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Production of brined soft cheese from frozen ultrafiltered sheep's milk. Part 2 Compositional, physicochemical, microbiological and organoleptic properties of cheese

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Skimmed milk was concentrated by ultrafiltration (UF) to 19·37, 23·40 or 26·49% total solids (TS), mixed with cream to prepare recombined UF concentrates (R-UFCS) with 30·40, 33·95 or 36·90% TS, respectively, and then frozen and stored at −20°C. After 2, 4 and 6 months frozen storage, the concentrates were fast-thawed and used directly for making brined soft cheese generally following the traditional procedure of Feta cheese. The compositional, physicochemical, microbiological and organoleptic properties of UF cheeses were compared with those of control Feta cheese. The UF cheeses had similar pH, higher protein and calcium, but lower fat, moisture and yield values than the control cheese. The UF cheeses underwent greater proteolysis, but less lipolysis than the control cheese. The UF cheeses had a sandy texture, received lower scores for appearance, were harder and more acidic in flavour, and ranked lower in overall quality than the control cheese. The higher calcium content was apparently responsible for the sandy texture and the lower overall quality of the UF cheeses. Because of the inferior quality of the UF cheeses and the lack of a significant increase in yield, the production of brined soft cheese from frozen concentrated by UF sheep's milk does not seem to be commercially applicable.

INTRODUCTION

Greece ranks fifth in the world in total number of sheep. Total sheep's milk production was 581 760 t in 1981, representing about 35% of the total milk production of the country. The availability of sheep's milk is highly seasonal, since the lactation period of sheep lasts only 5–6 months. Thus, dairies using sheep's milk encounter a fundamental problem in trying to achieve uniform operation throughout the year. Any mechanism that would distribute work in cheese factories more evenly throughout the year would be of considerable importance, technically as well as economically (Alichanidis *et al.*, 1981). A solution to the above problem may be the concentration of sheep's milk by ultrafiltration (UF) during peak production, followed by freezing and storage. When required, the milk concentrate could be thawed and made into cheese. The effects of concentration of sheep's milk by UF and long-term frozen storage on some of its physicochemical, microbiological and physical stability properties have been reported (Voutsinas *et al.*, 1995). The objective of the present study was to determine the compositional, physicochemical, microbiological and organoleptic properties of brined soft cheese made from frozen UF sheep's milk.

MATERIALS AND METHODS

Preparation and handling of UF concentrates

The preparation, packaging, freezing, storage and thawing of the recombined UF concentrates from sheep's milk were described by Voutsinas *et al.* (1995).

Cheesemaking

Cheese was manufactured at the pilot plant of the Institute on a 20 kg (for UF milk) or 40 kg (for control milk) scale. Control and experimental cheeses were made generally by conventional Feta cheese manufacturing techniques and equipment. The following procedure was used in the production of control cheese. The milk (stored at 3°C for 1 day) was repasteurised at 63°C for 15 min in a 56-litre double-walled stainless-steel vat, cooled to 35°C, inoculated with 0·5% starter culture (Visbyvac Joghurt 7, Laboratorium Wiesby

GmbH & Co. KG, Niebull, Germany) and left to ripen for 15 min. Then, 0·47 g (2·35 g per 100 kg milk) powdered calf rennet (HA-LA, Hansen's Laboratorium, Copenhagen, Denmark), dissolved in cold water, was added and mixed well. Coagulation was achieved in about 45–50 min at 35°C. After coagulation, the curd was cut into cubes of 2–3 cm size, and left to rest for 10 min. The sliced curd was then transferred into two perforated rectangular moulds for draining. The moulds were turned upside-down four times during the first 3 h of draining and then left at rest for a further 3 h at 20°C to complete draining. Then, the curd from each mould was cut in four blocks, 20 × 14 × 8 cm, and weighing about 2·3–2·5 kg, which were placed individually into cans and granular recrystallised NaCl, equivalent to 2·5% of the weight of the cheese, added. After 1 day, the cans were filled with a 7% NaCl solution (brine) and sealed. The lid of the can had a hole which was closed, air-tightly, with a plastic cap which was opened during ripening, when needed, to allow the release of gases. The cans remained in the ripening room (18°C) until the pH and the moisture of the cheese decreased below values 4·6 and 56%, respectively. Then, the cans were transferred into a storage room (3–4°C) and held for up to 6 months.

For the experimental UF cheeses, the following modifications to the conventional procedure were made: (i) if the UF concentrate had been heated after concentration, it was warmed to 40°C before cheesemaking; otherwise, it was heated to 70°C for 5 min and then cooled to 40°C; (ii) 3% starter culture was added and the milk allowed to ripen until its pH decreased to about 6·00 (it required 60–90 min); (iii) the curd was cut into cubes of 1–1·5 cm size; and (iv) when UF cheeses were made from recombined concentrates with 36·90% TS stored frozen for 4 months or from all concentrates frozen for 6 months, the cans were filled with the corresponding defatted whey containing 6% NaCl and not with a 7% NaCl brine.

Samples (one can) from each group of cheeses were taken for analyses at 0, 15, 60, 120 and 180 days after cheesemaking. At 0 days, samples were taken before salting. The reported values are the means of two cheeses (two replicates per milk treatment).

Composition and physicochemical properties

Samples of whey and cheese were examined for pH (pH-meter, Metrohm, AG, Switzerland), fat (Gerber method; BSI, 1955), protein (Kjeldahl method; IDF, 1986), titratable acidity of whey (Dornic method), moisture (IDF, 1958), sodium chloride (Kosikowski, 1978), calcium (Pearce, 1977) and lactose content (Acton, 1977). The yield of cheese was expressed as kg cheese per 100 kg milk (the quantity of UF concentrate used in cheesemaking was first converted to the corresponding quantity of control milk on the basis of protein content (Boyazoglu & Veinoglou, 1983). Cheese yield was also expressed on a 55% moisture content ($yield_{55}$).

