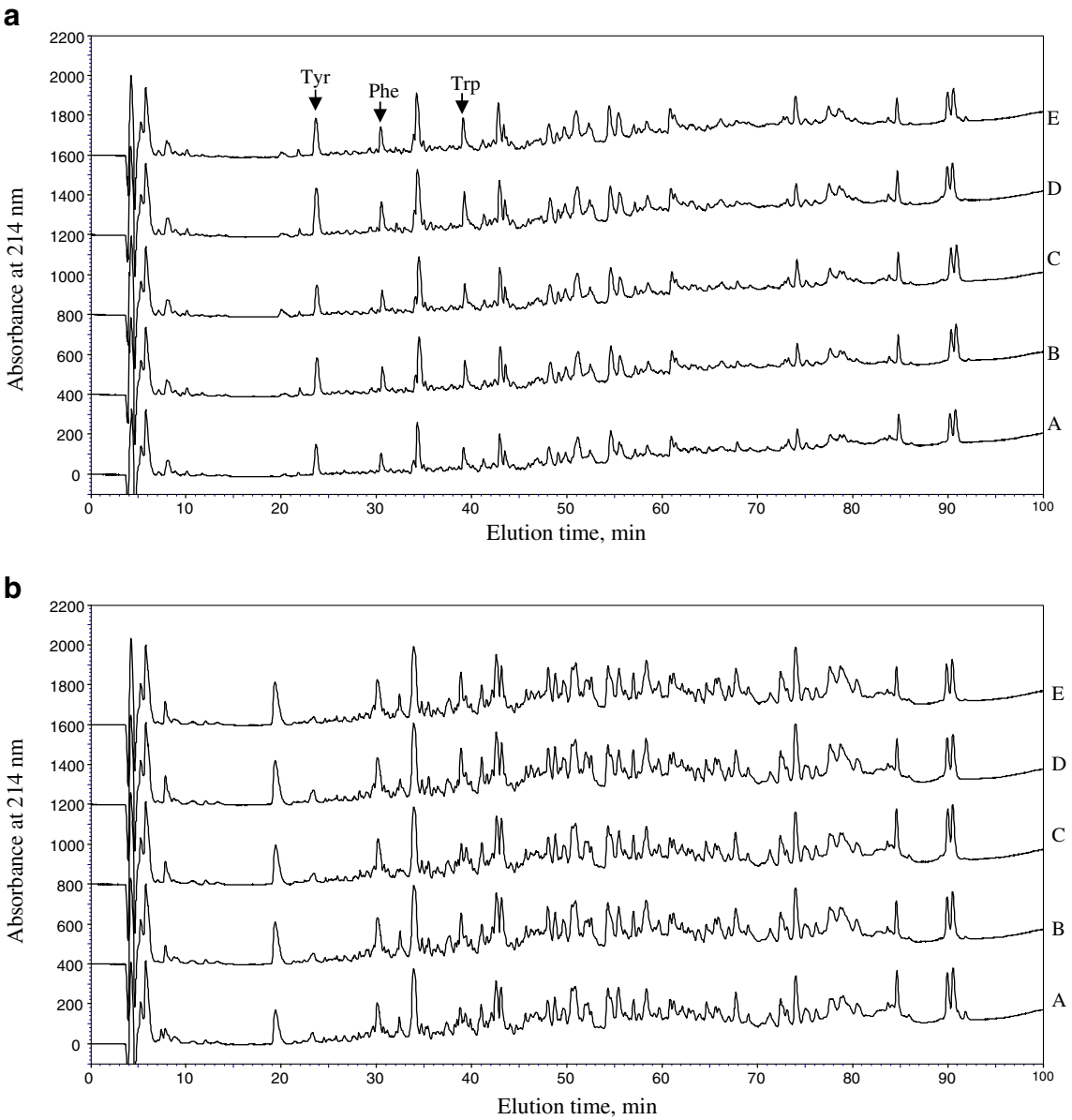

Fig. 1 Reverse-phase HPLC profiles of the water-soluble fraction of cheese samples at 1 day (**a**) and 90 day (**b**) of ripening. A: control, B: 1 % milk fat plus 1 % corn oil, C: 1 % milk fat plus 1.5 % corn oil, D: skim milk plus 1 % corn oil, E: skim milk plus 1.5 % corn oil. Tyr: Tyrosine, Phe: Phenylalanine, Trp: Tryptophan

