Food Chemistry 49 (1994) 53–60

Manufacture of low-fat Feta cheese

Maria C. Katsiari & Leandros P. Voutsinas*

National Agricultural Research Foundation, Dairy Research Institute, 452 16 Katsikas, Ioannina, Greece

(Received 6 November 1992; revised version received and accepted 15 March 1993)

Feta cheese was manufactured by the traditional procedure from ewe's milk containing 6·0 (control), 4·5, 3·0, or 1·5% fat. Results indicated that, as the fat content of cheese milk decreased, the FDM, MNFS, and yield values of Feta cheese significantly decreased, but the moisture and protein values significantly increased. Salt, S/M, pH, and acidity values of cheeses were not affected by the fat level in the cheese milk. The extents of proteolysis and lipolysis in the cheeses decreased as the amount of milk fat decreased. Body and texture, and flavour scores of cheeses were adversely affected by the decreases in the amount of milk fat, but significant differences in these characteristics were observed between cheeses only at 180 d of storage for the former and throughout storage for the latter. The rheological properties of cheeses were not significantly affected by the fat level in the cheese milk, but cheeses tended to become firmer (less fracturable), shorter, and harder as fat in the milk decreased. Good low-fat Feta cheese with acceptable flavour, body, and texture can be manufactured from cheese milk containing 1·5% fat. No off-flavour or bitterness was noted in any low-fat cheese.

INTRODUCTION

Fat consumption by western populations has been linked to several chronic diseases, including cardiovascular diseases, obesity, and certain forms of cancer (Mela, 1990). These associations have led to numerous recommendations from private- and public-health authorities for a reduction in dietary-fat intakes over the past 30 years (American Heart Association, 1961). Hurt (1972) found a correlation between milk-fat consumption and the incidence of certain heart diseases. Public-health professionals say that the need for light dietary products is clear and present (AHA, 1988; Surgeon General, USA, 1988).

Numerous attempts have been made by the cheese industry and others to develop an acceptable low-fat cheese (Reisfield & Harper, 1955; Hargrove *et al.*, 1966; Madsen *et al.*, 1970; Banks *et al.*, 1989; Mondal *et al.*, 1989; McGregor & White, 1990). These references are not exhaustive but indicate the chronology of this development. In recent years, the resulting consumer interest and demand for lightened dairy products are beyond question (Kraft General Foods, 1989).

No research has been conducted on the manufacture of low-fat Feta cheese, the most popular cheese in Greece, made from ewe's milk by the traditional method. The objectives of the present work were: (i) to investigate the feasibility of manufacturing a low-fat Feta cheese of acceptable quality, and (ii) to determine the effects of fat reduction in the cheese milk on the compositional, physicochemical, sensory, and rheological properties of the Feta cheese produced.

* To whom correspondence should be addressed.

Food Chemistry 0308-8146/93/$06.00

MATERIALS AND METHODS

Milk

Fresh ewe's milk was obtained from the herd of the Agricultural Research Station of Ioannina.

Cheesemaking

The milk was standardized, by separation, to 6·0% (control), 4·5%, 3·0%, or 1·5% fat, respectively. Cheese manufacture was carried out at the pilot plant of the Institute on a 30 kg scale according to the procedure followed by the Greek cheese factories, all conditions being kept as similar as possible. Each batch of milk was pasteurized in a double-walled stainless-steel vat at 63°C for 30 min and then cooled to 35°C. Starter culture (Dry-Vac lactic culture no. CH-1, Chr. Hansen's Laboratorium A/S, Copenhagen, Denmark) was added at the rate of 0·75%, and the milk was allowed to ripen for 30 min. $CaCl_2$ solution (10% w/v) was then added (100 ml/100 kg milk), this being followed by the addition of powdered calf rennet (HA-LA, Hansen's

Laboratorium, Copenhagen, Denmark), dissolved in cold water. Coagulation was achieved in about 45 min at 35°C. After coagulation, the curd was cut into cubes of 2-cm side and was left to rest for 10 min. The sliced curd was then transferred into two perforated rectangular moulds for draining. The moulds were then turned upside down three times during the first 3 h of draining and then left at rest overnight (16–18°C) to complete draining. The next morning, the curd of each mould was cut into four blocks, each weighing about 1 kg. The cheese blocks were placed into individual cans, and granular recrystallized NaCl, equivalent to 2·5% of the weight of the cheese, was added. After 2 d, the salty aqueous phase was removed and replaced by a 7% NaCl solution in a ratio of brine : Feta cheese of 1 : 3. The cans were then sealed. The lid of the can had a hole, which was made airtight with a plastic cap, which was opened during ripening, when needed, in order to allow the release of the gases produced. The cans remained in the ripening room (16–18°C) until the pH and the moisture content of Feta cheese dropped below the values of 4·6 and 56%, respectively. Subsequently, the cans were transferred into the storage room (3–4°C) and remained there for up to six months. Three cheesemaking trials were carried out for each level of fat in the cheese milk.

