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Lipolysis in Urfa cheese produced from raw and pasteurized goats' and cows' milk with mesophilic or thermophilic cultures during ripening

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ABSTRACT

Lipolysis was evaluated in Urfa cheese made from raw and pasteurized goats' and cows' milk with mesophilic or thermophilic cultures. The acid degree values (ADVs) of the cows' milk cheeses were significantly ($P < 0.05$) higher until 60 d of storage than that of cheese made from goats' milk. Total free fatty acid (FFA) contents of goats' milk cheese were significantly ($P < 0.001$) lower than that of cows' milk cheese throughout ripening, whereas goats' milk cheese flavour was higher ($P < 0.05$) than cows' milk cheese. Pasteurization of milk prior to cheese-making has a negative influence, not only on the level of lipolysis throughout ripening, but also on the relative amounts of short chain FFAs and sensory properties of the cheeses ($P < 0.001$). Cheese produced without starter bacteria underwent significantly ($P < 0.05$) higher lipolysis than cheeses produced with mesophilic or thermophilic starter bacteria, while cheese made with thermophilic starter culture had similar flavour to cheese made without starter culture.

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1. Introduction

The biochemistry of cheese ripening involves glycolysis, proteolysis and lipolysis. Free fatty acids (FFA) are released by the actions of lipases from different sources, milk, rennet paste, starter and non-starter bacteria, moulds included as secondary starters, and other exogenous lipases, during lipolysis (Perotti, Bernal, Meinardi, & Zalazar, 2005). FFAs contribute positively to the flavour of cheese, particularly when properly balanced by the products of proteolysis and other enzyme-catalysed reactions, and they are precursors of more complex aroma compounds. However, extensive lipolysis may be considered undesirable in most cheese varieties (Sousa & Malcata, 1997).

Cheeses made from raw milk possess strong and unique flavours and, therefore, raw milk cheeses are popularly sold in many parts of the world. Nowadays, most cheeses are made from pasteurized rather than from raw milk due to hygienic reasons. However, pasteurization inactivates some enzymes that could play an important role in cheese ripening, e.g. indigenous milk lipase (Buffa, Guamis, Pavia, & Trujillo, 2001). Hence, lipolysis in raw milk cheese is different from that in pasteurized milk cheese.

The fact that Urfa cheese is traditionally produced without starter bacteria at all is one of the causes of its frequent indifferent quality. Therefore, the selection, maintenance, and use of starter cultures in Urfa cheese is probably the most important step of cheese-making, especially in the context of modern mechanized processes. Starter cultures consisting of lactic acid bacteria (LAB) have to be added when producing cheese from pasteurized milk, and can be usefully employed for those produced from raw milk to obtain a high degree of control over the fermentation process (Herreros et al., 2007). In Turkey, most of large factories use pasteurized milk and commercial starters, mostly blended with *Lc. lactis* subsp. *lactis* and *Lc. lactis* subsp. *cremoris* as a mesophilic starter culture. Furthermore, small-scale dairies and family farms generally use yoghurt as a thermophilic culture (Goncu & Alpkent, 2005).

Traditional Urfa cheese is generally produced from pure ovine milk or appropriate mixtures of ovine and caprine milk. Recently, the industrial Urfa cheese has been made from bovine milk due to very short lactation period of small ruminants in Turkey. The FFA composition of Urfa cheeses made from caprine and bovine milk, and the accumulation of FFAs during ripening have not been reported. Only one reference is available on the FFA composition of Urfa cheese made from ovine milk (Atasoy & Türkoğlu, 2008). The purpose of the present study was to examine the changes in FFAs during storage of Urfa cheese made from raw and pasteurized goats' or cows' milk with addition of mesophilic or thermophilic cultures.

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2. Materials and methods

2.1. Materials

Raw caprine and bovine milk supplied from a local and Harran University dairy (Sanlıurfa, Turkey), respectively. The mean composition of goats' and cows' milk used in the production of Urfa cheeses was pH 6.53 ± 0.04, 6.62 ± 0.03, total solids 12.75 ± 0.19 g 100 g^{-1}, 12.70 ± 0.15 g 100 g^{-1}, total nitrogen 0.58 ± 0.11 g 100 g^{-1}, 0.56 ± 0.08 g 100 g^{-1}, and fat 4.00 ± 0.22 g 100 g^{-1}, 3.75 ± 0.15 g 100 g^{-1}, respectively. The milk was pasteurized at 65 °C for 20 min.

Each kind of pasteurized milk was used in making Urfa cheese with the following starter culture variables, that is (i) a freeze-dried mesophilic culture (M) (Peyma-Chr. Hansen, Istanbul, Turkey) consisting of *Lc. lactis* subsp. *lactis* and *Lc. lactis* subsp. *cremoris* and (ii) a freeze-dried yoghurt thermophilic culture (T) (Peyma-Chr. Hansen, Istanbul, Turkey) consisting of the microorganisms *Str. thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*. Raw goats' (GR) and cows' (CR) milk cheeses were produced with no starter cultures.

To assist curdling of pasteurized milk, 40% $CaCl_2$ solution was added at a ratio of 20 ml 100 kg^{-1} of caprine and bovine milk. $CaCl_2$ solution was not added to raw milk.

Rennet of animal origin (Mayasan, A.Ş., Istanbul, Turkey) was added at 20 ml 100 kg^{-1} goats' milk and 25 ml 100 kg^{-1} cows' milk.

2.2. Methods

2.2.1. Cheese-making and sampling

Six Urfa cheese-making trials were performed, denoted GR (raw goats' milk cheese), GM (pasteurized and mesophilic culture added goats' milk cheese), GT (pasteurized and thermophilic culture added goats' milk cheese), CR (raw cows' milk cheese), CM (pasteurized and mesophilic culture added cows' milk cheese), and CT (pasteurized and thermophilic culture added cows' milk cheese). Schematic productions of experimental Urfa cheeses are shown in Fig. 1. The experiment was replicated 3 times on different days.

From each batch, 1, 15, 30, 60 and 90 day-old cheeses were taken. Each sample from each batch consisted of four cheese blocks (each block contained approximately 250 g of cheese). At the laboratory, the cheese blocks were ground and kept in airtight containers at −40 °C until they were analyzed.

2.2.2. Cheese analyses

2.2.2.1. Chemical analyses. Total solids and salt were determined according to Turkish Standards (Turkish Standards (TS), 1989). The pH was determined by using a pH-meter (Orion 420). The fat content was determined according to Turkish Standards by the Gerber method (Turkish Standards (TS), 1978). All analyses were performed in duplicate.

2.2.2.2. Acid degree value (ADV). Fat hydrolysis was estimated by determination of the ADV, according to the method described by Renner (1986).

2.2.2.3. Free fatty acid analyses. Fat from cheese samples was extracted as outlined by Garcia-Lopez, Echeverria, Tsui, and Balch (1994). Cheese (10 g) was ground and fatty acids were extracted with a mixture of methanol and methylene chloride. Fat samples were methylated according to the procedure of Sukhija and Palmquist (1988).

Fatty acid methyl esters were analyzed using a gas chromatograph (Shimadzu GC-17 AAF, V3, 230 V series; Shimadzu Corporation, Kyoto, Japan) equipped with flame ionisation detector (FID), and fitted with a fused silica capillary column (SP-2380, 100 m × 0.25 mm; Supelco Inc., Bellefonte, PA). Helium was used as a carrier gas. Injector and detector temperature was 250 °C. The initial oven temperature was 40 °C for 1.0 min, and then increased to 240 °C at 5 °C/min. The final temperature was maintained for 10 min. The internal standard used was nonanoic acid. A standard fatty acid mixture containing 50 fatty acids and purified known individual fatty acids were used to provide standard retention times. Fatty acids were identified by comparing their retention times with those of fatty acids in standard samples.