(Dhamsaniya et al. 2012). In the current study, texture profile analysis (TPA) were used to describe the textural properties of cheese samples and the mean values of TPA parameters are given in Table 2. Most of the data of instrumental textural properties showed irregular fluctuations. The analysis of variance of TPA values showed that the ripening period had an important effect on cheese texture ($p<0.05$). The contents of moisture, fat, emulsifying agents and pH have an important effects on cheese texture. The moisture in the protein network acted as a plasticiser making it more elastic and less easily fractured. A higher fat content resulted in softer, less springy, more cohesive and adhesive cheese (Bachmann 2001). In low fat variants, there is inadequate breakdown of casein and, therefore, the cheese appears to have a relatively firm texture (Mistry 2001).

Hardness values of white cheeses showed irregular fluctuations during the ripening period. At the end of the ripening period, it was found that the hardness of the cheeses containing corn oil (D, E) was higher than that of the other cheeses. There were no significant ($p>0.05$) differences in springiness value of various treatments. The values of springiness in the present study are in agreement with those of Zalazar et al. (2002) and Lteif et al. (2009).

The mean values of gumminess and chewiness of white cheeses showed irregular fluctuations during the ripening period. It was determined that sample D had the highest

Table 2 Textural analysis of Turkish white cheeses during the ripening period

Textural properties	Ripening period (days)	Cheese code				
		A	B	C	D	E
Hardness, N	1	4.6±0.14^{c}	2.9±0.28^{a}	3.5±0.28^{b}	5.1±0.25 ^{c}	6.0±0.15^{d}
	30	2.8±0.07^{ab}	3.5±0.36^{ab}	2.1±0.11^{a}	5.1±0.35 ^{c}	3.7±1.09^{b}
	60	3.8±0.03^{b}	3.1±0.11^{ab}	2.6±0.73^{a}	5.3±0.28 ^{c}	3.4±0.51^{ab}
	90	3.3±0.61^{a}	3.8±0.11^{a}	4.0±0.21^{a}	5.3±1.79^{ab}	6.4±0.32^{b}
Springiness, mm	1	5.6±0.03	5.5±0.13	5.6±0.17	6.6±0.45	6.1±0.32
	30	5.6±0.31	5.3±0.17	5.2±0.16	5.7±0.18	5.8±0.12
	60	5.6±1.22	5.4±0.81	5.4±0.88	4.8±0.18	4.6±0.95
	90	5.8±0.01	4.5±0.83	5.6±0.12	5.5±0.25	5.5±0.21
Chewiness, N mm	1	8.1±1.54^{a}	6.7±1.13^{a}	7.4±1.34^{a}	15.6±1.45^{b}	12.4±1.47^{b}
	30	3.9±2.13^{a}	5.6±2.51^{a}	3.4±0.63^{a}	12.0±1.38^{b}	5.8±0.31^{a}
	60	6.9±3.93^{a}	4.8±2.04^{a}	2.6±0.62^{a}	6.0±0.91^{a}	5.0±2.03^{a}
	90	7.1±0.77^{a}	5.8±1.67^{a}	6.2±0.15^{a}	11.0±4.84^{a}	8.7±3.22^{a}
Gumminess, N	1	1.4±0.28^{ab}	1.2±0.25^{a}	1.3±0.27^{a}	2.4±0.23^{c}	2.1±0.24^{bc}
	30	0.7±0.42^{a}	1.2±0.29^{a}	0.7±0.10^{a}	2.1±0.27^{b}	1.0±0.08^{a}
	60	1.2±0.44^{ab}	1.0±0.23^{ab}	0.5±0.04^{a}	1.3±0.24^{b}	1.1±0.22^{ab}
	90	1.4±0.14^{a}	1.3±0.13 ^{a}	1.1±0.18^{a}	2.0±0.80^{a}	1.6±0.34^{a}

