Effect of rate of addition of starter culture on textural characteristics of buffalo milk *Feta* type cheese during ripening

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Abstract The effect of rate of addition of starter culture on textural characteristics of buffalo milk *Feta* type cheese was investigated during ripening period up to two months. The textural characteristics of buffalo milk *Feta* type cheese in terms of hardness, cohesiveness, springiness, gumminess and chewiness were analyzed by using textural profile analyzer. The maximum hardness was found with cheese made using 1% culture, while the minimum was found with 2% culture. The cohesiveness and springiness decreased as the level of addition of starter culture increased. The chewiness of cheese also decreased, as the rate of addition of starter culture increased for cheese making. In addition to this, yield, moisture, fat, FDM, protein, salt and S/M of fresh buffalo milk *Feta* type cheese increased with the increase in rate of addition of starter culture; however, TS of experimental cheeses decreased.

Keywords Starter culture · Buffalo milk · *Feta* cheese · Ripening · Textural characteristics

The word '*Feta*' has a special meaning in the Greek language, and it is synonymous with the word 'slice' in English, 'tranche' in French, 'pezza' in Italian, and 'schnitt' in German. *Feta* cheese is one of the most popular white brine cheeses, originated in Greece. The cheese that was made by the Cyclops Polyphemus was undoubtedly the ancestor of modern *Feta*, and there are many references proving the Greek origin of this cheese (Anifantakis 1990, 1998; Anonymous 1953).

It is traditionally made from sheep milk, goat milk or mixture of both. In European countries, technology has

been developed for manufacture of *Feta* type cheese from cow milk to meet the demand of international cheese markets. Since one of the typical characters of cheese is white in colour, cow milk has to be bleached to result in the desired white colour. Bleaching destroys valuable β -carotene. Buffalo milk can be an appropriate substitute to cow milk as no bleaching is required to get characteristics colour of *Feta* type cheese.

India is the largest milk producer in the world producing 108.5 million tonnes (NDDB 2010). Buffalo milk currently constitutes around 13% of the total world milk production. Almost 90% of the total volumes of buffalo milk are solely produced in India and Pakistan with strong annual growth every year (IDF 2008). There is a need to develop suitable technologies for manufacture of new products from buffalo milk to meet the requirement of national and international markets. Presently, there is a great scope for manufacture of *Feta* type cheese particularly from buffalo milk and its export to Middle-East countries. Mild acidic flavour of this cheese may even popular in India.

Davis (1965) considered the starter culture as the "heart of cheese making". It is responsible for acid production at a rate desirable for particular type of cheese to supply suitable microflora for ripening. Traditionally, yogurt was used as a starter but nowadays commercial starters containing mixtures of mesophilic and thermophilic lactic acid bacteria (LAB) are successfully used for *Feta* cheese (Manolopoulou et al. 2003). A yoghurt culture or a combination of mesophilic and thermophilic lactic acid bacteria is used for large-scale production of *Feta* cheese (Tamime and Kirkegaard 1991). In fact, mesophilic LAB or a mixture of mesophilic and thermophilic strains are more suitable than using only thermophilic LAB or yoghurt culture for the high acidification rate that is essential for the production of high-quality *Feta* cheese

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(Kandarakis et al. 2001; Pappa and Anifantakis 2001a, b; Pappas et al. 1996).

White brined cheeses are traditionally produced with no starter cultures at all. This is one of the causes their frequent indifferent quality. The selection, maintenance and use of starter culture are perhaps the most important aspects of cheese making, particularly, in the context of modern mechanized processes where predictability and consistency are essential. The use of starter culture leads to the inhibition of undesirable growth of bacteria, improved whey drainage, production of characteristic flavour and aroma and controlled acid development and also aids the action of rennet by reducing pH (Ozer et al. 2002). The quality of cheese is also affected by the rate of starter addition.

The texture of cheese is one of the important characteristics by which a consumer determines the identity of any specific variety and its quality before assessing the flavour. The texture of cheese depends upon the cheese composition and the extent of biochemical changes during ripening (De Jong 1976; Fox et al. 2000, Lawrence et al. 1987). It has been reported by Chen et al. (1979) that the textural contribution of independent variables follows the sequence of Protein>NaCl>Water>pH>Fat. The rate and extent of texture development during ripening can be monitored by measuring some of the quantifiable rheological characteristics of *Feta* type cheese in terms of hardness, cohesiveness, springiness, gumminess and chewiness by using texture profile analyzer (TPA). TPA simulates the human chewing action by subjecting a sample to a compressive deformation (first bite), followed by a relaxation and a second deformation (second bite). The instrument records the force over time and the resulting stress strain curves gives the texture properties.