2.2.2.4. Sensory analyses. The sensory evaluations of the 90 day-old cheeses were carried out with three replications by 10 trained panelists who were members of the Division of Dairy Technology Department of Food Engineering, Harran University. The attributes of cheese were organised into flavour (odour and taste), body and texture, colour and appearance, and saltiness categories. Flavour attributes was scored between 0 (the worst) and 10 point (the best quality). Body and texture, colour and appearance attributes were assessed on a 0–5 scale, scoring 0 for the worst and five for the best quality. Panelists were asked to evaluate the saltiness (0 = extremely salty, 5 = not salty). The total score was obtained by adding the scores for the four attributes. An excellent cheese would receive a total score of 25.

2.2.2.5. Statistical analyses. General linear model procedure of SAS system (1990) software, Version 6 (SAS Institute Inc., Cory, NJ) was used to determine the significance in differences of chemical composition, ADV, FFAs, and sensory properties of trial (GR, GM, GT, CR, CM, CT) Urfa cheese samples during storage. Tukey's Studentized range test (honestly significant difference) was used to differentiate between samples (Snedecor & Cochran, 1989). Statistical significance for differences was determined at 5% probability level.

3. Results and discussion

3.1. Acid degree value

The ADVs of the six cheese samples are shown in Table 1 during ripening. In general, ADVs of all experimental cheeses were statistically increased ($P < 0.05$) during storage, except GT cheese. The increase in ADVs in cheese during storage has been reported previously (Franco, Prieto, Urdiales, Fresno, & Carballo, 2001). Cows' milk cheese exhibited significantly higher ($P < 0.05$) ADVs than goats' milk cheese at 1, 15, 30 and 60 days. However, no significant differences in ADVs were found between bovine and caprine milk cheeses at the end of ripening. These findings are in good agreement with a previous study on Teleme cheese (Mallatou, Pappa, & Massouras, 2003).

Regardless of milk species, cheeses made from raw milk had slightly higher ($P < 0.001$) ADVs than that of made from pasteurized milk for all storage periods. Moreover, the ADVs observed in cheeses made from raw milk without starter culture were significantly higher ($P < 0.05$) than cheeses made with mesophilic or thermophilic culture added at all ages. However, there were no significant differences in ADVs between mesophilic and thermophilic culture added cheese during ripening.

3.2. Free fatty acids

The total FFAs of the experimental cheeses are presented in Table 1 during storage. Total FFAs of GR, GM, GT, CR, CM and CT cheeses were significantly increased ($P < 0.05$) during storage.

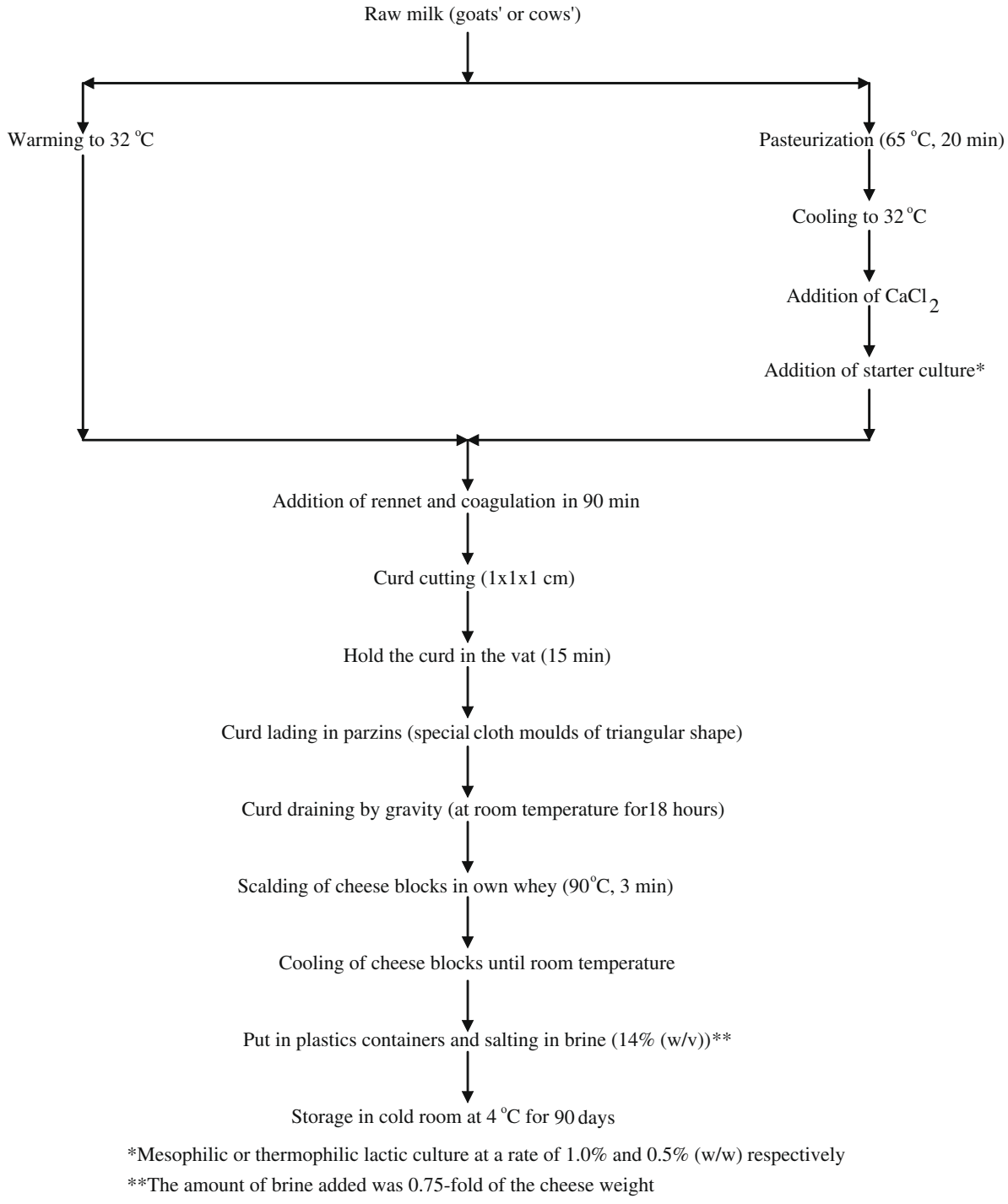

Fig. 1. Flow diagram of experimental Urfa cheese production.

The increase in FFAs in cheese during ripening has been reported previously (Mallatou et al., 2003). Total FFA contents of goats' milk cheese were significantly ($P < 0.001$) lower than that of cows' milk cheese at all ages examined. This can be due to the fact that the lipoprotein lipase (LPL) of goats' milk is distributed primarily in cream and in milk serum (46% of the activity recovered in each of these fractions) and only a small part (8%) is associated with casein micelles (Chilliard, Selselet-Attou, Bas, & Morand-Fehr, 1984), which are incorporated into cheese. Another reason may be that the interactions of caseins with indigenous lipase in cows' milk are higher than in goats' milk (Chilliard et al., 1984).