Proteolysis and lipolysis

Total N (TN) of cheese and fractions thereof was determined by the Kjeldahl method (IDF, 1986) using the Kjeldatherm digestion system KT 20S and Vapodest distillation system four titrimatic (C. Gerhardt GmbH & Co KG, Bonn, Germany) equipped with an endpoint titration system ETS 822 (Radiometer Copenhagen, Denmark). Water-soluble N (WSN) and N soluble in 12% TCA (TCA-SN) were determined in aliquots of the same cheese extract prepared as described by Kuchroo and Fox (1982), except that a Sorvall Omni-mixer (Dupont Company, Newton, CT, USA) was used for homogenisation and the supernatant obtained was filtered through No. 42 filter paper.

Lipolysis was determined by measuring the acid degree value (ADV) as described by Deeth and Fitz-Gerald (1976). Samples were prepared by mixing 5 g of cheese with 37·5 ml of 2% sodium citrate at 50°C in a Sorvall Omni-mixer at setting 3 for 1 min, and then at setting 7 for 2 min. The ADV was determined on 35 ml samples of this extract.

Microbiological analyses

The total bacteria (TVC) and coliforms of cheese samples (cfu/g) were determined using the pour-plate method (APHA, 1967), the former on plate count agar (Merck) at 32°C for 3 days, the latter on desoxycholate lactose agar (Merck) at 32°C for 1 day.

Organoleptic evaluation

The quality of the cheeses was evaluated after 60, 120 and 180 days of ripening by a five-member trained panel familiar with Feta cheese for appearance, body and texture, and flavour (odour and taste) using a 10-point scale, 1 being the worst and 10 the best quality. Dominating importance was given to the attributes of body and texture, and flavour over the appearance, as advised by the IDF (1987). Thus, the scores obtained for these two attributes were multiplied by 4 and 5, respectively. Total score was obtained by adding the scores of the three attributes. An excellent cheese received a total score of 100. Panel members were also instructed to report any defects in appearance (e.g. dry, wet, cracks), body and texture (e.g. soft, granular, crumbly, spongy, pasty, hard) or flavour (e.g. acid, rancid, bitter, sharp, yeasty, fermented, and salty), detected according to IDF (1987) guide for the sensory evaluation of cheese.

Statistical analysis

The data were analysed by analysis of variance using Statgraphics (Statistical Graphics Corp., Rockville, MD, USA). At each storage time studied the experimental means were compared with the control mean and between themselves. When significant ($P < 0.05$) differences were found among treatments, means were separated by Tukey's test (Steel & Torrie, 1960).

RESULTS AND DISCUSSION

Cheese whey and fresh cheese curd

The mean values for the pH, acidity, fat and protein of the various wheys are given in Table 1. The control cheese whey had a significantly ($P < 0{\cdot}05$) higher pH and lower acidity than the UF cheese wheys. Fat and protein contents in the wheys increased with increasing concentration of the milk and the UF cheese wheys contained significantly ($P < 0{\cdot}05$) higher levels of fat and protein than the control whey. Green *et al.* (1981) and Rao and Renner (1988*b*) also observed much higher contents of fat and protein in the whey from UF cheese than in whey from control Cheddar cheese. The pH of the l-day-old UF cheeses was higher than that of the control, in agreement with the reports of Mocquot (1979) and Rao and Renner (1988*b*). However, there were no significant ($P > 0{\cdot}05$) differences in pH between control and UF cheeses 1 and 18 days after manufacture (Table 1). The control curd had a significantly ($P < 0{\cdot}05$) higher moisture content than the UF curds at day 1, but by day 18, the differences in moisture had been narrowed and became non-significant ($P > 0{\cdot}05$), although the control cheese still had the highest moisture content. Boyazoglu and Veinoglou (1984) reported that the moisture content of young UF Feta was higher than that of the control, because for the former the curd was not cut and there was little whey drainage. The lower moisture content in the UF cheeses compared with the control found in this study is attributed to the cutting of the UF curd into smaller particles (1·0–1·5 cm) which was considered necessary for achieving good fusion of curd particles, especially in cheesemaking from highly concentrated milks.

Compositional and physicochemical properties of cheeses

Kosikowski (1979) studied the characteristics of cheese from water-reconstituted UF retentates, employing Cheddar methodology and found that the cheese had a pleasing, mild, sweet flavour, and optimum pH attainment was generally normal. Goat's milk is concentrated by UF on a commercial scale in France and the concentrate is stored frozen, thus enabling the cheese industry to continue production of goat's cheese throughout the year. When required, the concentrate is thawed, diluted with water and made into cheese. The process is claimed to improve the uniformity of quality (Anon., 1979*a,b*).