The selection of proper level of culture in preparation of buffalo milk *Feta* type cheese is very important not only with respect to sensory characteristics but also to textural attributes of the product. The desirable texture of *Feta* type cheese also depends upon the rate of addition of starter culture. The effect of different levels of starter culture on the textural attributes of *Feta* type cheese using microbial rennet has not been studied earlier from buffalo milk. The objective of this study was to determine the best desirable textural characteristics of the buffalo milk *Feta* type cheese made by using 1.0, 1.5 and 2.0% culture levels.

Materials and methods

Feta cheese preparation from buffalo milk *Feta* cheese was manufactured by using method described by Gilles (1974) with some modification. Buffalo milk was standardized to C/F ratio of 0.70. The standardized buffalo milk was

subjected to heat treatment 65 °C with a holding time of 30 min and cooled in a cheese vat to 30–35 °C. Thereafter, mesophilic cheese culture (NCDC-149) at the rate of 1.0, 1.5 and 2.0% by weight of cheese milk was added to three lots of milk kept in the different cheese vats. Subsequently, after 40–50 min, cheese milk was renneted at 31–32 °C and coagulation took place within 40–50 min. The curds were cut into approximately 1–2 cm³ cubes with vertical and horizontal knives and left for 10–20 min for removal of whey and the curds were transferred into perforated moulds lined with muslin cloth for further removal of whey and texturization of cheese curd without pressure. Whey was collected and stored at 5 °C for making brine. Moulds were turned every 2–4 h to form a firm curd. After four-five turns, the moulds were left undisturbed overnight. Subsequently, cheese blocks were cut into uniform size and transferred to the whey brine solution for about 22–24 h. Cheese blocks were then transferred into plastic packages for vacuum packaging. Subsequently, packaged cheeses were stored for maturation at 10±1 °C and relative humidity of 80%.

Packaging of Feta cheese *Feta* cheese samples were packaged in medium density polyethylene of 60–65 µm thickness, under vacuum by using a vacuum chamber machine. (Indvac, Saurabh Engineers, Ahmedabad, India) after establishing a vacuum of 20 mm of Hg (<0.70 kpa).

Chemical analysis The fat in milk was determined by Gerber method and in cheese by Mojonnier method (IS:SP-18 1981). The casein content of milk was determined by Pyne's method (1932). The total protein content of cheese was estimated by micro-kjeldal method and the moisture was determined by drying to a constant weight at 102 °C using IDF method (1982). The salt content of cheese was determined by the method of Kosikowski (1978).

Cheese analysis Cheese samples from each lot were taken for analysis at 0, 15, 30, 45 and 60 days after manufacture. All the analysis were made five replicates.

Textural analysis Various textural characteristics such as hardness, cohesiveness, springiness, gumminess and chewiness were measured for *Feta* type cheese using Stable Micro Systems Texture Analyzer (Model TA.XT2i Stable Micro systems, double cycle compression, fitted with 25 kg load cell, combined with Texture Expert Exceed Software). A cylindrical shape of *Feta* type cheese sample of 1 cm diameter and 1 cm height was used for determining the textural characteristics. A data acquisition rate of 200 pps with probe P75, was used and samples were compressed twice to 80% of its height. Probe speeds of 2.5 mm/s during test, and 2.5 mm/s for pre- test and 5.0 mm/s for post- test

were used throughout the study. All measurements of samples were carried out at 25 ± 1 °C.

Data analysis The data were statistically analyzed using the SYSTAT Software (version 6.01). When significant (1 and 5% levels) differences were observed, individual means were compared by using Fisher's least significant difference model. The data are presented as mean of five replicates.

Results and discussion

Composition

The effect of rate of addition of starter culture on yield and composition in terms of mean and standard deviation ($\pm$ SD) are presented in Table 1. The yield of cheese increased from 22.79% to 24.23% with the increase in rate of addition of starter culture. Further, the fat, fat in dry matter (FDM), protein, salt and salt in moisture (S/M) content of buffalo milk *Feta* type cheese increased with the increase in rate of addition of starter culture, whereas total solid (TS) of buffalo milk *Feta* type cheese decreased with the increase in rate of addition of starter culture for cheese making. This was in accordance with the result of Najafi et al. (2008) who also reported that yield and moisture content of Iranian brine cheese increased as the rate of addition of starter culture was increased.

