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Flavour enhancement of low-fat Feta-type cheese using a commercial adjunct culture

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Abstract

The effect of a commercial adjunct culture (CR-213), containing *Lactococcus lactis* subsp. *cremoris* and *Lactococcus lactis* subsp.*lactis*, added at the level of 0.06 or 0.09% (w/w) to cheese milk, on the characteristics of the resultant low-fat Feta-type cheese during aging, was studied. Two controls, a full-fat cheese (~22% fat) and a low-fat cheese (~7% fat, made using the standard procedure), were also prepared. The results indicated that the adjunct containing low-fat cheeses exhibited no significant ($P>0.05$) differences in compositional (moisture, fat, protein, salt, pH) or textural (force and compression to fracture, hardness) characteristics in comparison with the low-fat control cheese. It was also found that the use of the adjunct culture slightly improved the flavour intensity of the low-fat cheese which received a flavour score similar to that of the full-fat control cheese. Moreover, the experimental low-fat cheeses received significantly ($P<0.05$) higher total scores (overall quality) than the low-fat control cheese but lower than the full-fat cheese.

Keywords: Low-fat cheese; Feta cheese; Adjunct culture

1. Introduction

Dietary fat has been shown to be associated with an increased risk of obesity, atherosclerosis, coronary heart disease, elevated blood pressure and tissue injury diseases associated with lipid oxidation (Fenelon & Guinee, 2000). This association has created an increased consumer awareness and a dramatic increase in the supply of, and demand for, low-fat foods, including cheese (Dexheimer, 1992). However, the consumption of low/reduced-fat cheeses is still low because of the poor consumer perception of the products, based on inadequate taste and texture (Jameson, 1990; Muir, Banks, & Hunter, 1992; Olson & Johnson 1990). Low-fat cheeses have low intensity of typical flavour, bitter taste and hard, rubbery, dry and grainy textures (Emmons, Kalab, Larmond, & Lowrie, 1980; Ohren & Tuckey, 1969). Therefore, the challenge in low-fat cheese development is to improve both the sensory attributes and texture of the product to produce a cheese that is comparable to its full-fat counterpart (Wilkinson, Meehan, Stanton, & Cowan, 2001).

Several approaches have been investigated in attempts to improve the flavour and texture of low-fat cheeses, e.g. modification of conventional manufacturing process, use of enzymes, additives (stabilizers and fat replacers), specially-designed starters or adjunct cultures (Fenelon & Guinnee, 2000; Mistry, 2001; Rodriquez, 1998). Combinations of these approaches have also been studied.

Addition of adjunct cultures has shown great promise in manufacturing low-fat cheese with reduced defects and improved flavour (Banks, Hunter, & Muir, 1993; Drake, Boylston, Spence, & Swanson, 1997; Tempas & Morris, 1993).

In a preceding work, we found (Katsiari & Voutsinas, 1994) that low-fat Feta-type cheese of acceptable quality can be made from ewe's milk containing 1.5% fat using the conventional procedure. However, the cheese was inferior in sensory quality to the full-fat counterpart. The purpose of the present study was to extend the work of Katsiari and Voutsinas (1994) to improve the sensory quality of low-fat Feta-type cheese by using a commercial adjunct culture. The effect of the adjunct culture addition to the cheese milk on the compositional,

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sensory and textural characteristics of the resulting cheese during aging are reported in this paper.

2. Materials and methods

2.1. Adjunct culture

The CR-213 culture is a commercially-available mesophilic culture containing three *Lactococcus lactis* strains; two are subsp. *lactis* and the third is subsp. *cremoris*. It is a selected lactose-negative culture with unique balanced aminopeptidase composition. This culture was a gift from Chr. Hansen's Laboratorium (Copenhagen, Denmark).

2.2. Cheese manufacture

Bulk ewes' milk was obtained from the herd of the Agricultural Research Station of Ioannina and standardized to 6.0% fat for the full-fat cheese and 1.5% fat for the low-fat cheeses by mixing skim milk and whole milk. Full-fat and low-fat cheeses were made according to the conventional method as described by Katsiari and Voutsinas (1994) with the following modifications: (1) dry-salting of all cheeses lasted for one instead of two days and (2) the ratio of brine volume to cheese weight, in all cans, was 1:5 instead of 1:3. Four vats of cheese were made in one day. The cheeses were designated as full-fat control (A), low-fat control (B) with no adjunct culture added, and experimental low-fat cheeses made by adding the adjunct culture CR-213 to the cheese milk, along with the normal starter culture, at the level of 0.06 or 0.09% (w/w; cheese C and D, respectively). The experiment was replicated three times.