Samples from each group of cheeses were taken at 1, 15, 30, 60, 120 and 180 d after cheesemaking for analyses. Each time a different can of cheese was opened for sampling. In the 1 d sample, the samples were taken before salting. The reported values are the means of the three cheesemaking trials.

Chemical analysis

Milk
Samples of cheese milk were analysed for fat content by the Gerber method (British Standards Institution, 1955) and for total solids and casein by the methods of the International Dairy Federation (IDF, 1962, 1964). The pH was determined with a pH-meter (Metrohm AG, Switzerland) and the titratable acidity by the Dornic method.

Proteolysis
Total N (TN) of cheese was determined by the Kjeldahl method. Water-soluble N (W-SN) and N soluble in 12% TCA (TSA-SN) were determined by the Kjeldahl method 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 homogenization and the supernatant obtained was filtered through No. 42 filter paper. Nitrogen soluble in 5% phosphotungstic acid (PTA-SN) was determined by the Kjeldahl method according to Stadhouders (1960), except that the cheese extract was prepared as described above. The Kjeldahl method was carried out by using the Kjeldatherm digestion system KT 20S and Vapodest distillation system 4 titramatic (C. Gerhardt GmbH & Co KG, Bonn, Germany) equipped with an end-point titration system ETS 822 (Radiometer, Copenhagen, Denmark).

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

Other analyses
The fat content of cheese was determined by the Gerber method (British Standards Institution, 1955), moisture by the method of the IDF (1958), pH with a pH-meter, and acidity as described by Ling (1963). Sodium chloride content was determined by the modified Volhard method (Kosikowski, 1978). Cheese yield was determined as kg cheese/100 kg milk. Yield was also expressed on a 55% moisture content ($Yield_{55}$).

Sensory evaluation

Organoleptic evaluation of cheese after 60, 120, and 180 d of ripening was carried out by a five-member trained panel familiar with Feta cheese. Panel members evaluated cheese for appearance, body and texture, and flavour (odour and taste) by using a 10-point scale, with 1 being the worst and 10 the best quality. More importance was given to body and texture and to flavour than to appearance. Thus, the scores obtained for these two attributes were multiplied by 4 and 5, respectively. The total score was obtained by adding the scores of the three attributes. An excellent cheese obtained 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, salty), detected according to the IDF (1987) guide for the sensory evaluation of cheese.

Rheological evaluation

Compression testing was performed on Feta cheeses after 60, 120, and 180 d of ageing by using an Instron Universal Testing Instrument, Model 1011 (Instron Ltd, High Wycombe, Bucks, UK), equipped with a 50-kg load cell and a Yokogawa Model 3021 pen recorder. A plunger, 35 mm in diameter, was attached to the moving crosshead. Cubes (20 mm) from each cheese (4°C) were prepared by using a sharp hand cutter. The cubes were placed on a small dish, covered airtightly with a plastics-wrap adhesive membrane, and allowed to equilibrate to measuring temperature (20 ± 1°C). The sample temperature was checked by inserting a small glass thermometer into the central region of a cubic sample. The operating conditions were: crosshead speed 30 mm/min, chart speed 60 mm/min, and chart recording range 0–10 kgf. From each force–distance curve, obtained, by 70% compression of the sample in one stroke; the following parameters were determined as described by Bourne (1978): (i) force (kgf) required to fracture the cheese sample, i.e. the force recorded at the fracture inflection (yield point), as a measurement of fracturability, (ii) the compression (%) at which the sample fractured, as a measurement of cheese shortness, and (iii) the force (kgf) recorded at 70% compression of the sample, as a measurement of cheese hardness. At least six replicate measurements were made for each cheese, and the average values ± s.e.m. for the three cheesemaking trials are reported.

Statistical analysis

The data were analysed by analysis of variance by using Statgraphics (Statistical Graphics Corporation, Rockville, MD, USA). When significant ($p < 0{\cdot}05$) differences were found among treatments, means were separated by Tukey's test (Steel & Torrie, 1960).

RESULTS AND DISCUSSION

Compositional and physicochemical properties

The average composition and some physicochemical properties of standardized ewe's milk used for evaluating the effect of fat reduction on the manufacture of Feta cheese are given in Table 1. It is obvious that reduction of the fat content of cheese milk affected its total solids content and casein : fat ratio, whereas no effect was observed on the physicochemical properties studied.