In the first series of experiments in this study brined soft cheese of structured Feta type was manufactured using concentrates reconstituted with tap water to 26% TS. However, a problem was encountered with the pH of the cheese which did not decrease below the critical value of 4·6 during ripening. The average pH of the UF cheeses was 5·15, 4·80 and 4·90 after 1, 20 and 60 days after cheesemaking, respectively. Kosikowski (1979) also encountered some difficulty in attaining optimum pH in cottage cheese produced from water reconstituted UF milk retentate. In order to solve the problem of the pH of UF cheese, in a second series of experiments structured brined soft cheese was manufactured directly from UF concentrates, i.e. without reconstitution. Table 2 shows that the UF cheeses made from fresh concentrates had higher pH than the control cheese, but significant ($P < 0{\cdot}05$) differences in pH were observed only between the control cheese and that made from the R-UFCS (36·90% TS) at 6 months of age. The UF cheeses made from concentrates stored frozen for 2 months had higher pH values than the control cheese, but the differences were significant only after aging for 4 and 6 months (Table 2). It is also evident from Table 2 that the pH of these UF cheeses was generally higher than the 4·6 which is considered critical for good keeping quality. Higher pH values in UF cheeses than in corresponding controls have also been reported by other investigators (Green *et al.*, 1981; El-Zayat & Omar, 1987; Sharma *et al.*, 1989; Everett & Jameson, 1993) for various cheese types. The higher pH in the UF cheeses than in the controls found in this study is attributed to two factors: (i) The increased buffering capacity of the UF concentrates compared with milk, which resulted in a slower decline in pH (Green *et al.*, 1981); as can be seen from Table 3, the protein and calcium contents of the UF cheeses were higher than those of the control cheese, and (ii) The less lactose retained in the fresh UF curds because of their significantly lower moisture content compared with the control (Table 1). It was found that the 1-day-old UF cheeses contained 41·6–49·2% less lactose than the control.

In an attempt to improve the pH of UF brined soft cheese, the cheese made from the recombined UF

Table 1. Physicochemical properties of various cheese wheys and young cheeses during ripening (1, 18 days)[a]

Cheese milk[b]	Cheese whey				Young cheese			
	pH	Acidity	Fat	Protein	pH		Moisture (%)	
		(°D)	(%)	(%)	1 day	18 days	1 day	18 days
Control milk	6·36b	14·0a	0·40a	1·61a	4·77	4·50	62·93b	55·80
R-UFCS (30·40% TS)	5·98a	20·5b	1·73b	2·69b	4·86	4·42	56·90a	54·30
R-UFCS (33·95% TS)	5·95a	19·0b	2·14b	3·32c	4·94	4·48	55·63a	54·68
R-UFCS (36·90% TS)	5·94a	21·0b	2·68b	3·61c	4·95	4·53	55·17a	54·12

[a]Means in each column without, or sharing a common following letter did not differ significantly ($P > 0{\cdot}05$).
[b]The UF cheeses were produced directly from the concentrates and the cans were filled with defatted cheese whey.

Table 2. Mean values for pH, moisture, MNFS and fat in sheep's milk brined soft cheeses made from control milk or various UF concentrates (fresh or frozen) during ripening (2, 4 and 6 months)[a]

Duration of frozen storage (months)	Cheese milk[b]	pH			Moisture (%)			MNFS[c] (%)			Fat (%)		
		2 months	4 months	6 months	2 months	4 months	6 months	2 months	4 months	6 months	2 months	4 months	6 months
0	Control milk	4·38	4·28a	4·27a	55·24	55·21	56·30	73·15	72·84	74·07c	24·50	24·25	24·00
	R-UFCS (30·40% TS)	4·42	4·40a	4·38ab	54·44	54·77	55·44	72·11	71·95	72·99c	24·50	23·88	24·00
	R-UFCS (33·95% TS)	4·57	4·55a	4·58ab	54·40	54·28	54·52	70·66	70·94	71·50c	23·00	23·50	23·75
	R-UFCS (36·90% TS)	4·63	4·76a	4·80b	54·89	54·23	53·89	70·82	70·89	70·09c	22·50	23·50	23·13
2	R-UFCS (30·40% TS)	4·56	4·62b	4·68b	53·61	53·62	52·39	70·99	70·52	69·15c	24·50	24·00	24·25
	R-UFCS (33·95% TS)	4·57	4·71b	4·73b	55·28	56·45	57·05	72·16	73·88	74·92c	22·00	22·25	22·50
	R-UFCS (36·90% TS)	4·73	4·80b	4·83b	55·50	54·58	54·02	71·74	70·65	70·50c	22·65	22·75	23·38
4	R-UFCS (30·40% TS)	4·51	4·56ab	4·60a	55·00	54·49	55·18	72·90	72·46	73·35bc	24·50	24·75	24·75
	R-UFCS (33·95% TS)	4·65	4·76b	4·83b	56·48	57·48	55·63	72·89	73·82	71·32b	22·50	22·13	22·00
	R-UFCS[d] (36·90% TS)	4·54	4·43a	4·48a	52·34	52·09	51·84	67·85	67·65	67·21a	22·88	23·00	22·88
6	R-UFCS[d] (30·40% TS)	4·29	4·29a	4·25a	51·66	51·76	51·10	68·51	68·14	67·53c	24·50	24·00	24·25
	R-UFCS[d] (33·95% TS)	4·42	4·32a	4·30a	54·47	54·11	54·20	69·80	69·73	69·84c	22·00	22·50	22·50
	R-UFCS[d] (36·90% TS)	4·35	4·39a	4·31a	52·85	51·66	52·44	68·62	67·49	67·21c	23·00	23·50	22·00

[a]Experimental means in each column, regardless of the storage time, bearing a common following letter with the control mean did *not* differ significantly ($P > 0{\cdot}05$) from it; experimental means in each column and at the same storage time sharing a common following letter did not differ significantly ($P > 0{\cdot}05$).
[b]See footnote *b* to Table 1.
[c]MNFS, moisture in the non-fat substance.
[d]The UF cheeses prepared from these concentrates were pickled in their defatted salted wheys.