Samples from each cheese were taken at 2, 20, 60, 120 and 180 days after manufacture for assessment of compositional characteristics. The values reported are the means of the three cheesemaking trials.

2.3. Chemical analyses

Full- and low-fat cheese milks were analysed for fat (BSI, 1955) and casein (IDF, 1964). All cheeses were analysed for fat (BSI, 1955), protein (IDF, 1986), moisture (IDF, 1958), salt (Kosikowski, 1978) and pH (Metrohm model 605-pH meter, Switzerland).

2.4. Sensory evaluation

Samples of cheese were cut into pieces about $3\times3\times2$ cm in size and placed on white plates coded with three-digit random numbers. The pieces were tempered by holding at ambient temperature ($18\pm2^\circ$ C) and then presented to the panellists in random order for testing. Water was provided for mouth washing between samples.

The cheeses were evaluated organoleptically after 60, 120 and 180 days of ripening by a five-member trained panel familiar with Feta cheese. Panel members evaluated cheese for appearance, body and texture, and flavour (odour and taste) using a 10-point scale, with 1 being the worst and 10 the best quality. Importance was given predominantly to the attributes of flavour, and body and texture over the appearance of the cheese, as advised by the IDF (1987). Thus, the scores obtained for these two attributes were multiplied by 5 and 4, respectively. The total score was obtained by adding the scores for 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, grainy, crumbly, spongy, pasty, hard) or flavour (e.g. acid, rancid, bitter, salty), detected according to the IDF (1987) guide for the sensory evaluation of cheese.

2.5. Texture evaluation

Compression testing was performed on the cheeses after 60, 120 and 180 days of ripening 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 using a sharp hand cutter. Once the samples were cut, they were placed on a small dish, covered with an air-tight, plastic wrap adhesive membrane and allowed to equilibrate to assay temperature ($19\pm1^\circ$ 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^{-1}, chart speed 60 mm min^{-1} and chart recording range 0–10 kg. From each force-distance curve, obtained by compression of the sample to 70% in one bite, the following texture-profile parameters were determined, as described by Bourne (1978): (1) the force (kg) required to fracture the cheese sample, i.e. the force recorded at the fracture inflection (yield point), as a measure of *fracturability*, (2) the compression (%) at which the sample fractured, as a measure of cheese *shortness,* and (3) the compressive force (kg) recorded at maximum compression, i.e. the force recorded at 70% compression of the sample, as a measure of cheese *hardness*. At least five replicate measurements were made for each cheese and the average values $\pm$S.E. for the three cheesemaking trials are reported.

2.6. Statistical analysis

The data were analysed by Analysis of Variance using Statgraphics (Statistical Graphics Corp., Rockville, MD, USA). When significant ($P<0.05$) differences were

found among treatments, means were separated by Tukey's test (Steel & Torrie, 1960).

3. Results and discussion

3.1. Compositional characteristics

The mean casein to fat ratio of the milk used for the full-fat cheese was 0.80 and that for the low-fat cheeses 3.28. The mean values for the compositional characteristics of the full-fat and various low-fat cheeses during aging are given in Table 1. As can be seen, significant ($P<0.05$) differences in moisture, fat, FDM and protein were found between the full-fat and low-fat cheeses, while the MNFS, salt, S/M and pH values were similar ($P>0.05$) in all cheeses. The average fat content of the mature (60-day-old) low-fat cheeses was 6.6%, that is 70% lower than that (21.9%) of the full-fat control cheese. The gross compositions of control and experimental low-fat cheeses were not significantly ($P>0.05$) different at any sampling age, indicating that the addition of the adjunct culture CR-213 at both levels to the cheese milk did not affect the composition of the resultant cheese. These results are in agreement with those reported by Banks et al. (1993) who used the same adjunct culture to improve the sensory properties of a Cheddar-type low-fat hard cheese. Similar results have also been found for other low-fat cheese varieties by other workers (Bhowmik, Riesterer, VanBoekel, & Marth, 1990; El-Soda, Chen, Riesterer, & Olson, 1991; Lee, Johnson, & Marth, 1992; Muir et al., 1992), who noted that the gross compositions of experimental low-fat cheeses was not affected by using various adjunct cultures in the cheesemaking.