The effects of reducing the fat content of cheese milk on the mean values of the moisture, moisture in the non-fat substance (MNFS), fat, and fat in dry matter (FDM) of manufactured Feta cheese during ripening and storage are shown in Table 2. As may be seen, the fat content of cheese milk significantly ($p < 0{\cdot}05$) affected all these parameters of Feta cheese. The moisture content of manufactured Feta cheese was inversely related to the fat content of cheese milk. The full-fat control Feta cheese had a lower moisture content than the cheeses made from milks with lower fat contents. This finding is in agreement with the results of Dulley

Table 1. Composition and physicochemical properties of milk used in the manufacture of low-fat Feta cheeses

Parameter \ Fat content of cheese milk (%)	6·0	4·5	3·0	1·5
Total solids (%)	17·36	16·40	15·10	13·95
Casein (%)	4·82	4·87	4·93	4·95
Casein : fat	0·80	1·08	1·64	3·30
pH	6·62	6·62	6·58	6·58
Acidity (°D)	24·00	24·00	24·00	24·00

and Grieve (1974) and Gollu and Kocak (1989) but is in contrast with the results of other workers (Lelievre, 1983; El-Neshawy *et al.*, 1988). The differences in the moisture content among Feta cheeses observed in this study may be attributed to the differences in their protein content, that is, the higher protein content found in the low-fat Feta cheeses (Table 3) may have contributed to their increased moisture contents by increasing the water-binding capacity. Table 2 shows that the mean MNFS, fat, and FDM contents of Feta cheeses were directly related to the fat content of the cheese milk. These results are in accordance with those reported by other workers (Dully & Grieve, 1974; Lelievre, 1983; El-Neshawy *et al.*, 1986, 1988).

The mean values of protein, protein in dry matter (PDM), salt, and salt in moisture (S/M) of the manufactured Feta cheeses at different sampling times are given in Table 3. The protein content of cheeses increased up to 15 d and then gradually decreased throughout the rest of ageing. The initial increase in protein is due to the moisture decrease observed in the cheeses during this period (Table 2). On the other hand, the continuous decrease observed after 15 d of ripening could be due to the transfer of protein degradation products, i.e. soluble nitrogen compounds, to the brine by diffusion. A similar observation has been reported by El-Neshawy *et al.* (1988) for Domiati cheese. Table 3 also shows that the protein and PDM values of cheeses were significantly ($p < 0{\cdot}05$) affected by the level of fat in the cheese milk. The values of these components were inversely related to the amount of fat in the milk. The observed differences in the protein content of cheese could be attributed to the

Table 2. Effects of reducing the fat content of cheese milk on the mean moisture, MNFS, fat, and FDM values of Feta cheeses during ripening and storage

Fat† \ Age (d)	Moisture (%)				MNFS* (%)				Fat (%)				FDM* (%)			
	6·0	4·5	3·0	1·5	6·0	4·5	3·0	1·5	6·0	4·5	3·0	1·5	6·0	4·5	3·0	1·5
0	61·77^{a}	63·88^{b}	66·45^{c}	68·40^{d}	75·56^{b}	74·28^{ab}	73·42^{ab}	71·81^{a}	18·25^{d}	14·00^{c}	9·50^{b}	4·75^{a}	47·73^{d}	38·76^{c}	28·20^{b}	15·04^{a}
15	57·42^{a}	60·29^{b}	62·16^{c}	64·41^{d}	72·68^{b}	71·14^{b}	70·24^{ab}	68·52^{a}	21·00^{d}	15·25^{c}	11·50^{b}	6·00^{a}	49·31^{d}	38·40^{c}	30·39^{b}	16·86^{a}
30	55·98^{a}	57·89^{ab}	59·09^{ab}	60·88^{b}	71·54^{b}	70·38^{b}	68·12^{ab}	64·94^{a}	21·75^{d}	17·75^{c}	13·25^{b}	6·25^{a}	49·41^{d}	42·14^{c}	32·39^{b}	15·97^{a}
60	56·17^{a}	57·30^{ab}	59·02^{bc}	60·94^{c}	72·01^{c}	70·30^{c}	68·13^{b}	65·53^{a}	22·00^{d}	18·50^{c}	13·38^{b}	7·00^{a}	50·19^{d}	43·32^{c}	32·64^{b}	17·87^{a}
120	55·75^{a}	56·88^{ab}	59·03^{bc}	60·92^{c}	71·35^{c}	69·57^{bc}	67·66^{b}	65·33^{a}	21·88^{d}	18·25^{c}	12·75^{b}	6·75^{a}	49·44^{d}	42·32^{c}	31·12^{b}	17·28^{a}
180	55·92^{a}	57·64^{b}	58·98^{b}	60·96^{c}	71·46^{c}	70·30^{c}	67·79^{b}	65·56^{a}	21·75^{d}	18·00^{c}	13·00^{b}	7·00^{a}	49·34^{d}	42·50^{c}	31·69^{b}	17·94^{a}