Pasteurization of milk prior to cheese-making significantly affected the total FFAs content of cheese at 1, 15, 30, 60 and 90 days of ripening ($P < 0.001$). Pasteurization reduces the effect of enzymes from milk (Urbach, 1997). Indigenous lipase mainly causes significant lipolysis in raw milk cheese. It is well known that lipoprotein lipase is a relatively heat-labile enzyme, which may be completely inactivated by heating at $\geqslant 78$ °C for 10 s (Driessen, 1989). Regardless of milk species, total FFAs contents of mesophilic and thermophilic culture added cheeses were similar at all ages ($P > 0.05$). This finding is line with Katsiari, Kondyli, and Voutsinas (2009). However, during ripening raw milk cheeses (not including

Table 1
Changes in acid degree values (ADVs) (mg KOH 100 g^{-1} fat), total free fatty acids (FFAs) (mg 100 g^{-1} cheese), pH, total solids (g 100 g^{-1}), fat in dry matter (g 100 g^{-1}) and salt in moisture (g 100 g^{-1}) content of Urfa cheese samples during ripening[A].

Cheese samples	Age (days)	ADV	Total FFAs	pH	Total solids	Fat in dry matter	Salt in moisture
GR	1	2.08 ± 0.05^{d1}	59.61 ± 0.23^{e2}	5.45 ± 0.05^{a3}	55.14 ± 0.44^{a1}	45.39 ± 0.74^{a}	7.61 ± 0.56^{b}
	15	3.18 ± 0.14^{c2}	66.90 ± 0.56^{d2}	5.20 ± 0.03^{b3}	54.82 ± 0.66^{a1}	43.78 ± 0.18^{ab1}	10.27 ± 0.70^{a}
	30	4.47 ± 0.16^{b2}	85.49 ± 0.48^{c2}	5.12 ± 0.03^{b3}	52.80 ± 0.66^{ab1}	43.72 ± 0.32^{ab}	10.51 ± 0.21^{a}
	60	5.09 ± 0.10^{a2}	92.38 ± 0.08^{b2}	5.10 ± 0.03^{b3}	51.92 ± 0.58^{b1}	43.35 ± 0.64^{ab}	10.17 ± 0.14^{a12}
	90	5.62 ± 0.10^{a1}	98.89 ± 0.28^{a2}	5.10 ± 0.05^{b2}	50.77 ± 0.18^{b1}	42.68 ± 0.46^{b}	9.94 ± 0.27^{a12}
GM	1	0.91 ± 0.08^{c2}	56.27 ± 0.25^{e3}	5.23 ± 0.05^{a4}	54.10 ± 0.32^{a12}	42.66 ± 1.11	8.25 ± 0.29
	15	1.14 ± 0.04^{bc3}	61.98 ± 0.25^{d3}	5.12 ± 0.02^{ab3}	53.05 ± 0.41^{ab2}	42.08 ± 0.80^{12}	9.95 ± 0.36
	30	1.22 ± 0.03^{b3}	65.07 ± 0.47^{c4}	4.99 ± 0.01^{b3}	51.90 ± 0.49^{bc12}	41.57 ± 0.87	9.98 ± 0.57
	60	1.36 ± 0.04^{ab3}	67.94 ± 0.25^{b4}	5.02 ± 0.02^{b3}	51.39 ± 0.26^{c12}	40.95 ± 1.60	9.64 ± 0.23^{23}
	90	1.49 ± 0.04^{a2}	72.13 ± 0.38^{a4}	5.05 ± 0.03^{b2}	50.42 ± 0.19^{c12}	40.98 ± 1.73	9.79 ± 0.35^{12}
GT	1	1.01 ± 0.08^{2}	55.98 ± 0.15^{e3}	5.26 ± 0.03^{a4}	52.68 ± 0.20^{a23}	42.54 ± 0.64^{ab}	7.53 ± 0.07^{b}
	15	1.12 ± 0.01^{3}	62.76 ± 0.28^{d3}	5.14 ± 0.05^{ab3}	52.12 ± 0.37^{a23}	43.06 ± 0.35^{a12}	9.61 ± 0.25^{a}
	30	1.26 ± 0.11^{3}	65.66 ± 0.22^{c4}	5.06 ± 0.04^{b3}	50.71 ± 0.29^{b23}	42.16 ± 0.86^{ab}	9.31 ± 0.26^{a}
	60	1.33 ± 0.13^{3}	68.40 ± 0.32^{b4}	5.11 ± 0.02^{ab3}	50.04 ± 0.06^{b234}	40.14 ± 0.41^{b}	9.34 ± 0.14^{a3}
	90	1.46 ± 0.16^{2}	72.11 ± 0.31^{a4}	5.10 ± 0.01^{b2}	49.64 ± 0.06^{b12}	40.12 ± 0.13^{b}	9.53 ± 0.51^{a2}
CR	1	2.65 ± 0.39^{c1}	65.08 ± 0.40^{e1}	5.97 ± 0.03^{a1}	53.98 ± 0.33^{a12}	44.54 ± 0.33^{a}	8.34 ± 0.09^{c}
	15	3.88 ± 0.27^{bc1}	77.35 ± 0.22^{d1}	5.80 ± 0.06^{ab1}	52.17 ± 0.14^{b23}	42.97 ± 0.63^{ab12}	9.26 ± 0.09^{b}
	30	5.54 ± 0.17^{ab1}	91.47 ± 0.56^{c1}	5.71 ± 0.05^{b1}	51.22 ± 0.20^{bc123}	42.13 ± 0.71^{ab}	10.01 ± 0.30^{a}
	60	6.59 ± 0.21^{a1}	101.61 ± 0.09^{b1}	5.63 ± 0.02^{b1}	50.43 ± 0.31^{cd123}	41.64 ± 0.59^{b}	10.27 ± 0.09^{a12}
	90	6.85 ± 0.69^{a1}	111.10 ± 0.56^{a1}	5.61 ± 0.06^{b1}	49.28 ± 0.24^{d3}	41.43 ± 0.60^{b}	$9.69 \pm 0.0.05^{ab12}$
CM	1	1.23 ± 0.02^{b2}	59.39 ± 0.27^{e2}	5.81 ± 0.02^{a2}	52.19 ± 0.19^{a3}	42.56 ± 0.99	7.76 ± 0.37^{b}
	15	1.35 ± 0.03^{b3}	65.64 ± 0.53^{d2}	5.62 ± 0.02^{b2}	51.34 ± 0.15^{a23}	41.23 ± 0.24^{2}	10.09 ± 0.46^{a}
	30	1.41 ± 0.03^{ab3}	72.78 ± 0.44^{c3}	5.52 ± 0.02^{bc2}	50.35 ± 0.21^{b23}	40.55 ± 0.42	10.68 ± 0.18^{a}
	60	1.48 ± 0.06^{ab3}	77.70 ± 0.18^{b3}	5.47 ± 0.02^{c2}	49.42 ± 0.30^{bc34}	41.14 ± 0.76	10.66 ± 0.04^{a1}
	90	1.68 ± 0.11^{a2}	83.61 ± 0.19^{a2}	5.48 ± 0.03^{c1}	49.03 ± 0.17^{c34}	40.96 ± 1.14	11.14 ± 0.32^{a1}
CT	1	1.14 ± 0.04^{c2}	59.94 ± 0.15^{e2}	5.87 ± 0.02^{a12}	51.28 ± 0.27^{a3}	42.82 ± 0.38	8.71 ± 0.11^{b}
	15	1.25 ± 0.04^{bc3}	66.24 ± 0.52^{d2}	5.70 ± 0.03^{b12}	50.45 ± 0.20^{ab3}	41.54 ± 0.58^{12}	9.52 ± 0.57^{ab}
	30	1.31 ± 0.01^{bc3}	72.76 ± 0.14^{c3}	5.57 ± 0.02^{c12}	49.45 ± 0.26^{bc3}	40.62 ± 0.88	10.09 ± 0.22^{ab}
	60	1.37 ± 0.02^{b3}	78.26 ± 0.18^{b3}	5.54 ± 0.02^{c2}	48.65 ± 0.24^{c4}	41.45 ± 0.35	10.58 ± 0.19^{a1}
	90	1.58 ± 0.07^{a2}	83.76 ± 0.14^{a2}	5.52 ± 0.04^{c1}	48.37 ± 0.23^{c4}	40.31 ± 1.00	10.76 ± 0.27^{a12}