3.2. Sensory characteristics

The results of the sensory panel's assessment of cheese quality during aging for 60, 120 and 180 days are shown in Table 2. The appearance of all cheeses was considered good at all sampling ages, with no significant differences among cheeses. Regarding body and texture, significant differences between the full-fat and low-fat cheeses were found only at the age of 60 days. The good textural quality of low-fat cheeses observed in the present study was probably due to their high moisture content. It is well-known that one way to overcome the textural defects caused by fat reduction in a cheese is to increase its moisture level and achieve a MNFS value similar to

Table 1
Moisture, fat, moisture in the non-fat-substance (MNFS), fat in dry matter (FDM), protein, salt, salt in moisture (S/M) and pH values[c] of full-fat Feta and low-fat Feta-type cheeses[a,b] made with or without adjunct culture during aging

Age of cheese (days)	Cheese[d]	Moisture (%)	Fat (%)	MNFS (%)	FDM (%)	Protein (%)	Salt (%)	S/M (%)	pH
2	A	57.12 a	21.58 b	72.84	50.36 b	17.9 a	1.64 a	2.88	4.77
	B	66.82 b	6.83 a	71.73	20.62 a	22.4 b	2.54 b	3.80	4.88
	C	66.56 b	7.16 a	71.70	21.44 a	22.9 b	2.50 b	3.76	4.91
	D	66.40 b	7.08 a	71.47	21.08 a	22.5 b	2.48 b	3.73	4.88
20	A	56.91 a	21.75 b	72.72	50.48 b	16.9 a	2.41 a	4.23	4.61
	B	66.13 b	6.58 a	70.78	19.44 a	20.8 b	3.00 b	4.55	4.65
	C	65.66 b	6.83 a	70.48	19.91 a	20.9 b	2.88 ab	4.39	4.69
	D	64.92 b	7.00 a	69.80	19.98 a	21.8 b	2.80 ab	4.30	4.64
60	A	56.46 a	21.92 b	72.31	50.33 b	16.7 a	2.60	4.58	4.63
	B	66.86 b	6.50 a	71.50	19.60 a	19.7 b	2.97	4.44	4.59
	C	66.18 b	6.75 a	70.96	19.96 a	20.7 b	2.97	4.49	4.69
	D	66.29 b	6.50 a	70.90	19.27 a	20.4 b	2.93	4.42	4.65
120	A	56.42 a	21.85 b	72.20	50.14 b	15.9 a	2.52	4.46	4.57
	B	66.81 b	6.50 a	71.44	19.56 a	20.1 b	3.03	4.54	4.68
	C	66.65 b	6.92 a	71.59	20.70 a	20.8 b	3.03	4.58	4.72
	D	65.62 b	6.92 a	70.50	20.14 a	20.9 b	2.86	4.36	4.59
180	A	55.92 a	22.00 b	71.70	49.92 b	16.1 a	2.76	4.94	4.54
	B	66.10 b	6.83 a	70.93	20.17 a	20.2 b	3.08	4.66	4.65
	C	66.13 b	6.67 a	70.86	19.69 a	20.4 b	3.02	4.57	4.67
	D	65.79 b	6.67 a	70.48	19.45 a	20.6 b	2.86	4.34	4.61

[a] Means in each column and at the same age without a letter or bearing a common letter did not differ significantly ($P>0.05$).
[b] Means in each column and at the same age without a letter or bearing a common letter did not differ significantly ($P>0.05$)
[c] Means of three trials.
[d] Cheese: A, full-fat control; B, low-fat control; C, low-fat with 0.06% (w/w) adjunct culture CR-213; D, low-fat with 0.09% (w/w) adjunct culture CR-213.