^{a,b,c,d} Means in the same row and parameter group bearing a common superscript do not differ significantly ($p > 0{\cdot}05$).
* MNFS = moisture in the non-fat substance; FDM = fat in dry matter.
† 'Fat' indicates fat content of cheese milk (%).

Table 3. Effects of reducing the fat content of cheese milk on the mean protein, PDM, salt, and S/M values of Feta cheeses during ripening and storage

Fat†	Protein (%)				PDM* (%)				Salt (%)				S/M* (%)			
Age (d)	6·0	4·5	3·0	1·5	6·0	4·5	3·0	1·5	6·0	4·5	3·0	1·5	6·0	4·5	3·0	1·5
0	17·10^{a}	18·53^{ab}	18·95^{ab}	19·55^{b}	45·01^{a}	51·71^{ab}	56·18^{bc}	61·10^{c}	—	—	—	—	—	—	—	—
15	17·74^{a}	19·33^{ab}	21·18^{b}	21·98^{b}	41·57^{a}	48·68^{ab}	56·27^{bc}	62·65^{c}	2·64	2·78	2·88	3·02	4·60	4·61	4·64	4·69
30	17·00^{a}	18·12^{ab}	18·53^{ab}	19·68^{b}	39·98^{a}	43·67^{ab}	46·03^{bc}	51·62^{c}	2·84	2·99	3·08	3·20	5·06	5·16	5·20	5·26
60	16·88	17·76	17·90	18·47	38·35^{a}	42·27^{ab}	44·02^{ab}	47·69^{b}	2·88	2·97	3·07	3·15	5·14	5·18	5·20	5·17
120	15·76^{a}	17·00^{ab}	18·16^{ab}	19·24^{b}	36·08^{a}	39·56^{a}	42·40^{a}	49·32^{b}	2·84	3·00	3·17	3·22	5·10	5·27	5·36	5·29
180	15·63	16·36	16·59	17·70	35·70^{a}	38·51^{ab}	40·07^{ab}	46·22^{b}	2·80	3·03	3·10	3·18	5·01	5·26	5·26	5·22

^{a,b,c} Means in the same row and parameter group without a superscript or bearing a common superscript do not differ significantly ($p > 0·05$).
* PDM = protein in dry matter; S/M = salt in moisture.
† 'Fat' = indicates fat content of cheese milk (%).

differences in the relative proportions of casein to fat present in the standardized milks, which are manifested in the cheeses (Sundar & Upadhyay, 1990). The results of this study regarding the effect of fat reduction on the protein content of Feta cheese agree with those of other workers (El-Neshawy *et al.*, 1988; Banks *et al.*, 1989; Gollu & Kocak, 1989; Sundar & Upadhyay, 1990) for various cheese varieties. In addition, McGregor and White (1990) have also found that the full-fat control Cheddar had a significantly ($p < 0·05$) lower PDM level than the low-fat cheese.

As may be seen from Table 3, the fat level of the cheese milk did not influence ($p > 0·05$) the salt and S/M contents of the resultant cheeses. As the fat content of milk decreased, the salt and S/M values of cheeses generally increased. This trend was observed throughout cheese ripening and storage and is in agreement with the results of Dulley and Grieve (1974) for Cheddar and Gollu and Kocak (1989) for white cheeses. The higher salt content in the low-fat Feta cheeses, when compared with the control, may be linked to their higher protein content (Table 3). Increased protein could contribute more binding sites for the salt and thus increase salt retention in the curd (McGregor & White, 1990).

The effects of reducing the fat content of cheese milk on the mean pH, acidity, and yield values of the manufactured Feta cheeses are shown in Table 4. There were no significant ($p > 0·05$) differences in pH and acidity between control and experimental cheeses at any sampling time during ripening and storage. These results agree with those reported by Dulley and Grieve (1974) and McGregor and White (1990) for Cheddar cheese. It is also obvious from Table 4 that, as the fat content of cheese milk decreased, the pH of the resultant cheeses tended to increase slightly. With regard to acidity, experimental cheeses generally had similar values to those of the control (Table 4).