Textural characteristics

Hardness of *Feta* type cheese Hardness is the force required by a material to produce a given deformation. The effect of levels of starter culture on hardness of buffalo *Feta* type cheese is presented in Table 2. The overall maximum mean hardness (30.1N) was observed in cheese made using 1.0% level of culture, while the overall minimum mean hardness (25.5N) was found in cheese prepared using 2.0% level of starter culture. In addition to that, the maximum hardness (32.8N) was found at 0 days in cheese manufactured by using 1.0% level of starter culture, while the minimum hardness (20.9N) was found at 30 days

of ripening with cheese using 2.0% level of starter culture. In all experimental cheeses, hardness decreased up to 30 days of ripening. Creamer and Olson (1982) suggested that the hydrolysis of α_{s1} -casein to α_{s1} -1-casein is responsible for early softening of high moisture cheeses. Pappas et al. (1996) also suggested that increased degradation of α_{s1} -casein during ripening softens the cheese.

However, after 30 days, the hardness of experimental *Feta* type cheeses had increased. It could be due to the fact that the extent of proteolysis, probably is not sufficient enough to compensate for the loss of moisture in cheese towards the end of ripening period. The change in the state of water could also be the reason for this development. The peptide bond is cleaved and two new ionic groups are generated. Thereafter, each of these will compete for the available water in the system. Thus, the water previously available for solvation of the protein chain will become tied up with the new ionic groups, leading to the increase in the hardness of cheese (Creamer and Olson 1982).

Cohesiveness of *Feta* type cheese Cohesiveness is defined as the extent to which a material can be deformed before its rupture. It expresses the strength of the internal structure. The effect of level of starter culture on cohesiveness of *Feta* type cheese during ripening is presented in Table 2. It revealed that the maximum cohesiveness (0.25) was found in cheese using 1.0% level of culture. However, the minimum cohesiveness (0.22) was found in the cheese manufactured using 2.0% level of culture. The cohesiveness of cheese was decreased as the ripening period progressed regardless of levels of starter culture. The interaction between levels of culture and ripening period showed that the maximum cohesiveness (0.33) was found at 0 day, while the minimum cohesiveness (0.16) was found in cheese using 2.0% level of starter culture and ripened for 60 days. This may be due to retention of more moisture caused by higher degree of proteolysis in cheese prepared using higher level of starter culture.

Springiness of *Feta* type cheese Springiness is the rate at which the sample returns to its original shape when the deforming force is removed. The effect of levels on

Table 1 Effect of rate of addition of starter culture on yield and composition of fresh *Feta* type cheese

Starter culture (%)	Yield (%)	Moisture (%)	Fat (%)	FDM (%)	Protein (%)	Salt (%)	S/M (%)	TS (%)
1.0	22.8 $\pm$ 0.09	59.6 $\pm$ 0.09	19.1 $\pm$ 0.07	47.2 $\pm$ 0.29	15.0 $\pm$ 0.08	2.7 $\pm$ 0.02	4.5 $\pm$ 0.04	40.4 $\pm$ 0.08
1.5	23.4 $\pm$ 0.13	61.1 $\pm$ 0.09	19.2 $\pm$ 0.05	49.5 $\pm$ 0.25	15.4 $\pm$ 0.04	2.8 $\pm$ 0.30	4.6 $\pm$ 0.04	38.9 $\pm$ 0.11
2.0	24.2 $\pm$ 0.11	62.3 $\pm$ 0.26	20.0 $\pm$ 0.13	53.2 $\pm$ 0.71	16.1 $\pm$ 0.28	2.9 $\pm$ 0.01	4.6 $\pm$ 0.08	37.7 $\pm$ 0.22
C.D.	0.382	0.464	0.155	0.832	0.108	0.021	0.048	0.358

Each value of mean $\pm$ SD of three replicates ($n=3$), FDM Fat in dry matter, S/M Salt in moisture, TS Total solid, C.D. Critical difference

Table 2 Effect of rate of addition of starter culture on textural characteristics of buffalo milk *Feta* type cheese during ripening