A: Control, B: 1 % milk fat plus 1 % corn oil, C: 1 % milk fat plus 1.5 % corn oil, D: Skim milk plus 1 % corn oil, E: Skim milk plus 1.5 % corn oil
All values are mean ± SD (n=6). The values having different exponential letters in same row are significantly different (p<0.05)

chewiness and gumminess at the 90th day of ripening (p<0.05). Dinkci et al. (2011) found that the use of vegetable fat caused a decrease of hardness, cohesiveness, gumminess, and chewiness in kashar cheese whilst adhesiveness and springiness values were not affected. In another study, the reduction of fat content of Hallomi cheese caused an increase of hardness and chewiness values (Lteif et al. 2009). Stevens and Shah (2002) found that the cheeses containing Maltrin as fat replacer were harder than skim milk Mozzarella cheese. Overall, the analysis of variance indicated that hardness, chewiness and gumminess values were significantly affected by the treatment and also by the ripening period (Table 2).

Profile of fatty acids

Fatty acid composition of cheese samples is presented in Table 3. The PUFA and total *cis* fatty acid contents were found to be higher whilst the SFA and *trans* fatty acid content were found to be lower than those of the control cheese. In many studies, it has been stated that saturated fatty acids increase blood cholesterol levels, but monounsaturated and polyunsaturated fatty acids decrease blood cholesterol levels (Melsink and Katan 1989). Polyunsaturated fatty acids are also called "essential fatty acids" as these are crucial to the body's function and are introduced externally through the diet (Das et al. 2012). The recommended ratio of the polyunsaturated to saturated fatty acid ratios (PUFA/SFA) should be higher than 0.4 (Wood et al. 2003). The PUFA/SFA was found as 0.04, 0.80, 1.09, 2.76, 3.12 in A, B, C, D and E cheeses, respectively. The fatty acids with short chain (C4-C10) in the ester form have an important role on the milk fat having its own-taste and aroma. However, the fatty acids with short chain in free form are responsible for a rancid taste (O'Brien 1998). The addition of corn oil altered levels of short chain, *trans* and saturated fatty acids. The results showed that the saturated, *trans* and short chain fatty acids levels of cheeses decreased depending on the level of corn oil. The *trans* fatty acids in the diet show a similar action to that of the saturated fatty acids, making them potentially hazardous to the organism, especially with respect to coronary diseases (Cunha et al. 2010).

The SFA and *trans* fatty acid contents of cheeses produced in 14 European countries were 60.74–68.99 % and 3.59–5.68 % respectively (Aro et al. 1998). In another research related to fatty acid composition of Feta and Greek cheeses, the SFA of samples were found to be 68.9–74.1 %, MUFA values were 18.5–22.1 %; PUFA, *cis* and *trans* fatty acid contents of cheeses were found 3.8–4.8, 18.1–22.1 and 4.2–4.8 %, respectively (Zlatanos et al. 2002). The SFA, MUFA and PUFA contents of in kashar cheese made from vegetable fat blends were found to be 46.63, 41.30 and 11.88 at the beginning of ripening period, respectively (Kesenkas et al. 2009).