As may be seen from Table 4, there was a significant effect ($p < 0·05$) of the fat level of cheese milk on both yield and yield$_{55}$ values of resultant Feta cheeses. The yields of Feta cheeses were directly related to the level of fat in the cheese milk. An over-all reduction in cheese yield is inevitable in the production of cheese from milk of low fat content, since the sum of the casein and fat contents of the milk, the principal components that determine cheese yield, is reduced (Banks *et al.*, 1989). The results of this study concerning the effect of the level of fat in milk on the cheese yield are in conformity with those reported by Lelievre (1983) and Banks *et al.* (1989) for Cheddar, El-Neshawy *et al.* (1988) for Domiati, and Sundar and Upadhyay (1990) for Mozzarella cheese.

Proteolysis

The rate and extent of proteolysis in the cheeses, monitored by measuring the levels of W-SN, TCA-SN, and PTA-SN produced during cheese ripening and storage are shown in Table 5. The W-SN level continuously increased in all cheeses throughout ageing. The rate of increase was high up to 30 d and then declined. A decreasing trend was observed in the production of W-SN in Feta cheeses as the fat level of cheese milk

Table 4. Effects of reducing the fat content of cheese milk on the mean pH, acidity, yield and yield$_{55}$ values of Feta cheeses during ripening and storage

Fat†	pH				Acidity (% lacic acid)				Yield (%)				Yield$_{55}$* (%)			
Age (d)	6·0	4·5	3·0	1·5	6·0	4·5	3·0	1·5	6·0	4·5	3·0	1·5	6·0	4·5	3·0	1·5
0	4·99	5·03	5·07	5·09	0·82	0·79	0·77	0·80	31·78^{b}	30·75^{ab}	28·87^{ab}	26·57^{a}	27·00^{c}	24·69^{bc}	21·53^{ab}	18·67^{a}
15	4·52	4·59	4·61	4·62	1·17	1·18	1·25	1·28	29·77^{b}	27·65^{ab}	25·21^{a}	23·69^{a}	28·17^{c}	24·40^{b}	21·20^{ab}	18·73^{a}
30	4·40	4·42	4·43	4·45	1·11	1·10	1·08	1·16	26·75^{b}	24·86^{ab}	23·40^{a}	22·21^{a}	26·16^{d}	23·25^{c}	21·27^{b}	19·29^{a}
60	4·43	4·46	4·49	4·51	0·97	0·99	1·05	1·02	25·65^{b}	24·47^{ab}	23·15^{a}	22·08^{a}	24·99^{c}	23·43^{bc}	21·08^{ab}	19·16^{a}
120	4·52	4·54	4·55	4·55	1·06	1·09	1·11	1·14	25·70^{c}	24·60^{bc}	23·10^{ab}	21·76^{a}	25·27^{d}	23·57^{c}	21·02^{b}	18·89^{a}
180	4·54	4·55	4·57	4·58	1·08	1·06	1·05	1·10	26·20^{b}	24·50^{ab}	23·00^{a}	21·90^{a}	25·67^{c}	23·06^{bc}	20·97^{ab}	19·09^{a}

^{a,b,c,d} Means in the same row and parameter group without a superscript or bearing a common superscript do not differ significantly ($p > 0·05$).
* Yield adjusted to 55% moisture.
† 'Fat' indicates fat content of cheese milk (%).

Table 5. Effects of reducing the fat content of cheese milk on the mean W-SN, TCA-SN, PTA-SN, and ADV values of Feta cheeses during ripening and storage

Fat†	W-SN (%TN)				TCA-SN (% TN)				PTA-SN (% TN)				ADV (meq KOH/100g fat)			
Age (d)	6·0	4·5	3·0	1·5	6·0	4·5	3·0	1·5	6·0	4·5	3·0	1·5	6·0	4·5	3·0	1·5
0	14·67	14·95	14·68	14·01	7·48	6·93	6·06	6·14	1·08	1·02	0·96	0·92	0·75	0·70	0·68	0·65
15	15·65	14·94	14·54	14·20	10·83	10·34	9·27	9·04	1·29	1·18	1·06	1·03	1·33^{c}	1·16^{b}	1·06^{b}	0·87^{a}
30	16·70	16·24	16·10	15·28	12·08	11·79	10·80	10·86	1·68	1·50	1·36	1·19	1·50	1·37	1·21	1·08
60	17·16^{b}	16·79^{ab}	16·61^{ab}	16·38^{a}	12·93	12·45	11·33	11·27	1·81	1·67	1·49	1·38	1·74	1·57	1·42	1·25
120	19·47	18·60	18·42	17·95	14·25	13·54	13·27	13·21	3·67^{b}	3·25^{ab}	2·80^{a}	2·51^{a}	1·99	1·86	1·65	1·46
180	23·15^{b}	22·42^{ab}	21·68^{ab}	20·95^{a}	15·38	14·49	14·20	14·01	4·24^{c}	3·89^{bc}	3·26^{ab}	3·04^{a}	2·22	2·05	1·91	1·73