[a–e]Means with different letters were significantly different among storage periods within the rows each cell ($P < 0.05$); [1–4]Means with different numbers were significantly different among cheese samples within the column of the similar ripening period ($P < 0.05$); GR: raw goats' milk cheese; GM: pasteurized and mesophilic culture added goats' milk cheese; GT: pasteurized and thermophilic culture added goats' milk cheese; CR: raw cows' milk cheese; CM: pasteurized and mesophilic culture added cows' milk cheese; CT: pasteurized and thermophilic culture added cows' milk cheese.
[A] Mean values (±SD) of three replicates.

starter culture) had higher total FFAs than cheeses made with pasteurized and culture added milk ($P < 0.05$). This result could be due to natural microflora of these cheeses. The importance of the non-starter microflora in raw milk cheese ripening and developing strong flavour has been demonstrated in Cheddar cheese (McSweeney, Fox, Lucey, Jordan, & Cogan, 1993).

The low ADVs and total FFAs indicates that goats' and cows' milk Urfa cheese undergoes very little lipolysis during storage. The degradation of lipids in cheese during ripening is catalysed by the indigenous lipase of the milk and by microbial lipases. Scalding of cheese blocks at 90 °C for 3 min could inactivate milk and microbial lipase. Lipoprotein lipase is partially inactivated and lipolysis is usually low in Swiss cheese due to cooking (Grappin & Beuvier, 1998). Moreover, the pH and salt concentration in Urfa cheese (Table 1) are far from the range of optimum values of the action of native milk lipase (Driessen, 1989). Some researchers have observed the inhibitory effect of pH and salt on LPL activity (Pavia, Trujillo, Sendra, Guamis, & Ferragut, 2000; Vlaemynck, 1992). During ripening of culture added cheeses under suitable conditions, lipase is mainly derived from starter bacteria, which are mostly sensitive to salt in moisture content and pH (Fox, Lucey, & Cogan, 1990). On the other hand, the low lipolysis in Urfa cheese could be associated with low storage temperature. Lipolysis in white pickled cheese stored at 5 °C was lower than cheese stored at 10–20 °C (Abd El-Salam, Alichanidis, & Zerfiridis, 1993).

The amount of all individual FFAs of the cheeses is shown in Table 2. Generally throughout ripening, parallel to the increase of the acid degree value of the fat values and total FFAs of the cheeses, an increase in the individual contents of each one of the free fatty acids in GR, GM, GT, CR, CM and CT cheese was observed.

Regardless of milk treatment and starter culture, butyric acid (C_4) content of cows' milk cheese was higher than goats' milk cheese throughout ripening ($P < 0.001$). However, the caproic acid (C_6) value of bovine milk cheese was lower than caprine milk on the first ($P < 0.05$) and last ($P < 0.001$) days of storage. Moreover, the concentration of caprylic (C_8) and capric (C_{10}) acids were significantly higher in Urfa cheeses made from goats' milk than in cheeses made from cows' milk at all ages ($P < 0.001$). According to Attaie and Richter (1996), these three free fatty acids are likely to contribute to the flavour of goats' milk cheese. Raw milk cheese had significantly higher butyric ($P < 0.05$), caproic ($P < 0.01$), caprylic and capric ($P < 0.001$) acids values than pasteurized ones after 1 d of ripening. At the end of storage, the concentration of these fatty acids was significantly ($P < 0.001$) lower in pasteurized milk cheese than raw milk cheese. Regardless of milk species, cheese made with mesophilic starter bacteria had similar butyric, caproic and caprylic acids content to its thermophilic counterpart at all ages ($P > 0.05$). Moreover, cheese produced without starter culture had higher ($P < 0.05$) butyric acid at 90 d, caproic acid at 15, 30, 60 and 90 d, and caprylic acid at 30, 60 and 90 days of storage. Positioning of fatty acids on the triacylglyceride is distributed non-randomly. Butyric and caproic acids are predominantly situated at the *sn*-3 position and the *sn*-1 and *sn*-3 positions, respectively (Collins, McSweeney, & Wilkinson, 2003). The outer esters bond of tri- or diacylglycerides are mostly hydrolysed by the lipases involved in cheese ripening. However, the lipases of the

Table 2
Concentration of individual free fatty acids (mg 100 g^{-1} cheese) of Urfa cheese during storages[A].