Table 3. Mean values for protein, calcium, salt and S/M in sheep's milk brined soft cheeses made from control milk or various UF concentrates (fresh or frozen) during ripening (2, 4 and 6 months)[a]

Duration of frozen storage (months)	Cheese milk[b]	Protein (%)			Ca (mg/100 g)			Salt (%)			S/M[c] (%)		
		2 months	4 months	6 months	2 months	4 months	6 months	2 months	4 months	6 months	2 months	4 months	6 months
0	Control milk	16·1	15·8a	15·8a	310a	313	303	2·75a	2·80	2·83a	4·98a	5·07a	5·02
	R-UFCS (30·40% TS)	16·9	16·9a	16·4a	371ab	337	356	2·81ab	2·92	2·95a	5·15a	5·33a	5·31
	R-UFCS (33·95% TS)	17·3	16·9a	16·9a	405ab	413	388	3·08bc	3·14	3·06a	5·66b	5·78a	5·61
	R-UFCS (36·90% TS)	17·9	17·4a	17·3a	478b	442	438	3·19c	3·15	3·19a	5·81b	5·81a	5·90
2	R-UFCS (30·40% TS)	17·3	17·1a	17·3b	335ab	342	340	2·99a	3·07	2·94ab	5·59a	5·73a	5·61
	R-UFCS (33·95% TS)	17·9	17·4a	17·3b	410ab	443	406	3·02a	3·11	3·04ab	5·36a	5·41a	5·24
	R-UFCS (36·90% TS)	18·6	18·9a	18·5b	424b	455	427	3·14a	3·05	3·14b	5·65a	5·59a	5·81
4	R-UFCS (30·40% TS)	17·4	16·9ab	17·2a	359ab	379	362	3·10b	3·07	3·06a	5·63a	5·63b	5·54
	R-UFCS (33·95% TS)	17·5	16·9ab	17·1a	409ab	459	430	3·12b	3·17	3·05a	5·53a	5·51b	5·48
	R-UFCS[d] (36·90% TS)	20·0	20·1b	20·1b	492b	505	469	2·92ab	2·86	2·93a	5·59a	5·50b	5·65
6	R-UFCS[d] (30·40% TS)	18·2	18·0a	18·1a	346b	348	359	2·59a	2·79	2·66a	5·02a	5·39a	5·20
	R-UFCS[d] (33·95% TS)	19·0	19·0a	18·6a	444ab	430	439	2·99a	2·99	2·99a	5·49a	5·53a	5·53
	R-UFCS[d] (36·90% TS)	19·8	20·1a	19·9a	459b	442	449	2·93a	2·93	2·94a	5·55a	5·69a	5·61

[a]Experimental means in each column, regardless of the storage time, bearing a common following letter with the control mean did not differ significantly ($P > 0{\cdot}05$) from it; experimental means in each column and at the same storage time sharing a common following letter did not differ significantly ($P > 0{\cdot}05$).
[b]See footnote *b* to Table 1.
[c]S/M, salt in moisture.
[d]The UF cheeses prepared from these concentrates were pickled in their defatted salted wheys.

concentrates (R-UFCS) (36·90%) stored frozen for 4 months was pickled in its defatted salted whey and not in an NaCl brine, since whey is a rich source of lactose for fermentation within the cheese through diffusion (Abd El-Salam, 1987). As seen from Table 2, the pH of this cheese was close to that of the control cheese and remained below 4·6 even after 6 months. Consequently, the UF cheeses made from all R-UFCS stored frozen for 6 months were pickled in their defatted salted wheys. These UF cheeses had pH values similar to the control during the 6 months of ripening. The average residual lactose content in these UF cheeses was 0·47% after ripening for 2 months.

The moisture content of the control cheese was generally higher than that of the UF cheeses made from either fresh or frozen concentrates (Table 2). However, there were no significant ($P > 0·05$) differences in moisture between the control and the UF cheeses during ageing. Green *et al.* (1981) reported that UF Cheddar cheese contained a higher proportion of moisture than normal cheese, presumably because of its higher protein content. On the other hand, Boyazoglu and Veinoglou (1984) reported that the moisture content of mature UF cast Feta cheese was higher than in controls due to the water-binding capacity of the whey proteins. It should be noted that, in that study, the UF Feta cheese had a lower protein content than the control. The slightly lower moisture content of the UF cheeses in this study compared with the control cheese could be attributed to the decrease in the cut size of the coagulum from 2–3 (control) to 1–1·5 cm. It is also evident from Table 2 that, generally, the UF cheeses prepared from concentrates stored frozen for 6 months contained less moisture than the corresponding cheeses made from concentrates frozen for a shorter period. The lower moisture content of these cheeses might be due to changes in the casein molecules and in the structure of the casein micelles during freezing (Fuster, 1970; Alekseeva *et al.*, 1973), which might influence the water-holding capacity of caseins.

The MNFS (moisture in the non-fat substance) value of the control cheese was higher than those of the cheeses made from either fresh or frozen UF concentrates (Table 2), but generally these differences were not significant ($P > 0·05$). Green *et al.* (1981) also reported that there was no systematic variation in the MNFS of Cheddar cheese with increasing CF of the milk from 1·0 to 4·0. Table 2 also shows that the UF cheeses contained less fat than the control cheese, and that the fat content of UF cheeses decreased as the CF increased. However, no significant ($P > 0·05$) differences in the fat content were observed between the control and the cheeses made from frozen UF concentrates. Lower fat content in UF cheese than in controls have also been reported by other investigators (Green *et al.*, 1981; Veinoglou & Boyazoglu 1982; Boyazoglu & Veinoglou, 1984; Kim & Olson, 1989) for various cheese types.