^{a,b,c} Means in the same row and parameter group without a superscript or bearing a common superscript do not differ significantly ($p > 0·05$).
† 'Fat' indicates fat content of cheese milk (%).

decreased. However, significant ($p < 0·05$) differences in W-SN levels were observed only between control cheese and that made from milk with 1·5% fat at 60 and 180 d of storage. These results are in conformity with those of other workers (El-Neshawy *et al.*, 1986, 1988; Banks *et al.*, 1989), who reported that the values for W-SN in reduced-fat cheeses were slightly lower than those seen in the cheeses of standard fat content.

TCA-SN showed a continuous increase in all cheeses throughout ageing. The rate of increase was high during the first 30 d of ripening, and then it slowed. As the fat content of milk decreased, the TCA-SN values of Feta cheeses also decreased, but the differences were not significant ($p > 0·05$) at any sampling time.

The PTA-SN level continuously increased in all cheeses during ageing (Table 5). The rate of increase was steady up to 60 d of ageing, and then increased up to 120 d, to be followed by a decrease thereafter. From Table 5, it can be seen that the values of PTA-SN of Feta cheeses decreased as the fat in milk decreased. However, significant ($p < 0·05$) differences in PTA-SN levels were observed only at 120 and 180 d of ageing between control and some experimental cheeses. A decrease in the production of PTA-SN with decreasing fat in cheese milk was also observed by El-Neshawy *et al.* (1986) for Cephalotyre cheese.

Despite the higher moisture content of the experimental Feta cheeses as compared with the control, the level of MNFS, which determines the rate of protein degradation in the cheese (Banks *et al.*, 1989), was lower in the former cheeses. The reduced proteolysis of low-fat Feta cheeses observed in this study was therefore probably due to the lower MNFS, which retarded the rate of protein degradation and the formation of soluble nitrogen compounds in the cheeses. Comparison of Tables 2 and 5 shows that the proteolysis and MNFS values of cheeses followed the same decreasing trend with decreasing fat level of cheese milk.

Lipolysis

The extents of lipolysis in the cheeses, expressed as the acid-degree value (ADV), during ripening and storage are shown in Table 5. The ADV of all cheeses increased continuously during ageing. The rate of increase was high up to 15 d, when the cheeses ripened at high temperature (16–18°C), and then it slowed during the storage in the cold room. The ADV of cheeses decreased as the fat content of cheese milk was reduced. However, significant ($p<0·05$) differences in ADV between cheeses were observed only at 15 d of ripening. The declining trend observed in the ADV of cheeses with decreasing fat content of milk is in line with the results of Dulley and Grieve (1974).

Sensory evaluation

The results of the taste panel's assessment of cheese quality during ageing for 60, 120 and 180 d are shown in Table 6. These data show that the appearance, body and texture, flavour, and total score (over-all quality) of Feta cheeses were affected by the fat content of cheese milk. Regarding appearance, a significant difference was observed only at 60 d of ageing between control cheese and that made from milk containing 1·5% fat. Table 6 shows that, as the fat content of cheese milk decreased, the body-and-texture score of the resultant Feta cheeses decreased. Moreover, the body and texture of cheeses made from milk containing 6·0, 4·5, or 3·0% fat improved slightly during storage, whereas

Table 6. Effects of reducing the fat content of cheese milk on the sensory properties of Feta cheeses during storage

Fat†	Appearance (10)*				Body and Texture (40)*				Flavour (50)*				Total score (100)*			
Age (d)	6·0	4·5	3·0	1·5	6·0	4·5	3·0	1·5	6·0	4·5	3·0	1·5	6·0	4·5	3·0	1·5
60	9·20^{b}	8·85^{ab}	8·60^{ab}	8·15^{a}	35·50	35·10	33·80	33·20	42·50^{b}	41·50^{b}	40·65^{ab}	38·25^{a}	87·20^{b}	85·45^{b}	83·05^{ab}	79·60^{a}
120	8·85	9·10	8·85	8·25	36·70	36·25	34·80	32·85	44·00^{b}	41·70^{ab}	40·25^{ab}	36·80^{a}	90·05^{b}	87·05^{b}	83·90^{ab}	77·90^{a}
180	8·75	9·10	8·25	8·50	37·45^{c}	36·45^{bc}	34·30^{ab}	32·15^{a}	44·40^{c}	42·50^{bc}	38·15^{ab}	35·40^{a}	90·60^{c}	88·05^{c}	80·70^{b}	76·05^{a}

^{a,b,c} Means in the same row and parameter group without a superscript or bearing a common superscript do not differ significantly ($p > 0·05$).
* Values in parentheses are maximum attainable scores.
† 'Fat' indicates fat content of cheese milk (%).