FFA	Age (days)	GR	GM	GT	CR	CM	CT
C_4	1	0.49 ± 0.04^{d2}	0.45 ± 0.02^{d2}	0.42 ± 0.02^{c2}	0.83 ± 0.03^{e1}	0.72 ± 0.04^{c1}	0.77 ± 0.03^{c1}
	15	0.74 ± 0.03^{c34}	0.67 ± 0.02^{c4}	0.73 ± 0.02^{b34}	1.22 ± 0.02^{d1}	0.86 ± 0.02^{c23}	0.89 ± 0.03^{c2}
	30	0.95 ± 0.02^{b34}	0.87 ± 0.04^{b4}	0.86 ± 0.05^{b4}	1.73 ± 0.02^{c1}	1.05 ± 0.03^{b23}	1.16 ± 0.05^{b2}
	60	1.08 ± 0.04^{b2}	1.02 ± 0.02^{a2}	1.06 ± 0.05^{a2}	1.90 ± 0.03^{b1}	1.13 ± 0.03^{b2}	1.17 ± 0.05^{b2}
	90	1.39 ± 0.02^{a23}	1.11 ± 0.02^{a5}	1.14 ± 0.01^{a45}	2.09 ± 0.05^{a1}	1.28 ± 0.04^{a34}	1.43 ± 0.04^{a2}
C_6	1	0.63 ± 0.03^{e1}	0.59 ± 0.02^{d12}	0.56 ± 0.02^{c12}	0.60 ± 0.02^{e12}	0.51 ± 0.02^{d1}	0.54 ± 0.02^{d12}
	15	0.85 ± 0.03^{d1}	0.70 ± 0.01^{c23}	0.71 ± 0.01^{b23}	0.77 ± 0.04^{d12}	0.63 ± 0.02^{c3}	0.69 ± 0.02^{c23}
	30	1.18 ± 0.03^{c1}	0.79 ± 0.02^{cb3}	0.74 ± 0.03^{b3}	1.05 ± 0.03^{c2}	0.74 ± 0.03^{bc3}	0.83 ± 0.02^{b3}
	60	1.67 ± 0.05^{b1}	0.84 ± 0.02^{b3}	0.87 ± 0.01^{a3}	1.27 ± 0.03^{b2}	0.84 ± 0.02^{ab3}	0.97 ± 0.03^{a3}
	90	2.56 ± 0.04^{a1}	0.94 ± 0.02^{a3}	0.97 ± 0.03^{a3}	1.58 ± 0.04^{a2}	0.93 ± 0.03^{a3}	1.04 ± 0.02^{a3}
C_8	1	0.58 ± 0.03^{d1}	0.48 ± 0.02^{e2}	0.48 ± 0.02^{e2}	0.48 ± 0.01^{d2}	0.27 ± 0.03^{e3}	0.26 ± 0.02^{d3}
	15	0.79 ± 0.02^{d1}	0.59 ± 0.01^{d2}	0.60 ± 0.00^{d2}	0.55 ± 0.02^{d2}	0.43 ± 0.03^{d3}	0.41 ± 0.01^{c3}
	30	1.59 ± 0.08^{c1}	0.72 ± 0.03^{c2}	0.75 ± 0.02^{c2}	0.71 ± 0.04^{c2}	0.58 ± 0.02^{c2}	0.59 ± 0.02^{b2}
	60	2.03 ± 0.05^{b1}	0.85 ± 0.01^{b2}	0.86 ± 0.02^{b2}	0.91 ± 0.01^{b2}	0.71 ± 0.02^{b3}	0.67 ± 0.03^{b3}
	90	2.96 ± 0.09^{a1}	1.00 ± 0.01^{a23}	1.02 ± 0.03^{a23}	1.08 ± 0.01^{a2}	0.88 ± 0.02^{a3}	0.90 ± 0.02^{a23}
C_{10}	1	2.35 ± 0.10^{d1}	1.95 ± 0.04^{d2}	1.85 ± 0.09^{d2}	0.65 ± 0.03^{d3}	0.49 ± 0.01^{d3}	0.44 ± 0.01^{d3}
	15	4.83 ± 0.18^{c1}	2.33 ± 0.06^{c2}	2.31 ± 0.05^{c2}	0.78 ± 0.05^{d3}	0.71 ± 0.02^{c3}	0.68 ± 0.00^{c3}
	30	8.88 ± 0.09^{b1}	2.64 ± 0.03^{b2}	2.55 ± 0.03^{b2}	1.02 ± 0.03^{c3}	0.89 ± 0.02^{b3}	0.90 ± 0.01^{b3}
	60	9.31 ± 0.10^{ab1}	2.85 ± 0.06^{ab2}	2.81 ± 0.02^{a2}	1.23 ± 0.03^{b3}	0.96 ± 0.01^{ab4}	1.00 ± 0.02^{a34}
	90	9.52 ± 0.08^{a1}	3.05 ± 0.11^{a2}	2.98 ± 0.02^{a2}	1.83 ± 0.04^{a3}	1.04 ± 0.03^{a4}	1.07 ± 0.04^{a4}
C_{12}	1	2.57 ± 0.06^{c1}	2.28 ± 0.04^{c2}	2.34 ± 0.04^{d2}	0.98 ± 0.05^{d3}	0.82 ± 0.02^{c3}	0.92 ± 0.02^{d3}
	15	2.77 ± 0.08^{c1}	2.36 ± 0.03^{bc2}	2.47 ± 0.03^{cd2}	1.37 ± 0.05^{c3}	0.97 ± 0.02^{c4}	1.07 ± 0.04^{c4}
	30	3.49 ± 0.05^{b1}	2.51 ± 0.03^{b2}	2.61 ± 0.05^{bc2}	1.84 ± 0.06^{b3}	1.18 ± 0.03^{b4}	1.31 ± 0.03^{b4}
	60	3.76 ± 0.05^{b1}	2.46 ± 0.03^{b2}	2.63 ± 0.02^{b2}	2.01 ± 0.01^{ab3}	1.34 ± 0.05^{a4}	1.41 ± 0.03^{ab4}
	90	4.11 ± 0.05^{a1}	2.75 ± 0.04^{a2}	2.89 ± 0.01^{a2}	2.20 ± 0.02^{a3}	1.44 ± 0.04^{a4}	1.52 ± 0.03^{a4}
C_{14}	1	11.27 ± 0.12^{e2}	10.21 ± 0.09^{cd34}	10.01 ± 0.09^{d4}	12.49 ± 0.30^{e1}	10.81 ± 0.07^{e23}	10.49 ± 0.18^{e34}
	15	12.11 ± 0.20^{d2}	10.97 ± 0.04^{c3}	10.57 ± 0.21^{cd3}	14.74 ± 0.07^{d1}	11.78 ± 0.11^{d2}	11.70 ± 0.12^{d2}
	30	15.08 ± 0.11^{c2}	11.27 ± 0.16^{bc4}	11.04 ± 0.03^{bc4}	16.60 ± 0.23^{c1}	12.56 ± 0.06^{c3}	12.60 ± 0.07^{c3}
	60	17.24 ± 0.18^{b2}	11.72 ± 0.13^{cb4}	11.65 ± 0.10^{b4}	18.71 ± 0.13^{b1}	13.04 ± 0.05^{b3}	13.40 ± 0.16^{b3}
	90	18.47 ± 0.07^{a2}	12.41 ± 0.12^{a4}	12.32 ± 0.16^{a4}	19.70 ± 0.17^{a1}	14.10 ± 0.07^{a3}	14.19 ± 0.06^{a3}
C_{16}	1	18.22 ± 0.06^{d3}	17.92 ± 0.06^{d3}	17.50 ± 0.13^{c3}	22.57 ± 0.34^{e1}	21.18 ± 0.29^{e2}	21.76 ± 0.19^{d12}
	15	19.53 ± 0.25^{c3}	18.26 ± 0.07^{cd4}	18.39 ± 0.10^{b4}	28.54 ± 0.26^{d1}	22.60 ± 0.31^{d2}	22.38 ± 0.30^{d2}
	30	22.31 ± 0.17^{b3}	18.68 ± 0.18^{bc4}	18.56 ± 0.05^{b4}	31.49 ± 0.27^{c1}	25.70 ± 0.18^{c2}	25.01 ± 0.08^{c2}
	60	24.26 ± 0.08^{a3}	19.27 ± 0.05^{b4}	19.12 ± 0.20^{b4}	36.11 ± 0.09^{b1}	27.97 ± 0.07^{b2}	28.47 ± 0.23^{b2}
	90	25.05 ± 0.21^{a3}	20.58 ± 0.29^{a4}	20.25 ± 0.25^{a4}	40.24 ± 0.20^{a1}	30.05 ± 0.04^{a2}	30.53 ± 0.18^{a2}
C_{18}	1	10.66 ± 0.12^{e23}	10.39 ± 0.15^{e3}	10.63 ± 0.19^{d23}	11.58 ± 0.13^{d1}	10.90 ± 0.04^{e13}	11.07 ± 0.03^{e12}
	15	11.57 ± 0.31^{d3}	12.46 ± 0.06^{d2}	12.66 ± 0.11^{c12}	12.84 ± 0.11^{c12}	12.82 ± 0.12^{d12}	13.22 ± 0.10^{d1}
	30	15.19 ± 0.09^{c2}	13.17 ± 0.10^{c4}	13.56 ± 0.15^{b4}	17.47 ± 0.17^{b1}	14.50 ± 0.11^{c3}	14.45 ± 0.19^{c3}
	60	15.94 ± 0.09^{b2}	13.77 ± 0.06^{b4}	14.09 ± 0.02^{b4}	18.13 ± 0.10^{b1}	15.14 ± 0.06^{b3}	15.00 ± 0.06^{b3}
	90	16.92 ± 0.02^{a2}	14.31 ± 0.03^{a4}	14.69 ± 0.08^{a4}	19.41 ± 0.23^{a1}	16.94 ± 0.04^{a2}	16.17 ± 0.06^{a3}
$C_{18:1}$	1	12.37 ± 0.11^{d3}	11.55 ± 0.05^{d4}	11.73 ± 0.13^{d4}	14.44 ± 0.11^{e1}	13.26 ± 0.06^{d2}	13.26 ± 0.06^{d2}
	15	13.00 ± 0.07^{c4}	12.86 ± 0.16^{c4}	13.53 ± 0.03^{c34}	15.80 ± 0.23^{d1}	14.14 ± 0.11^{c23}	14.51 ± 0.28^{c2}
	30	15.95 ± 0.12^{b2}	13.55 ± 0.29^{bc5}	14.10 ± 0.09^{b45}	18.74 ± 0.21^{c1}	14.72 ± 0.19^{b34}	15.04 ± 0.02^{bc3}
	60	16.15 ± 0.02^{b2}	14.25 ± 0.11^{b4}	14.37 ± 0.19^{b4}	20.39 ± 0.02^{b1}	15.65 ± 0.01^{a3}	15.25 ± 0.04^{b3}
	90	16.85 ± 0.16^{a2}	15.07 ± 0.04^{a4}	14.92 ± 0.05^{a4}	21.90 ± 0.13^{a1}	16.05 ± 0.03^{a3}	15.99 ± 0.08^{a3}
$C_{18:2}$	1	0.47 ± 0.02^{e}	0.45 ± 0.02^{c}	0.47 ± 0.01^{d}	0.45 ± 0.01^{d}	0.42 ± 0.03^{c}	0.42 ± 0.03^{c}
	15	0.72 ± 0.01^{d23}	0.78 ± 0.02^{b12}	0.80 ± 0.01^{c1}	0.74 ± 0.01^{c123}	0.70 ± 0.01^{b3}	0.70 ± 0.01^{b3}
	30	0.87 ± 0.01^{c1}	0.87 ± 0.01^{a1}	0.89 ± 0.00^{b1}	0.82 ± 0.01^{c2}	0.87 ± 0.01^{a1}	0.87 ± 0.01^{a1}
	60	0.95 ± 0.01^{b1}	0.92 ± 0.00^{a12}	0.93 ± 0.00^{a12}	0.94 ± 0.01^{b12}	0.91 ± 0.01^{a1}	0.93 ± 0.01^{a12}
	90	1.06 ± 0.02^{a1}	0.91 ± 0.00^{a2}	0.93 ± 0.00^{a2}	1.07 ± 0.03^{a1}	0.91 ± 0.02^{a2}	0.92 ± 0.01^{a2}