Table 3 Fatty acid compositions of Turkish white cheeses

Fatty acid, %	Cheese code				
	A	B	C	D	E
C4	2.18±0.12^{c}	0.89±0.01^{b}	0.80±0.02^{b}	0.30±0.00^{a}	0.18±0.01^{a}
C6	1.49±0.04^{d}	0.69±0.07^{c}	0.52±0.01^{b}	0.14±0.00^{a}	0.09±0.00^{a}
C8	0.94±0.01^{e}	0.46±0.01^{d}	0.36±0.00^{c}	0.13±0.01^{b}	0.08±0.00^{a}
C10	2.17±0.02^{e}	1.06±0.01^{d}	0.82±0.01^{c}	0.23±0.01^{b}	0.16 ±0.00^{a}
C12	2.70±0.05^{e}	1.41±0.00^{d}	1.19±0.01^{c}	0.46±0.01^{b}	0.33±0.01^{a}
C14	10.66±0.11^{e}	5.16±0.01^{d}	4.04±0.01^{c}	1.17±0.00^{b}	0.80±0.00^{a}
C14:1	1.01±0.01^{d}	0.48±0.00^{c}	0.37±0.00^{b}	ND	0.06±0.00^{a}
C15	1.34±0.02^{d}	0.62±0.00^{c}	0.48±0.03^{b}	ND	0.08±0.00^{a}
C16	32.00±0.52^{e}	20.44±0.07^{d}	18.31±0.28^{c}	12.36±0.01^{b}	11.54±0.06^{a}
C16:1 *trans*	0.27±0.03^{d}	0.17±0.00^{c}	0.12±0.00^{b}	ND	0.04±0.00^{a}
C16:1 *cis*	1.60±0.02^{e}	0.82±0.01^{d}	0.65±0.00^{c}	0.26±0.01^{b}	0.20±0.00^{a}
C17	0.86±0.01^{e}	0.41±0.01^{d}	0.33±0.01^{c}	0.13±0.00^{b}	0.11±0.00^{a}
C18:0	12.29±0.21^{e}	7.07±0.03^{d}	6.07±0.28^{c}	3.37±0.01^{ab}	3.00±0.01^{a}
C18:1 *trans*	0.66±0.14	ND	ND	ND	ND
C18:1 *cis*	26.24±0.35^{a}	28.83±0.07^{b}	29.13±0.42^{bc}	29.48±0.11^{bc}	29.64±0.14^{c}
C18:2 *trans*	0.06±0.01^{a}	0.17±0.00^{c}	0.14±0.00^{b}	ND	ND
C18:2 *cis*	2.49±0.26^{a}	30.05±0.01^{b}	35.57±0.57^{c}	50.89±0.57^{d}	52.23±0.14^{e}
C18:3 *trans*	0.14±0.01^{d}	0.08±0.00^{c}	0.06±0.00^{b}	ND	0.05±0.00^{a}
C18:3 *cis*	0.28±0.03^{a}	0.50±0.00^{b}	0.57±0.03^{c}	0.69±0.01^{d}	0.72±0.01^{d}
C20:0	0.28±0.04^{a}	0.32±0.01^{b}	0.34±0.0.0^{bc}	0.39±0.00^{d}	0.38±0.01^{cd}
C20:1	0.20±0.02^{c}	0.09±0.00^{b}	0.10±0.00^{b}	ND	0.06±0.00^{a}
C22	0.13±0.01^{a}	0.20±0.00^{b}	0.22±0.00^{c}	ND	0.27±0.00^{d}
SFA	67.04±0.65^{e}	38.72±0.12^{d}	33.46±0.56^{c}	18.67±0.02^{b}	17.00±0.06^{a}
MUFA	29.98±0.64^{a}	30.38±0.07^{a}	30.37 ±0.42^{a}	29.74±0.11^{a}	30.00±0.14^{a}
PUFA	2.96±0.31^{a}	30.80±0.02^{b}	36.35±0.60^{c}	51.58±0.56^{d}	52.99±0.15^{e}
Total *cis*	31.81±0.67^{a}	60.77±0.05^{b}	66.39±1.01^{c}	81.32±0.44^{d}	82.90±0.01^{d}
Total *trans*	1.13±0.14^{c}	0.42±0.00^{b}	0.32±0.00^{b}	ND	0.09±0.0.00^{a}
Total C4-C10	6.78±0.07^{e}	3.09±0.07^{d}	2.49±0.01^{c}	0.80±0.02^{b}	0.50±0.00^{a}
PUFA/SFA	0.04±0.00^{a}	0.80±0.00^{b}	1.09±0.00^{c}	2.76±0.03^{d}	3.12±0.00^{e}

A: Control, B: 1 % milk fat plus 1 % corn oil, C: 1 % milk fat plus 1.5 % corn oil, D: Skim milk plus 1 % corn oil, E: Skim milk plus 1.5 % corn oil, *SFA* Saturated fatty acids, *MUFA* Monounsaturated fatty acids, *PUFA* Polyunsaturated fatty acids, *ND* Not detectable

All values are mean ± SD (n=4). The values having different exponential letters in same row are significantly different (p<0.05)

Cholesterol levels of cheese samples

The levels of cholesterol of the white cheese are given in Table 4. The amounts of cholesterol of control cheese varied from 71.1±1.25 to 74.7±0.57 mg/100 g whilst for other cheese samples they varied from 7.4±0.57 to 34.0±0.77 mg/100 g during the ripening period. The cholesterol contents of white cheeses with corn oil (D, E) were lower than those of the other samples. Little variation in the levels of cholesterol was observed during the ripening period. The cholesterol values of cheeses decreased between 52.7 % and 89.6 % depending on the level of corn oil addition at the beginning of ripening.