Table 7. Effects of reducing the fat content of cheese milk on some rheological properties of Feta cheeses during storage

Age (d) \ Fat†	Force to fracture* (kgf)				Compression to fracture (%)				Hardness* (kgf)			
	6·0	4·5	3·0	1·5	6·0	4·5	3·0	1·5	6·0	4·5	3·0	1·5
60	1·53 ± 0·26**	1·80 ± 0·44	2·36 ± 0·47	3·06 ± 0·50	18·68 ± 1·05	17·94 ± 0·65	17·69 ± 1·06	17·04 ± 0·60	2·68 ± 0·51	3·35 ± 0·55	4·12 ± 0·58	4·95 ± 0·59
120	1·42 ± 0·31	1·51 ± 0·28	1·93 ± 0·33	2·63 ± 0·55	17·55 ± 0·55	16·63 ± 0·63	15·86 ± 1·28	15·60 ±1·35	2·32 ± 0·32	2·66 ± 0·40	3·25 ± 0·64	4·12 ± 0·52
180	1·03 ± 0·16	1·20 ± 0·24	1·56 ± 0·37	1·97 ± 0·25	17·09 ± 0·94	16·60 ± 0·40	15·77 ± 0·48	15·25 ± 1·00	1·99 ± 0·32	2·38 ± 0·58	2·96 ± 0·51	3·56 ±0·46

* Values are means ± SEM.
** Means in the same row and parameter group without a superscript do not differ significantly ($p > 0·05$).
† 'Fat' indicates fat content of cheese milk (%).

that of cheese made from milk containing 1·5% fat deteriorated. However, significant ($p < 0·05$) differences in body and texture among cheeses were observed only at 180 d of ageing.

The content of fat in cheese milk had a significant ($p < 0·05$) negative effect on the flavour score of the resultant Feta cheeses (Table 6). As the content of fat in the milk decreased, the flavour score of the resultant cheeses decreased. Significant differences in flavour among cheeses were found at all sampling times investigated. However, differences were generally observed between the cheeses made from milk with the two extreme fat levels, i.e. 6·0 and 1·5%. The flavour scores of Feta cheeses made from milk containing 6·0 or 4·5% fat were increased slightly during storage, whereas those of the cheeses made from milk containing 3·0 or 1·5% fat decreased.

The total score (over-all quality) of Feta cheese was significantly ($p < 0·05$) and negatively affected by the level of fat in cheese milk (Table 6). The differences in the over-all quality of cheeses broadened as storage time increased. The adverse effect of milk-fat reduction on the sensory properties of the manufactured Feta cheeses observed in this study is in agreement with the results of other workers (El-Neshawy *et al.*, 1986, 1988; Banks *et al.*, 1989). While this study was in progress, Mondal *et al.* (1989) reported that the fat level (2·0, 3·5, and 5·0%) in the milk and ageing times (14 and 28 d) investigated had no significant effect on the flavour, body and texture scores of Feta cheese and that the best Feta cheese was that made from 2·0% fat milk. The results of Mondal *et al.* (1989) are in contrast to the results found in the present work. This disagreement may be attributed to the different conditions followed in the two studies, i.e. salting (the cheese was dry-salted and brined in this study whereas it was brined in 23% brine for 24 h and soaked in water for 4 h in Mondal *et al.*'s (1989 work)), packaging (in brine as against vacuum), ripening (about 20 d at 16–18°C as against 4·4°C), and testing times (60, 120, and 180 d as against 14 and 28 d).

All cheeses, but especially the low-fat ones, were criticized sometimes as being slightly salty. Moreover, the cheese made from milk containing 1·5% fat was always criticized for being hard. No off-flavour or bitterness was noted by any member of the taste panel in any low-fat cheese during storage. This may be due to their lower MNFS and higher S/M values, as compared with the control, which helped them avoid off-flavour development.