[a–e]Means with different letters were significantly different among storage periods within the rows each cell ($P < 0.05$); [1–5]Means with different numbers were significantly different among cheese samples within the rows of the similar ripening period ($P < 0.05$); GR: raw goats' milk cheese; GM: pasteurized and mesophilic culture added goats' milk cheese; GT: pasteurized and thermophilic culture added goats' milk cheese; CR: raw cows' milk cheese; CM: pasteurized and mesophilic culture added cows' milk cheese; CT: pasteurized and thermophilic culture added cows' milk cheese.

[A] Mean values (±SD) of three replicates.

Lactobacillus and *Lactococcus* are specific for the short chain fatty acids (Prieto, Franco, Prieto, Bernardo, & Carballo, 2002). Cheeses made with and without starter culture had similar capric acid throughout storage ($P > 0.05$).

Generally, the concentration of butyric, caproic and caprylic acids were low in all experimental Urfa cheeses, a display of the low lipolytic activity from the starter and non starter microorganisms. Therefore, rancid flavour was not noticed in the Urfa cheeses during ripening.

Lauric (C_{12}) acid level of goats' milk cheese was significantly ($P < 0.001$) higher than cows' milk cheese at all ages. However, the myristic (C_{14}) acid level of caprine milk cheese was significantly ($P < 0.0001$) lower than in bovine milk cheese throughout storage. Pasteurization of milk prior to cheese-making significantly ($P < 0.001$) reduced the concentration of lauric and myristic acid of cheese during storage. Cheeses made with and without starter culture had similar lauric acid during ripening ($P > 0.05$). However, cheese produced without starter bacteria had significantly higher myristic acid value than cheese produced with starter culture, while cheese made with mesophilic starter culture had similar myristic acid content with its thermophilic counterpart at all ages ($P > 0.05$).

Regardless of milk treatment and starter culture, the long chain FFAs (C_{16}–$C_{18:1}$) concentrations were significantly ($P < 0.001$) higher in the cows' milk cheese compared to those found in the goats' milk cheese. However, there was no statistically significant difference ($P > 0.05$) between cows' and goats' milk cheese for linoleic acid ($C_{18:2}$). Similar results were observed by Mallatou et al. (2003) for cows' and goats' milk Teleme cheese. Raw milk fresh Urfa cheese (1 d old cheese) had significantly similar stearic (C_{18}) and linoleic ($C_{18:2}$) acids to pasteurized milk ones. On the other hand, palmitic, stearic, oleic and linoleic acids content of raw milk cheese was significantly ($P < 0.001$) higher than pasteurized milk cheese at 90 d. Regardless of milk species, cheeses made with and without starter culture had similar palmitic (C_{16}) acid during ripening ($P > 0.05$). Cheese made with mesophilic culture had sim-

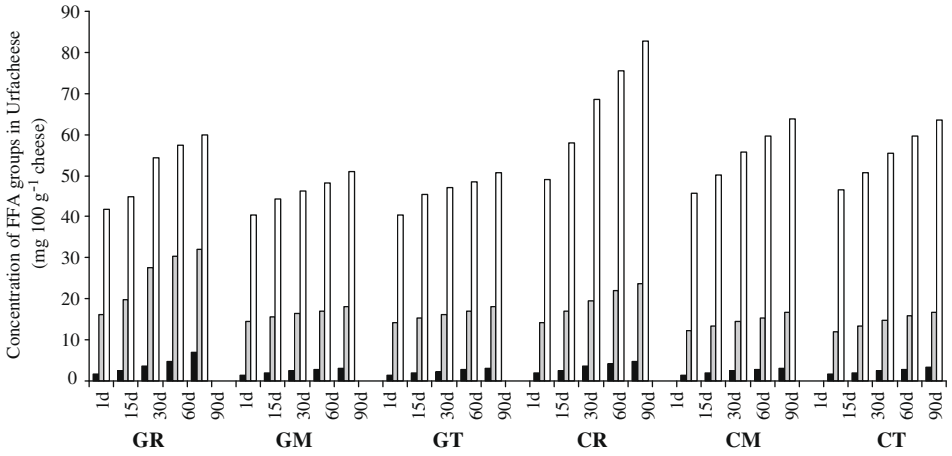

Fig. 2. Short (C_4–C_8), medium (C_{10}–C_{14}) and long (C_{16}–$C_{18:2}$) chain FFA of Urfa cheese samples at 1, 15, 30, 60 and 90 days. Values correspond to the mean of three trials. (■) C_4–C_8 (▒) C_{10}–C_{14} (□) C_{16}–$C_{18:2}$.

Table 3
Relative concentrations of short, medium and long chain FFA (% of total) in Urfa cheese during storage.