The UF cheeses made from frozen concentrates contained a higher proportion of protein than the control cheese (Table 3), but the differences generally were not significant. A higher protein content in UF cheeses than in controls has also been reported by other authors (Green *et al.*, 1981; El-Zayat & Omar, 1987), who attributed it to the greater recovery of protein from the milk in the cheese in the former case. On the other hand, Veinoglou and Boyazoglu (1982) and Boyazoglu and Veinoglou (1984) found lower protein values in UF cast Teleme and Feta cheeses, respectively, than in their controls. It is also evident from Table 3 that the protein content of the UF cheeses was higher when the cans were filled with salted whey than with an NaCl brine which might be attributed to the transfer of soluble nitrogen compounds from the whey in the cheese by diffusion. Table 3 shows that the UF cheeses had a higher calcium content than the control cheese, but the differences were significant ($P < 0·05$) only between the control cheese and the cheese made from the frozen R-UFCS with the highest TS content (36·90%) at 2 months of age. A higher calcium content in UF cheeses than in controls has also been reported by Mocquot (1979) and Everett and Jameson (1993). The higher level of calcium in the UF cheeses found in this study is attributed to their higher protein content and to the removal of less whey (Everett & Jameson, 1993).

Table 3 indicates that the UF cheeses generally contained more salt than the controls, but the differences generally were not significant ($P > 0·05$). Veinoglou and Boyazoglu (1982) also found a higher salt content in UF than in the control Teleme cheeses. Green *et al.* (1981) and Boyazoglu and Veinoglou (1984) reported almost similar levels of salt for UF and control Cheddar and Feta cheeses, respectively. The higher salt content in the UF brined soft cheeses, compared with the control, may be attributed to their higher protein content (Table 3). Increased protein could contribute more binding sites for the salt, thus increasing salt retention in the curd (McGregor & White, 1990). It is also evident from Table 3 that the UF cheeses had higher salt in moisture (S/M) values than the control cheese. However, the differences in S/M values generally were not significant. Veinoglou and Boyazoglu (1982) found slightly higher S/M values in UF than in control Teleme cheese. Green *et al.* (1981) reported that there was no systematic variation in the level of S/M in Cheddar cheese with milk concentration.

Proteolysis of cheeses

The extent of proteolysis in the cheeses, monitored by measuring the levels of WSN and TCA-SN produced during cheese aging, is shown in Table 4. The WSN and TCA-SN increased continuously in all cheeses during ageing. The UF cheeses prepared from fresh or frozen concentrates generally had higher levels of WSN and TCA-SN than the control cheese, which indicates that protein breakdown was more pronounced in the UF cheeses. Generally, the differences in WSN were not significant up to 6 months of age. Higher levels of WSN in UF cast Feta and Kareish cheeses than in the controls have also been reported by Boyazoglu and

Table 4. Mean values for WSN, TCA-SN and ADV in sheep's milk brined soft cheeses made from control milk or various concentrates (fresh or frozen) during ripening (2, 4 and 6 months)[a]

Duration of frozen storage (months)	Cheese milk[b]	WSN (%TN)			TCA-SN (%TN)			ADV (meq KOH/100 g fat)		
		2 months	4 months	6 months	2 months	4 months	6 months	2 months	4 months	6 months
0	Control milk	13·1	15·8a	17·4a	11·6	12·8	14·2	1·25	1·41	1·89
	R-UFCS (30·40% TS)	17·1	18·1a	18·4a	13·9	14·6	15·4	1·27	1·45	1·75
	R-UFCS (33·95% TS)	16·7	18·3a	08·8a	12·2	13·9	15·1	1·26	1·28	1·55
	R-UFCS (36·90% TS)	18·2	19·0a	20·3a	14·7	16·0	16·8	1·00	1·05	1·29
2	R-UFCS (30·40% TS)	15·1	16·1a	17·7a	12·9	13·6	14·0	1·14	1·41	1·67
	R-UFCS (33·95% TS)	18·1	19·8b	21·1a	14·7	15·7	16·1	1·26	1·45	1·76
	R-UFCS (36·90% TS)	14·8	15·9a	17·0a	11·9	13·0	14·2	1·08	1·22	1·11
4	R-UFCS (30·40% TS)	15·1	16·7a	17·7a	12·7	13·8	14·5	1·48	1·73	2·96
	R-UFCS (33·95% TS)	18·2	20·6a	22·2b	13·6	15·1	16·9	1·25	1·31	2·40
	R-UFCS[c] (36·90% TS)	15·5	16·9a	17·5a	11·9	13·5	14·4	1·18	1·32	1·37
6	R-UFCS[c] (30·40% TS)	13·5	15·2a	16·7a	10·4	11·7	13·4	1·33	1·59	1·71
	R-UFCS[c] (33·95% TS)	17·3	18·1a	19·7a	12·0	13·9	14·9	1·22	2·01	2·19
	R-UFCS[c] (36·90% TS)	15·0	15·9a	17·2a	11·6	12·4	13·7	0·98	1·24	1·54

[a]Experimental means in each column, regardless of the storage time, bearing a common following letter with the mean did not differ significantly ($P > 0{\cdot}05$) from it; experimental means in each column and at the same storage time sharing a common following letter did not differ significantly ($P > 0{\cdot}05$).
[b]See footnote *b* to Table 1.
[c]The UF cheeses prepared from these concentrates were pickled in their defatted salted wheys.