The Feta cheese made from milk containing 1·5% fat had a total score ranging from 79·60 at 60 d to 76·05 at 180 d of storage, which means that the cheese was good and acceptable, but not of excellent quality. Similar positive results have also been reported by others. Thus, good flavour was reported in cheese containing 6·8% fat and very good flavour in samples with 9·0% fat in extensive work done at the US Department of Agriculture (Olson, 1980). Moreover, El-Neshawy *et al.* (1988) produced Domiati cheese of acceptable quality from buffalo's milk containing 1% fat.

Milk fat is generally recognized to be a very important component influencing the flavour of cheese (Olson, 1980). Thus, a low-fat natural cheese generally has less flavour than full-fat cheese. However, the effect of fat reduction on cheese flavour depends on the type of cheese (Olson & Johnson, 1990). Low-fat Mozzarella tastes like full-fat Mozzarella, and low-fat Swiss can taste like full-fat Swiss, but low-fat Cheddar does not taste like full-fat Cheddar (Newton, 1991).

The characteristic flavour of Feta cheese is primarily due to its strong acidity (low pH) and high salt content. Efthymiou (1967) reported that the role of free fatty acids (FFA) in determining the quality and intensity of flavour in mild (non-rancid) Feta cheese is rather limited. Additional factors such as the total acidity and degree of protein degradation are also of great importance. Efthymiou (1967) further found that acetic acid accounted for 28–43% of all FFA present in the mild samples of Feta cheese, and this indicates the importance of acetic acid as a major fatty-acid constituent and as a flavour and aroma determinant in Feta cheese. Acetic acid can be produced from citrate, lactose, and amino acids (Law, 1984).

The good flavour of low-fat Feta cheese may be due to the satisfactory levels of proteolysis products (amino acids and peptides) found in this study as compared with the control, and mainly to the acetic acid produced, since reduction of the fat in cheese milk has been shown not to affect its production in cheese adversely. Acetic acid production was found to be very similar in full-fat and skim-milk Cheddar cheese

(Dulley & Grieve, 1974) and in Cephalotyre cheeses of different fat content (El-Neshawy *et al.*, 1986). Moreover, Ohren and Tuckey (1969) reported that, as fat in Cheddar cheese decreased, the concentration of acetic acid increased.

Rheological evaluation

The results of the objective evaluation of Feta-cheese texture after 60, 120, and 180 d of storage are presented in Table 7. The force required to fracture the cheese sample increased with a reduction in the fat content of cheese milk and continuously decreased during storage. Luten (1988) studied the influence of fat level (10 and 60% FDM) on the force required to fracture Gouda cheese, the other parameters, such as salt, moisture, pH, and water/SNF, being kept constant. He found the same type of relation between these two parameters as that observed in the present study. In addition, Walstra and van Vliet (1982) reported that increasing the fat content causes a slightly softer cheese at small deformation and a more marked decrease in the force needed for fracture.

From Table 7, it can be seen that, as the fat content of cheese milk decreased, the compression required to fracture the resultant Feta cheese also decreased. Moreover, a continuous decrease in this compression was observed for all cheeses during storage, i.e. all cheeses became shorter as storage time increased. It is also obvious that decreasing the fat content of cheese milk resulted in harder Feta cheeses (Table 7) and that all cheeses became softer as the storage time increased. An inverse relationship between the fat content and cheese hardness has also been reported by other workers (Chen *et al.*, 1979; Emmons *et al.*, 1980). Instron- and Bite-test measurements by Emmons *et al.* (1980) demonstrated that reduced-fat Cheddar cheese (17% fat) was considerably firmer and tougher than full-fat cheese (35% fat) even though the MNFS levels of the cheeses were the same. This difference was attributed to the presence in the reduced-fat cheese of about 30% more protein matrix, which must be cut or deformed in texture assessments.

The decrease in the values of the rheological properties of all Feta cheeses with increasing storage time observed in this study (Table 7) is in agreement with the results of other workers (Creamer & Olson, 1982; Zaki, 1990) for different cheese varieties. It should also be noted that, with the progress of storage time, the textural differences among Feta cheeses tend to decrease, except with regard to the compression required to fracture the sample, which remained nearly constant. Similar observations have been reported by Olson (1984) for Colby cheese.

CONCLUSIONS

Low-fat Feta cheese of acceptable quality can be successfully made from ewe's milk containing 1·5% fat by using the conventional procedure. No off-flavour or bitterness was noted in the cheese by any member of the taste panel. The importance of this finding to the cheese industry is significant owing to the great demand for a variety of low-fat food items by the consuming public.

ACKNOWLEDGEMENT

The authors are grateful to Mr V. Ziogos for his valuable assistance in cheesemaking.

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