Table 4 Changes in cholesterol content (mg/100 g cheese) in Turkish white cheeses during ripening

Ripening period (days)	Cheese code				
	A	B	C	D	E
1	71.1±1.25^{d}	31.4±0.70^{b}	33.6±0.70^{c}	8.0±0.57^{a}	7.4±0.57^{a}
90	74.7±0.57^{c}	32.7±0.60^{b}	34.0±0.77^{b}	8.2±0.57^{a}	7.8±0.53 ^{a}

A: Control, B: 1 % milk fat plus 1 % corn oil, C: 1 % milk fat plus 1.5 % corn oil, D: Skim milk plus 1 % corn oil, E: Skim milk plus 1.5 % corn oil

All values are mean ± SD (n=4). The values having different exponential letters in same row are significantly different (p<0.05)

Cholesterol contents of 10 cheese varieties produced in Greece were found to be 39.0–115.2 mg/100 g of cheese (Andrikopoulos et al. 2003). The cholesterol content in teleme cheese made from different types of milk (ewe's milk, goat's milk, cow's milk and mixture of ewe's and goat's milk) ranged from 59.2 to 67.5 mg/100 g of cheese (Mallatou and Pappa 2005).

Ghosh and Kulkarni (1996) reported the cholesterol contents of Mozzarella cheese with vegetable oil and control cheese as 4 and 120 mg/100 g of cheese respectively, which were statistically significant ($p<0.05$). In another study, the cholesterol contents in kashar cheese made from milk fat and vegetable fat blends were found to be 56.6 and 0.49 mg/100 g of cheese, respectively (Kesenkas et al. 2009).

Sensory properties

Flavor and compositional quality are the ultimate criterion of the desirability of any food product (Dhamsaniya et al. 2012). The sensory scores of all samples are given in Table 5. The data showed that the external appearance, internal appearance, taste and overall acceptability of white cheese were affected by the corn oil substitution in cheese making ($p<0.05$). However, these parameters were not significantly ($p>0.05$) affected by the ripening period. Taste and overall acceptability was the lowest for the cheese sample containing 1.0 % corn oil (D) at the end of the ripening period. In general, cheese samples (except E sample) showed the highest overall acceptability at the 60th day of ripening. At the end of the ripening period, no samples including full fatty cheese received top score of taste. Nevertheless, no rancid taste and odour were detected in the samples. Overall, the analysis of variance indicated that odour and structure scores of cheese were not significantly ($p>0.05$) affected by the treatment and also by the ripening period. However, from sensory viewpoint, Turkish white cheese produced with corn oil obtained similar scores that of full fatty cheese. The results showed that corn oil utilization instead of milk fat had a little effect on sensorial properties. It is well-known that stucture defects are the main problems caused by a fat reduction in cheeses. So, it is clear that the addition of the

Table 5 Effect of treatment and the ripening period on the mean values of sensory properties