Veinoglou (1984) and El-Zayat and Omar (1987), respectively. However, Rao and Renner (1989) found lower levels of WSN in cheese prepared from heated UF concentrate than in control Cheddar cheese. The levels of TCA-SN in UF cheeses were generally higher than in the control cheese, but the differences were not significant ($P > 0{\cdot}05$) at any sampling time (Table 4). El-Zayat and Omar (1987) also found higher level of TCA-SN in UF Kareish cheese than in control. Moreover, Kim and Olson (1989) reported that the levels of TCA-SN in UF and control Gouda cheeses were not significantly different. Green *et al.* (1981) assumed that the major factor influencing the relative rate of maturation, and thus the extent of proteolytic breakdown, of control cheese and those made with concentrated milks was probably the level of active rennet retained in the curd. In many studies on the production of UF cheeses, savings of rennet up to 70–80% have been obtained (Hansen, 1984; Glover, 1985; Kosikowski, 1986), depending on the type of cheese and the proportion of whey lost. However, Mocquot (1979) reported that, if coagulation times are longer than 15 min (up to 60 min or more), then a slightly larger amount of rennet is needed to coagulate the retentate in the same time than to coagulate the milk. In the present study the same amount of rennet per kg was added in the cheesemaking of UF and control cheeses. Therefore, the more pronounced proteolysis observed in the UF cheeses could be attributed to a higher amount of rennet retained in their curds because of the much smaller quantity of whey drained compared with that drained from the control curd.

Lipolysis of cheeses

The extent of lipolysis in the cheeses, expressed as acid degree value (ADV), during ageing is shown in Table 4. The ADV of all cheeses increased continuously during ageing. The UF cheeses generally had lower ADVs than the control. However, the differences in ADV between UF cheeses made from fresh or frozen UF concentrates and control cheese were not significant ($P > 0{\cdot}05$) during ageing. Green *et al.* (1981) reported that the concentration of free fatty acids in the curds and 5- and 28-week-old Cheddar cheeses did not vary significantly with the concentration factor of the milk, which indicated that the rate of lipolysis was essentially the same in all cheeses. The lower ADV in UF cheeses than in control cheeses found in this study is in agreement with the results of Rao and Renner (1989), who also reported less lipolysis in UF Cheddar cheese than in the control. The observed differences in the ADV of control and UF cheeses could be attributed to the different heat treatment of the control milk and UF concentrates before cheesemaking. It seems that the more severe heating of the UF concentrates (during and after UF processing) probably caused a greater inactivation of lipases. A similar explanation was given by Rao and Renner (1989) for Cheddar cheese.

Cheese yield

Cheese yield is one of the most economically important aspects of cheese manufacture. The viability of UF cheesemaking is governed mainly by the magnitude of the increase in cheese yield, which needs to be sufficiently large to justify the high capital cost required for the purchase of UF equipment (Lawrence, 1989). The actual yields and the yields adjusted to 55% moisture ($yield_{55}$) of the cheeses are given in Table 5. The cheese yield generally decreased as the concentration of the milk increased, but the differences in actual yield and $yield_{55}$ values between the control cheese and the UF cheeses prepared from frozen concentrates were not significant ($P > 0{\cdot}05$). Chapman *et al.* (1974) found that the yields of UF Cheddar and Cheshire cheeses made by the normal cheesemaking process were the same as those from control milk. Ernstrom (1989) reported that the solids content of the whey expelled from UF curd will be higher than in normal whey in proportion to the degree of concentration by UF, and that there is really no reason to expect that improved yields can be realised. The increased yield of UF cast Feta cheese over the control cheese is attributed mainly to: (i) avoiding the losses of fat and casein into the whey (Tamime & Kirkegaard, 1991); (ii) retention of the whey proteins which is influenced by the extent of their heat denaturation (Lelievre & Lawrence, 1988; Qvist, 1989), and (iii) higher moisture, lactose and mineral contents (Lawrence, 1989; Qvist, 1989). Increases in cheese yield for UF cast Feta cheese made from sheep's milk ranged from 3·9 (Veinoglou *et al.*, 1978) to 12·25% (Boyazoglu & Veinoglou, 1984). The lack of yield increase for UF structured brined soft cheese compared with the control, observed in this study can be attributed to the following factors: (i) Increased losses of fat and protein into the whey due to the decrease in the size of the curd particles and to the non-homogenisation of the recombined UF concentrates, which is a normal step in the manufacture of UF structure Feta (Mortensen, 1985; Tamime & Kirkegaard, 1991). Bush *et al.* (1983) reported that the loss of fat in the whey was approximately 40% and 90% greater when Brick and Colby cheeses were made from creamed UF retentate than from regular milk. In this case, the milk fat globules did not undergo shearing during membrane contentration. On the other hand, Green *et al.* (1983) observed that homogenisation of milk fat in the UF plant reduced the loss of fat during cheesemaking, and (ii) The relatively small retention of the whey proteins in the curd due to the small degree of denaturation achieved. Rao and Renner (1988*a*) reported that heating UF concentrate (34·9% TS) at 70°C for 5 min caused a degree of denaturation of the whey proteins of 20% compared with 54% obtained by heating at 75°C for 5 min. In the commercial production of UF structured Feta the retentate is heated to 90°C for 1 min (Tamime & Kirkegaard, 1991).