Parameters	Age (days)	GR	GM	GT	CR	CM	CT
SCFA as % of total FFAs	1	2.9	2.7	2.6	2.9	2.5	2.6
	15	3.6	3.2	3.2	3.3	2.9	3.0
	30	4.4	3.7	3.6	3.8	3.3	3.5
	60	5.2	4.0	4.1	4.0	3.5	3.6
	90	7.0	4.2	4.3	4.3	3.7	4.0
MCFA as % of total FFAs	1	27.1	25.7	25.4	21.7	20.4	19.8
	15	29.5	25.3	24.4	21.8	20.5	20.3
	30	32.1	25.2	24.7	21.3	20.1	20.4
	60	32.8	25.1	25.0	21.6	19.7	20.2
	90	32.5	25.2	25.2	21.4	19.8	20.0
LCFA as % of total FFAs	1	70.0	71.6	72.0	75.4	77.1	77.6
	15	67.0	71.6	72.3	74.9	76.6	76.7
	30	63.5	71.1	71.7	74.9	76.6	76.1
	60	62.0	70.0	70.9	74.4	76.8	76.2
	90	60.6	70.5	70.4	74.4	76.5	75.9

SCFA: short chain fatty acids (C_4–C_8); MCFA: medium chain fatty acids (C_{10}–C_{14}); LCFA: long chain fatty acids (C_{16}–$C_{18:2}$); GR: raw goats' milk cheese; GM: pasteurized and mesophilic culture added goats' milk cheese; GT: pasteurized and thermophilic culture added goats' milk cheese; CR: raw cows' milk cheese; CM: pasteurized and mesophilic culture added cows' milk cheese; CT: pasteurized and thermophilic culture added cows' milk cheese.

Table 4
Sensory evaluation of 90 day-old cheese samples[A].

Cheese samples	Flavour (10)[B]	Body-texture (5)[B]	Colour-appearance (5)[B]	Saltiness (5)[B]	Total (25)[B]
GR	8.97 ± 0.05^{a}	4.56 ± 0.07^{a}	4.02 ± 0.04^{ab}	3.45 ± 0.07^{a}	20.99 ± 0.10^{a}
GM	8.47 ± 0.05^{bc}	4.04 ± 0.07^{bc}	3.79 ± 0.06^{bc}	3.22 ± 0.04^{ab}	19.52 ± 0.06^{bc}
GT	9.05 ± 0.03^{a}	4.29 ± 0.06^{ab}	4.18 ± 0.04^{a}	3.35 ± 0.05^{a}	20.87 ± 0.11^{a}
CR	8.65 ± 0.05^{b}	3.86 ± 0.06^{c}	3.95 ± 0.05^{abc}	3.23 ± 0.06^{ab}	19.69 ± 0.11^{b}
CM	8.27 ± 0.05^{c}	3.23 ± 0.04^{e}	3.70 ± 0.08^{c}	2.65 ± 0.01^{c}	17.86 ± 0.23^{d}
CT	8.47 ± 0.05^{bc}	3.54 ± 0.06^{d}	4.05 ± 0.05^{ab}	3.02 ± 0.03^{b}	19.08 ± 0.03^{c}

[a–e]Means with different letters were significantly different among cheese samples within the column ($P < 0.05$); GR: raw goats' milk cheese; GM: pasteurized and mesophilic culture added goats' milk cheese; GT: pasteurized and thermophilic culture added goats' milk cheese; CR: raw cows' milk cheese; CM: pasteurized and mesophilic culture added cows' milk cheese; CT: pasteurized and thermophilic culture added cows' milk cheese.

[A] Arithmetic mean of three replicates.

[B] Numbers in the parantheses are the maximum attainable scores.

ilar stearic, oleic and linoleic acids level with its thermophilic counterpart at all ages ($P > 0.05$). Similar results were observed by Katsiari et al. (2009). After 15 d, cheese produced without starter bacteria had significantly higher ($P < 0.05$) stearic and oleic acids value than cheeses produced with starter culture.

The FFA content of all cheeses increased considerably during ripening; however, the ratio of liberation of individual FFAs was different (Fig. 2). The percentage of short chain fatty acids (SCFA) (C_4–C_8) was increased during ripening for all cheeses. This could be due to the specificity of both milk lipoprotein lipase and starter lipases towards FFA located at the positions *sn*-1 and 3 of the triglyceride. SCFA are predominantly esterified at the *sn*-3 position (Juarez, 1986). Increase rate of SCFA was more remarkable for GR cheese during ripening (Table 3). The percentage of medium chain fatty acids (MCFA) (C_{10}–C_{14}) increased for GR cheese, contrary to this, long chain fatty acids (LCFA) (C_{16}–$C_{18:2}$) of this cheese decreased during storage. This result may be attributed to the higher capric acid content of GR cheese. However, percentage MCFA and LCFA of other cheeses remained quite constant. Despite the quantitative importance of MCFA and LCFA, they are not the main contributors to cheese flavour (Freitas & Malcata, 1998). Myristic acid was the predominant MCFA. Palmitic acid was the main LCFA in the all experimental cheeses.

SCFA content of cows' milk cheese was statistically similar to goats' milk cheese during the first 30 d of storage (Fig. 2). After this time, goats' milk cheese had significantly ($P < 0.01$) higher SCFA value than cows' milk cheese. Cheese made from goats' milk had higher MCFA value than cheese made from cows' milk at all ages ($P < 0.001$). Contrary to this, LCFA concentration of cows' milk cheese was statistically higher than goats' milk cheese at the same period ($P < 0.001$). The differences of fatty acids profile between caprine milk cheese and bovine milk cheese can be partly explained by differences of regulation of mammary cells between goat' and cows' species (Lucas, Rock, Agabriel, Chilliard, & Coulon, 2008). Pasteurization of milk prior to cheese-making significantly ($P < 0.001$) reduced the concentration of SCFA, MCFA and LCFA at 1, 15, 30, 60 and 90 d. The concentration of all FFAs in pasteurized milk Cheddar cheese was lower than raw milk cheese (McSweeney et al., 1993). Regardless of milk species, cheese made with mesophilic starter bacteria had similar SCFA, MCFA and LCFA content to its thermophilic counterpart at all ages ($P > 0.05$). Cheeses made without starter culture had higher SCFA and MCFA during ripening ($P > 0.05$). After 15 d, starter culture added cheese had significantly lower ($P < 0.05$) LCFA than cheese with no starter culture.

3.3. Sensory evaluations

The sensory evaluation of 90 day-old cheese samples are shown in Table 4. Flavour and total scores of GR and GT cheeses were significantly higher than the other cheeses. Cheeses made from goats' milk had significantly higher flavour, body-texture, saltiness and total scores than cows' milk cheeses ($P < 0.001$). This may be due mainly to higher SCFA content of caprine milk cheese, which has significant impact on the development of the characteristic flavour and aroma of the cheese. Pasteurization of milk prior to cheese-making negatively affected the organoleptic properties of cheese ($P < 0.001$). Colour and appearance properties of cheese were not influenced by milk species and pasteurization ($P > 0.05$).

Cheeses made with and without starter culture had significantly similar body and texture properties at 90 d ($P > 0.05$). This could be due to the similar pH of the cheeses at the end of ripening, which has significant impact on the development of the textural properties of cheese. Cheeses made with mesophilic bacteria had significantly lower flavour and colour-appearance scores, but similar saltiness and total points, to its thermophilic counterpart. Generally, cheeses made with thermophilic starter culture had similar sensory properties to cheeses made without starter culture (raw milk cheeses) ($P > 0.05$).