Sensory properties	Ripening period (days)	Cheese code				
		A	B	C	D	E
External appearance	1	4.8±0.50^{a}	4.5±0.58^{a}	5.0±0.00^{a}	4.8±0.50^{a}	5.0±0.00^{a}
	30	4.6±0.48^{a}	4.5±0.58^{a}	4.9±0.25^{a}	4.6±0.48^{a}	4.9±0.25^{a}
	60	4.8±0.50^{a}	4.9±0.25^{a}	5.0±0.00^{a}	4.5±0.58^{a}	5.0±0.00^{a}
	90	4.5±0.58^{ab}	4.3±0.50^{a}	5.0±0.00^{b}	5.0±0.00^{b}	5.0±0.00^{b}
Interior appearance	1	4.5±0.58^{a}	4.5±0.58^{a}	4.5±0.58^{a}	5.0±0.00^{a}	5.0±0.00^{a}
	30	4.5±0.58^{a}	4.5±0.58^{a}	4.5±0.58^{a}	4.9±0.25^{a}	4.9±0.25^{a}
	60	4.8±0.50^{a}	4.9±0.25^{a}	4.8±0.50^{a}	4.5±0.58^{a}	4.8±0.50^{a}
	90	4.4±0.48^{ab}	4.0±0.41^{a}	4.5±0.58^{ab}	4.9±0.25^{b}	4.9±0.25^{b}
Structure	1	4.8±0.50	4.5±0.58	4.3±0.96	4.5±0.58	5.0±0.00
	30	4.8±0.50	4.5±0.58	4.3±0.96	4.5±0.58	5.0±0.00
	60	4.8±0.50	4.8±0.50	4.5±0.58	4.4±0.50	4.6±0.48
	90	4.3±0.96	4.5±0.58	4.5±0.58	4.4±0.75	4.6±0.48
Odour	1	4.8±0.50	4.8±0.50	5.0±0.00	4.8±0.50	4.3±0.50
	30	4.8±0.50	4.8±0.50	4.9±0.25	4.6±0.48	4.3±0.50
	60	5.0±0.00	4.9±0.25	4.8±0.50	4.5±0.58	4.5±0.58
	90	4.8±0.50	4.8±0.29	4.5±0.71	4.4±0.48	4.8±0.29
Taste	1	4.5±0.58^{a}	4.0±0.82^{a}	4.3±0.96^{a}	3.5±0.71^{a}	4.3±0.65^{a}
	30	4.5±0.58^{a}	4.0±0.82^{a}	4.0±0.82^{a}	3.5±0.71^{a}	4.3±0.65^{a}
	60	5.0±0.00^{b}	4.5±0.58^{ab}	4.8±0.50^{ab}	4.0±0.00^{a}	4.3±0.96^{ab}
	90	4.4±0.75^{a}	4.4±0.48^{a}	4.6±0.48^{a}	4.3±0.96^{a}	4.3±0.71^{a}
Overall acceptability	1	5.0±0.00^{b}	4.3±0.96^{ab}	4.3±0.96^{ab}	3.5±1.29^{a}	4.3±0.50^{ab}
	30	4.9±0.25^{a}	4.3±0.96^{a}	4.3±0.96 ^{a}	3.5±1.29^{a}	4.1±0.63^{a}
	60	5.0±0.00^{b}	4.4±0.48^{ab}	4.8±0.50^{ab}	4.4±0.48^{ab}	4.1±0.63^{a}
	90	4.5±0.41^{a}	4.4±0.48^{a}	4.6±0.48^{a}	4.1±0.75^{a}	4.5±0.41^{a}

A: Control, B: 1 % milk fat plus 1 % corn oil, C: 1 % milk fat plus 1.5 % corn oil, D: Skim milk plus 1 % corn oil, E: Skim milk plus 1.5 % corn oil
All values are mean ± SD of 5 panelist's scores. The values having different exponential letters in same row are significantly different ($p<0.05$)

corn oil was successful in overcoming this defect in this study. The taste scores of samples decreased by lowering fat content and using corn oil. The differences between taste scores can be mainly related to a difference in short-chain fatty acid compositions. Cunha et al. (2010) reported that the traditional processed cheese and the cheese analogue with 50 % vegetable fat received similar scores for the attribute of overall acceptability.

Conclusions

Decreasing of fat content and using of corn oil in white cheese production affected significantly the levels of moisture, protein, fat in dry matter, salt in dry matter and titratable acidity and pH and the ripening properties ($p<0.05$). However, the treatments did not influence effectively the formation of water soluble peptides detectable by RP-HPLC. Partially or totally corn oil substitution of milk fat changed PUFA/SFA ratio in cheese in a positive way for human health. It was determined that the levels of cholesterol were decreased by lowering the amount of milk fat which was an expected result. The mean sensory scores of the experimental cheeses were approximately similar indicating that these cheeses have commercial potential. It is considered that the white cheese produced by using corn oil shall be able to meet consumer's appreciation and need from sensory and functional properties. Moreover, production of white cheese by using corn oil is considered useful for the individuals having health problems.

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