Table 2
Sensory characteristics[c] of full-fat Feta and low-fat Feta-type cheeses[a,b] made with or without adjunct culture during aging

Age of cheese (days)	Sensory characteristic	Cheese[d]			
		A	B	C	D
60	Appearance (10)[e]	8.82±0.06	8.40±0.23	8.36±0.13	8.42±0.18
120		8.71±0.11	8.28±0.08	8.44±0.00	8.36±0.10
180		8.50±0.26	8.46±0.03	8.46±0.05	8.18±0.14
60	Body and texture (40)[e]	34.36±0.39 b	30.48±0.12 a	31.11±0.43 a	31.45±0.25 a
120		33.28±1.00	31.28±1.00	32.14±1.14	31.26±0.58
180		33.32±0.68	30.32±0.32	31.66±1.66	30.32±1.32
60	Flavour (50)[e]	43.87±0.57 b	37.30±0.29 a	41.82±1.27 ab	41.95±1.09 ab
120		43.95±1.05 b	37.55±0.45 a	40.68±1.46 ab	41.77±0.74 ab
180		42.65±0.55 b	37.48±0.43 a	40.75±1.39 ab	41.54±0.42 ab
60	Total score (100)[e]	87.05±0.96 c	76.18±0.59 a	81.29±0.99 b	81.83±1.31 b
120		85.94±0.02 c	77.11±0.87 a	81.26±1.67 b	81.39±0.02 b
180		84.47±0.55 c	76.26±0.70 a	80.87±0.33 b	80.04±0.90 b

[a] Means in each row without a letter or bearing a common letter did not differ significantly ($P > 0.05$).
[b] Means in each row without a letter or bearing a common letter did not differ significantly ($P > 0.05$)
[c] Mean values±S.E. of three trials.
[d] Cheese: see footnote d to Table 1.
[e] Values in parentheses are maximum attainable scores.

that of the full-fat counterpart (Ardo, 1993). As can be seen from Table 1, the full-fat and low-fat cheeses had similar MNFS values throughout aging.

Table 2 shows that the full-fat control cheese received significantly ($P < 0.05$) higher flavour score than the low-fat control cheese from the panellists at all sampling ages. The results may be attributed to the slightly higher levels of water-soluble nitrogen compounds but mainly to the significantly ($P < 0.05$) higher concentrations of phosphotungstic acid (5%) soluble nitrogen (small peptides and free amino acids) and total free fatty acids in the full-fat cheese than in the low-fat control cheese (Voutsinas, Katsiari, Kondyli, & Alichanidis, 2001).

Addition of the adjunct culture, at both levels, to the cheese milk increased slightly ($P > 0.05$) the Feta flavour score of the resultant cheese compared to the low-fat control cheese (Table 2). Moreover, both experimental low-fat cheeses had flavour scores similar ($P > 0.05$) to that of the full-fat cheese at all sampling ages. These results could be attributed to the similar concentrations of soluble nitrogen fractions (nitrogen soluble in water, 12% trichloroacetic acid, and 5% phosphotungstic acid) and total free fatty acids in the full-fat control and the experimental low-fat cheeses (Voutsinas et al., 2001). The peptidolytic enzymes (aminopeptidases) contributed by the adjunct culture CR-213 were probably responsible for the enhancement of flavour of low-fat Feta-type cheese.

The low-fat control cheese exhibited a slight bitterness at the age of 120 days and thereafter, a common defect in aged low-fat cheeses which can be partly explained by the high moisture content (Mistry, 2001). The fact that the experimental low-fat cheeses did not exhibit bitterness could be due to the increased peptidolytic activity of the added adjunct culture which may have contributed to the degradation of hydrophobic peptides which are responsible for cheese bitterness.

The positive results of the present study are in agreement with those of Banks et al. (1993) who found an enhancement of flavour of low-fat Cheddar-type cheese using the adjunct culture CR-213. These authors also reported that, by the end of the maturation period, the Cheddar flavour intensity of the low-fat cheeses containing high concentrations of the adjunct culture had attained an average score characteristic of commercial mature full-fat cheese. Several other workers have also reported the successful application of different adjunct cultures (modified or nonmodified) to improve the flavour of various low-fat cheese varieties, such as Cheddar (Bhowmik et al., 1990; Drake, Boylston, Spence, & Swanson, 1997; Johnson, Etzel, Chen, & Johnson, 1995; Lee et al., 1992; Madkor, Tong, & El Soda, 2000; Muir et al., 1992; Tempas & Morris, 1993), Ras (Kebary, Khader, Zedan, & Mahmoud, 1996), Dutch-type (Skeie, Narvhus, Ardo, Thorvaldsen, & Abrahamsen, 1997), Gouda-type (Skeie, Narvhus, Ardo, & Abrahamsen, 1995), Kashkaval (Aly, 1994) and Swedish semihard cheese (Ardo, Larsson, Mansson, & Hedenberg, 1989). It should be noted, however, that Drake, Herrett, Boylston, and Swanson (1995) found that the flavour enhancing adjunct culture CR-210 (a culture relative to CR-213 but containing one instead of two *Lactococcus lactis* subsp. *lactis* strains), added to the cheese milk, did not have a positive effect on flavour or overall acceptance of the resultant reduced-fat Monterey Jack-type