Table 5. Mean values for yield, yield$_{55}$, TVC and coliforms in sheep's milk brined soft cheeses made from control milk or various UF concentrates (fresh or frozen) during ripening (2, 4 and 6 months)[a]

Duration of frozen storage (months)	Cheese milk[b]	Yield (%)			Yield$_{55}$[c] (%)			TVC (cfu × 10^6/g)			Coliforms (cfu/g)		
		2 months	4 months	6 months	2 months	4 months	6 months	2 months	4 months	6 months	2 months	4 months	6 months
0	Control milk	25·65	25·70	26·20	25·51	25·56	25·44	109·0	77·5	75·0	0	0	0
	R-UFCS (30·40% TS)	25·87	25·51	25·80	26·18	25·64	25·53	98·0	72·5	30·5	0	0	0
	R-UFCS (33·95% TS)	25·28	25·36	25·11	25·61	25·74	25·35	83·5	44·5	48·5	0	0	0
	R-UFCS (36·90% TS)	25·06	24·45	23·78	25·12	24·87	24·37	92·5	63·0	33·0	7	0	0
2	R-UFCS (30·40% TS)	24·71	24·55	24·00	25·49	25·33	25·44	64·0	51·5	45·0	0	0	0
	R-UFCS (33·95% TS)	24·47	24·90	25·07	23·76	23·58	23·40	64·5	54·5	42·0	0	0	0
	R-UFCS (36·90% TS)	24·42	23·92	24·67	24·13	24·13	25·20	74·0	56·0	44·0	0	0	0
4	R-UFCS (30·40% TS)	26·50	26·11	25·39	26·50	26·41	25·29	50·0	74·5	34·5	0	0	0
	R-UFCS (33·95% TS)	26·10	26·42	24·83	25·24	24·98	24·51	78·0	41·0	38·5	0	0	0
	R-UFCS[d](36·90% TS)	21·86	21·82	22·02	23·24	23·27	23·58	82·0	77·5	33·0	0	0	0
6	R-UFCS[d] (30·40% TS)	26·41	25·88	25·51	28·36	27·74	27·71	33·0	16·5	32·5	0	0	0
	R-UFCS[d] (33·95% TS)	25·29	24·82	24·25	25·51	25·23	24·62	45·5	36·5	31·0	0	0	0
	R-UFCS[d] (36·90% TS)	21·82	21·24	21·77	22·91	22·88	23·09	41·0	24·0	28·0	0	0	0

[a]Experimental means in each column, regardless of the storage time, bearing a common following letter with the control mean did not differ significantly ($P > 0{\cdot}05$) from it; experimental means in each column and at the same storage time sharing a common following letter did not differ significantly ($P > 0{\cdot}05$).
[b]See footnote *b* to Table 1.
[c]Yield adjusted to 55% moisture.
[d]The UF cheeses prepared from these concentrates were pickled in their defatted salted wheys.

Microbiological quality of cheeses

Standard plate counts (TVC) and coliform counts for control and UF cheeses are shown in Table 5. Higher TVCs were observed in the control than in the UF cheeses prepared from fresh or frozen concentrates, but the differences were not significant ($P > 0.05$). The differences in TVC observed in this study could be attributed to the different heat treatment of the control milk and the UF concentrates before cheesemaking (63°C for 15 min versus 70°C for 5 min). It is also evident from Table 5 that, generally, the longer the frozen storage of the UF concentrates, the lower was the TVC of the resulting cheeses which could be attributed to the decrease in the TVC of UF concentrates during the frozen storage (Voutsinas *et al.*, 1995). The TVC of all cheeses generally decreased during ageing of the cheese (Table 5). A similar trend was reported by Boyazoglu and Veinoglou (1984) for UF Feta cheese. Generally, no coliforms were detected in the cheeses made from frozen UF concentrates (Table 5).

Organoleptic evaluation of cheeses

The results of a taste panel's assessment of cheese quality during ageing for 2, 4 and 6 months are shown in Table 6. The cheeses prepared from either fresh or frozen concentrates received lower scores than the controls. Generally, the score for appearance decreased as milk concentration increased. The only appearancedefect observed in UF cheeses was cracks, which were more pronounced in the cheeses made from the more concentrated milks. This defect was apparently due to the incomplete fusion of the curd particles because of the low volume of whey expelled.

The score for body and texture decreased as the milk concentration increased and there were generally significant ($P < 0.05$) differences between control and UF cheeses during ageing. The UF cheeses were generally criticised as having a sandy, grainy or powdery texture. This defect has also been reported by Veinoglou *et al.* (1978) and Jakobsen (1978) for UF cast Feta. It is well-known that the higher mineral content of UF concentrates leads to sandy-textured cheese (Glover, 1985). In addition, Maubois (1986) has stated that, if the mineral content of a cheese produced by ultrafiltration is controlled, the cheese is organoleptically identical to that made by a conventional process. The mineral content of UF concentrates can be reduced (Glover, 1985; Coton, 1986) by: (i) decreasing the pH of the milk before UF, (ii) diafiltering the concentrate, (iii) adding NaCl to the milk during UF to displace calcium, and (iv) lowering the pH at which renneting takes place. Thus, Veinoglou and Boyazoglu (1982) and Boyazoglu and Veinoglou (1984) eliminated the sandy feeling by adding 0·5% NaCl and acidifying the milk before UF and substantially improved the texture of UF Teleme and Feta cheeses, respectively. Moreover, Kyle and Hickey (1993) reported that the use of diafiltration prior to coagulation improved the texture, body and mouthfeel (smooth rather than rubbery or sandy) of UF Feta cheese. It is known that treatments such as the addition of NaCl or reducing the pH of the milk prior to UF lower the stability of the casein micelles (Lawrence, 1989). This was also observed in the first part of the present study (Voutsinas *et al.*, 1995). Because of this information and the fact that the UF concentrates were to be stored frozen for a long time, which was expected to lead to further deterioration of the proteins, the successful combination of NaCl addition and acidification of milk before UF (Veinoglou & Boyazoglu, 1982; Boyazoglu & Veinoglou, 1984) was not used in the present study in order to eliminate the problem of the sandy texture of UF cheese. Moreover, diafiltration was not examined in this study, because this technique removes most of the lactose in the concentrate, and therefore, the residual lactose would not be sufficient to obtain the optimum pH of Feta cheese (4·4–4·5). Therefore, the only remaining treatment available for reducing the mineral content of the concentrates was lowering the pH at renneting. In one trial, 0·5% NaCl was added to the milk before UF but the results in Table 3 indicate that these treatments were ineffective in substantially reducing the calcium content of the UF cheeses and, thus, eliminating the sandy texture. The fact that frozen UF-concentrated goat's milk is used for commercial production of cheese in France (Anon., 1979*a*,*b*), while, as demonstrated in this study, frozen UF-sheep's milk cannot, must be attributed to the much higher (50%) calcium content in sheep's milk than in goat's milk.