4. Conclusions

Parallel to the increase of the acid degree value of the fat values and total FFAs of the cheeses, an increase in the individual contents of each one of the free fatty acids in GR, GM, GT, CR, CM and CT cheese was observed throughout ripening. The ADVs of the cows' milk cheeses were significantly ($P < 0.05$) higher during storage, except after 90 d of ripening. Total FFA contents of cows' milk cheese were significantly ($P < 0.001$) higher than that of goats' milk cheese throughout ripening, whereas goats' milk cheese flavour was higher ($P < 0.05$) than cows' milk cheese. The results show that pasteurization of milk prior to cheese-making has a negative influence not only on the level of lipolysis throughout ripening, but also on the relative amounts of short chain FFAs and sensory properties of the cheeses. Regardless of milk species, flavour of thermophilic culture added cheeses was higher than mesophilic counterpart, but no significant differences in total FFAs were found among the starter cultures. Cheese produced without starter bacteria had significantly higher lipolysis than cheese produced with starter bacteria, while cheese made with thermophilic starter culture had similar organoleptic scores to cheese made without starter culture.

The percentages of MCFA and LCFA were higher than SCFA at all ages. However, the relative increase was only determined in short chain FFAs. The highest relative increases of SCFA were in GR cheese at the end of storage. Palmitic ($C_{16:0}$), and oleic acids ($C_{18:1}$) were the most abundant FFA in fresh and ripened Urfa cheese. The results clearly demonstrate that restricted lipolysis occurred in pasteurized and starter added milk Urfa cheese during ripening as compared to that made from raw milk. Future studies should be focused on overcoming this drawback. In the production of Urfa cheese, addition of lipase enzyme may be considered to enhance its lipolysis level and, therefore, flavour characteristics.

References

Abd El-Salam, M. H., Alichanidis, E., & Zerfiridis, G. K. (1993). Domiati and feta type cheese. In P. F. Fox (Ed.), *Cheese: Chemistry, physics and microbiology* (pp. 301–335). London, UK: Elsevier Applied Science.

Atasoy, A. F., & Türkoğlu, H. (2008). Changes of composition and free fatty acid content of Urfa cheeses (a white brined Turkish cheese) during ripening: Effects of heat treatments and starter cultures. *Food Chemistry, 110*, 598–604.

Attaie, R., & Richter, R. L. (1996). Formation of volatile free fatty acids during ripening of Cheddar-like hard goat cheese. *Journal of Dairy Science, 79*, 717–724.

Buffa, M., Guamis, B., Pavia, M., & Trujillo, A. T. (2001). Lipolysis in cheese made from raw, pasteurized or high-pressure-treated goats' milk. *International Dairy Journal, 11*, 175–179.

Chilliard, Y., Selselet-Attou, G., Bas, P., & Morand-Fehr, P. (1984). Characteristics of lipolytic system in goat milk. *Journal of Dairy Science, 67*, 2216–2223.

Collins, Y. F., McSweeney, P. L. H., & Wilkinson, M. G. (2003). Lipolysis and free fatty acid catabolism in cheese: A review of current knowledge. *International Dairy Journal, 13*, 841–866.

Driessen, F. M. (1989). Heat inactivation of lipases and proteinases (indigenous and bacterial). In *Heat induced changes in milk. Bulletion* (Vol. 238, pp. 71–93). Brussels: International Dairy Fedaration.

Fox, P. F., Lucey, J. A., & Cogan, T. M. (1990). Glycolysis and related reactions during cheese manufacture and ripening. *Critical Reviews in Food Science and Nutrition, 29*, 237–253.

Franco, I., Prieto, B., Urdiales, R., Fresno, J. M., & Carballo, J. (2001). Study of the biochemical changes during ripening of Ahumado de Aliva cheese: A Spanish traditional variety. *Food Chemistry, 74*, 463–469.

Freitas, A. C., & Malcata, F. X. (1998). Lipolysis in Picante cheese: Influence of milk type and ripening time on free fatty acid profile. *Lait, 78*, 251–258.

Garcia-Lopez, S., Echeverria, E., Tsui, I., & Balch, B. (1994). Changes in the content of conjugated linoleic acid (CLA) in processed cheese during processing. *Food Research International, 27*, 61–64.

Goncu, A., & Alpkent, Z. (2005). Sensory and chemical properties of white pickled cheese produced using kefir, yoghurt or a commercial cheese cultures as a starter. *International Dairy Journal, 15*, 771–776.

Grappin, R., & Beuvier, E. (1998). Possible implications of milk pasteurization on the manufacture and sensory quality of ripened cheese. *International Dairy Journal, 8*, 751–761.

Herreros, M. A., Arenas, R., Sandoval, M. H., Castro, J. M., Fresno, J. M., & Tornadijo, M. E. (2007). Effect of addition of native cultures on characteristics of Armada cheese manufactured with pasteurized milk: A preliminary study. *International Dairy Journal, 17*, 328–335.

Juarez, M. (1986). Physico-chemical characteristics of goats' milk as distinct from those of cow's milk. In *International dairy federation. Bulletion* (Vol. 202, pp. 54–67). Brussels: International Dairy Federation.

Katsiari, M. C., Kondyli, E., & Voutsinas, L. P. (2009). The quality of Galotyri-type cheese made with different starter cultures. *Food Control, 20*, 113–118.

Lucas, A., Rock, E., Agabriel, C., Chilliard, Y., & Coulon, J. B. (2008). Relationships between animal species (cow versus goat) and some nutritional constituents in raw milk farmhouse cheeses. *Small Ruminant Research, 74*, 243–248.

Mallatou, H., Pappa, E., & Massouras, T. (2003). Changes in free fatty acids during ripening of Teleme cheese made with ewes', goats', cows' or a mixture of ewes' and goats' milk. *International Dairy Journal, 13*, 211–219.

McSweeney, P. L. H., Fox, P. F., Lucey, J. A., Jordan, K. N., & Cogan, T. M. (1993). Contribution of the indigenous microflora to the maturation of Cheddar cheese. *International Dairy Journal, 3*, 613–634.

Pavia, M., Trujillo, A. J., Sendra, E., Guamis, B., & Ferragut, V. (2000). Free faty acid content of Manchego-type cheese salted by brine vacuum impregnation. *International Dairy Journal, 10*, 563–568.

Perotti, M. C., Bernal, S. M., Meinardi, C. A., & Zalazar, C. A. (2005). Free fatty acid profiles of Reggianito Argentino cheese produced from different starters. *International Dairy Journal, 15*, 1150–1155.

Prieto, B., Franco, I., Prieto, J. G., Bernardo, A., & Carballo, J. (2002). Proteolytic and lipolytic changes during ripening of leon raw cows' milk cheese, a Spanish traditional variety. *International Journal of Food Science and Technology, 37*, 661–671.

Renner, E. (1986). Milchpraktium. Fachgebiet Milchwissenchaft, Justic-Liebig-Universitat Giessen.

Snedecor, G. W., & Cochran, W. G. (1989). *Statistical methods*. Iowa State University Press/AMES.

Sousa, M. J., & Malcata, F. X. (1997). Ripening of ovine milk cheeses: Effects of plant rennet, pasteurization, and addition of starter on lipolysis. *Food Chemistry, 59*, 427–432.

Sukhija, P. S., & Palmquist, D. L. (1988). Rapid method for determination of total fatty acid content and composition of feedstuffs and feces. *Journal of Agricultural and Food Chemistry, 36*, 1202–1206.

Turkish Standards (TS). (1978). *Determination of fat in cheese*. TS 3046. Ankara, Türkiye: Turkish Standards Institute.

Turkish Standards (TS). (1989). *White cheese standard*. TS 591. Ankara, Türkiye: Turkish Standards Institute.

Urbach, G. (1997). The flavour of milk and dairy products II. Cheese: Contribution of volatile compounds. *International Journal of Dairy Technology, 50*, 79–89.

Vlaemynck, G. (1992). Study of lipolytic activity of the lipoprotein lipase in lunch cheese of the Gouda type. *Milchwissenschaft, 47*, 164–167.