Table 3
Textural characteristics[a] of full-fat Feta and low-fat Feta-type cheeses made with or without adjunct culture during aging

Age of cheese (days)	Textural characteristic	Cheese[b]			
		A	B	C	D
60	Force to fracture (kg)	1.31±0.19	2.09±0.47	1.95±0.31	1.88±0.23
120		1.15±0.08	1.92±0.39	1.92±0.34	1.85±0.27
180		1.05±0.08	1.81±0.40	1.79±0.45	1.80±0.38
60	Compression to fracture (%)	21.28±0.62	20.50±0.29	21.44±0.53	21.25±0.36
120		19.67±0.49	19.00±0.87	19.29±0.55	19.77±0.32
180		17.83±0.17	16.94±0.37	17.67±0.60	17.50±0.50
60	Hardness (kg)	2.80±0.25	5.01±0.63	4.28±0.49	4.84±0.45
120		2.62±0.29	4.37±0.51	3.77±0.24	4.17±0.27
180		2.42±0.48	4.29±0.33	3.68±0.57	3.79±0.32

[a] Mean values±S.E. of three trials.
[b] Cheese: see footnote d to Table 1.
Means in each row without a letter did not differ significantly ($P > 0.05$).

cheese compared to the reduced fat control cheese. Moreover, the experimental cheese was scored as 'bitter' and 'high acid' by trained panellists. Also, Tungjaroenchai, Drake, and White (2001) reported that no flavour benefits were detected in reduced fat Edam cheese by using four adjunct cultures [*Brevibacterium linens* (BL2), *Lactococcus lactis* subsp. *diacetylactis, Lactobacillus helveticus* (LH212), and *Lactobacillus reuteri* (ATCC 23272)] or their mixture. It has been suggested that positive results for flavour and texture development in reduced/low-fat cheeses depend strongly on the adjunct culture strain used (Ardo, 1997; El Soda, 1997; El Soda, Madkor, & Tong, 2000). Adjunct cultures can improve the flavour of reduced—and low-fat cheeses through increased proteolysis, specifically aminopeptidase activity, which reduces bitterness and increases the concentrations of desirable flavour peptides and precursors of flavour volatiles (Drake & Swanson, 1995).

The total score (overall quality) of low-fat cheese was significantly ($P < 0.05$) and positively affected by the use of the adjunct culture (Table 2). However, both experimental low-fat cheeses received significantly ($P < 0.05$) lower total scores than that of the full-fat control cheese.

3.3. Textural characteristics

The results of the objective evaluation of cheese texture after 60, 120 and 180 days of aging are given in Table 3. The low-fat control cheese was less fracturable and harder than the full-fat control cheese. However, no significant ($P > 0.05$) differences in the force and the compression required to fracture the samples and the hardness were observed between the full-fat and low-fat control cheeses. This finding is in accordance with the results of Katsiari and Voutsinas (1994) who studied the effect of fat reduction in cheese milk on the textural characteristics of the resultant Feta cheese.

As can be seen from Table 3, the use of the adjunct culture CR-213 did not affect the textural properties of the low-fat Feta-type cheese. As a result, the experimental low-fat cheeses had similar textural characteristics with both control cheeses. This observation is in agreement with the body and texture data of Table 2.

The decrease in the values of all textural characteristics of the cheeses with aging observed in the present study (Table 3) is in accordance with the results of Katsiari and Voutsinas (1994) for Feta cheese of various fat contents and is probably due to the proteolysis of α_{s1}-casein, mainly by residual coagulant.

4. Conclusion

The results of the present study indicate that low-fat Feta-type cheese, with flavour similar to that of the full-fat cheese, can be made by adding the commercially-available adjunct culture CR-213 to the cheese milk. However, the overall quality of this cheese is significantly lower than that of the full fat cheese.

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