Table 6 also indicates that the UF cheeses received lower flavour scores than the control cheese and that, as the milk concentration increased, the flavour score of the resultant cheese decreased. Significant ($P < 0.05$) differences in flavour were observed mainly between the control cheese and those prepared from the highly concentrated milks. The UF cheeses exhibited a more acid flavour than the control, especially when salted whey was used to fill the cans, probably due to their higher mineral content (Glover, 1985) as well as to the lactose in the added whey (in the latter case). No off-flavour or bitterness was noted in UF cheeses made from either fresh or frozen milk concentrates. This may be due to their high S/M values which helped them to avoid off-flavour development. Lelievre and Lawrence (1988) reported that, in UF cast Feta, the high salt content effectively masks many possible flavour defects, such as the bitterness resulting from the presence of excess minerals.

The total score (overall quality) of Feta cheese decreased as the milk concentration increased (Table 6). The UF cheeses generally received significantly ($P < 0.05$) lower total score than the control cheese. In general, the UF cheeses, especially those prepared from the relatively low concentrated milks (R-UFCS 30·40% TS), were considered of acceptable, but not excellent, quality.

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Table 6. Organoleptic properties of sheep's milk brined soft cheeses made from control milk or various UF concentrates (fresh or frozen) during ripening (2, 4 and 6 months)[a]

Duration of frozen storage (months)	Cheese milk[b]	Appearance (10)[c]			Body and texture (40)[c]			Flavour (50)[c]			Total score (100)[c]		
		2 months	4 months	6 months	2 months	4 months	6 months	2 months	4 months	6 months	2 months	4 months	6 months
0	Control milk	9·65b	9·75b	9·45b	38·00c	39·00c	36·95c	43·75b	43·12b	45·75c	91·40c	91·88c	92·15c
	R-UFCS (30·40% TS)	8·45ab	8·47ab	8·45b	30·80bc	32·20b	34·20c	39·25b	38·33ab	41·25bc	78·50b	79·00b	83·90bc
	R-UFCS (33·95% TS)	8·35ab	7·75ab	8·30b	30·40ab	30·00ab	32·20bc	38·25b	36·68ab	37·50ab	77·00b	74·43ab	78·00ab
	R-UFCS (36·90% TS)	7·00a	7·00a	7·25b	23·50a	26·80a	26·60b	30·00a	32·75a	34·00a	60·50a	66·55a	67·85a
2	R-UFCS (30·40% TS)	7·75a	7·75ab	8·00ab	30·73b	30·20b	30·80b	37·25ab	37·75ab	37·75bc	75·73b	75·70b	76·55b
	R-UFCS (33·95% TS)	7·53a	7·55a	7·85ab	30·80b	29·40b	29·80ab	33·67a	36·00ab	36·25b	72·00ab	72·95b	73·90b
	R-UFCS (36·90% TS)	7·70a	7·75ab	7·25a	24·80b	26·20b	27·50a	29·50a	32·00a	36·00b	62·00a	65·90b	70·75b
4	R-UFCS (30·40% TS)	8·00ab	7·95a	8·35ab	31·20bc	30·80b	31·60b	37·75ab	38·50b	37·00b	76·95bc	77·25b	76·95b
	R-UFCS (33·95% TS)	7·85ab	7·70a	8·00a	29·60b	30·00b	30·20b	37·00ab	37·25b	37·75b	74·45b	74·95b	75·95b
	R-UFCS[d] (36·90% TS)	7·50a	7·95a	7·60a	28·60b	30·20b	29·20b	34·50a	36·75b	36·00b	70·60b	74·90b	72·80b
6	R-UFCS[d] (30·40% TS)	8·05a	8·25b	8·25b	31·60b	32·00bc	31·05bc	38·50a	40·00b	38·00bc	78·15b	80·25bc	77·30bc
	R-UFCS[d] (33·95% TS)	8·65ab	8·20b	8·10b	30·80b	30·60b	30·00bc	38·00a	37·00b	36·75b	77·45b	75·80bc	74·85bc
	R-UFCS[d] (36·90% TS)	7·60a	7·90b	7·80b	29·20b	29·20b	28·00b	36·50a	36·75b	34·25b	73·30b	73·85b	70·05b

[a]Experimental means in each column, regardless of the storage time, bearing a common following letter with the control mean did not differ significantly ($P > 0{\cdot}05$) from it; experimental means in each column and at the same storage time sharing a common following letter did not differ significantly ($P > 0{\cdot}05$).
[b]See footnote *b* to Table 1.
[c]Values in parentheses are maximum attainable scores.
[d]The UF cheeses prepared from these concentrates were pickled in their defatted salted wheys.

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