Textural characteristics	Starter culture (%)	Ripening Days (R.D)					Overall mean
		0	15	30	45	60	
Hardness (N)	1.0	32.8±0.31	29.5±0.11	26.1±0.12	29.3±0.21	32.6±0.14	30.1
	1.5	31.1±0.29	26.6±0.17	24.7±0.11	27.9±0.14	31.6±0.17	28.4
	2.0	28.8±0.43	23.9±0.27	20.9±0.22	27.9±0.19	26.0±0.13	25.5
	Overall mean	30.9	26.6	23.9	28.3	30.1	
	C.D. _{0.01}	LSC=0.154		R.D=0.199		LSC×R.D =0.345	
Cohesiveness	1.0	0.33±0.04	0.29±0.02	0.24±0.01	0.21±0.05	0.18±0.01	0.25
	1.5	0.33±0.01	0.28±0.01	0.22±0.06	0.19±0.03	0.16±0.03	0.24
	2.0	0.30±0.07	0.23±0.05	0.21±0.02	0.19±0.01	0.16±0.02	0.22
	Overall mean	0.32	0.27	0.23	0.20	0.17	
	C.D. _{0.01}	LSC=0.0027		R.D=0.0035		LSC×R.D=0.0061	
Springiness (mm)	1.0	0.78±0.01	0.75±0.01	0.56±0.02	0.48±0.01	0.41±0.01	0.60
	1.5	0.75±0.04	0.71±0.02	0.53±0.01	0.46±0.02	0.39±0.03	0.57
	2.0	0.75±0.08	0.65±0.03	0.50±0.01	0.43±0.02	0.36±0.02	0.54
	Overall mean	0.76	0.70	0.53	0.46	0.39	
	C.D. _{0.01}	LSC=0.0028		R.D=0.0036		LSC×R.D=0.0062	
Chewiness (N.mm)	1.0	8.6±0.12	6.5±0.11	3.5±0.06	3.0±0.09	2.5±0.13	4.8
	1.5	7.8±0.11	5.3±0.16	3.0±0.10	2.5±0.12	2.0±0.09	4.1
	2.0	6.5±0.14	3.7±0.12	2.3±0.09	2.3±0.14	1.5±0.11	3.1
	Overall mean	7.6	5.2	2.9	2.6	2.0	
	C.D. _{0.01}	LSC=0.0027		R.D=0.0035		LSC R.D=0.0062	

Each value of mean ± SD of five replicates ($n=5$), LSC Level of addition of starter culture, C.D. Critical difference

springiness of *Feta* type cheese during ripening period is presented in Table 2. It revealed that the maximum springiness (0.60 mm) was found in cheese manufactured by using 1.0% culture, while the minimum springiness (0.54 mm) was found in cheese prepared using 2.0% culture. The springiness decreased in all experimental cheeses regardless of level of culture as the ripening period progressed. It could be attributed to the release of calcium ions from mono-calcium and calcium para- κ -caseinate molecules and to the hydrolysis of these molecules during ripening. These molecules are reported to be responsible for the springiness of cheese curd (Van Slyke and Price 1952). The proteolysis of cheese increase may be also responsible for decrease in springiness. The proteolysis of cheese is negatively correlated with springiness (Lawrence et al. 1987a, b). The interaction effect between levels of starter culture and ripening days on springiness showed that the maximum springiness (0.78 mm) of cheese was found 1 day, while the minimum springiness (0.36 mm) found in cheese prepared using 2.0% level of starter culture and ripened for 60 days.

Our finding is in accordance with the Erdem (2005), who also reported that springiness index of white brined cheese decreased as the ripening period increased up to 3 months. This may be probably due to higher proteolysis

in cheese prepared using higher level of starter culture as proteolysis in cheese significantly negatively correlated with springiness (Lawrence et al. 1987a, b).

Chewiness of *Feta* type cheese Chewiness is the work needed to masticate a semisolid food to a state ready for swallowing. The effect of levels of starter culture on chewiness is delineated in Table 2. The maximum chewiness (4.8 N.mm) was found in cheese using 1.0% level of starter culture. However, the minimum chewiness (3.1 N. mm) was found in cheese prepared using 2.0% level of culture. The interaction effect indicated that the highest chewiness (8.6 N.mm) was found in cheese using 1.0% starter culture on 0 day. The minimum chewiness (1.5 N. mm) was found in cheese using 2.0% level of culture and ripened for 60 days. This may probably be due to higher level of proteolysis in cheese made using higher concentration of starter culture than the cheese manufactured using lower level of culture.

Conclusion

A study was conducted for determining the effect of rate of addition of starter culture on textural characteristics of

buffalo milk *Feta* type cheese during ripening using textural profile analyzer. The hardness of buffalo milk *Feta* type cheese decreased as the ripening period progressed regardless of culture levels. The maximum hardness was found with cheese manufactured using 1% culture level. However, the minimum was found in cheese manufactured using 2% culture level. The cohesiveness and springiness of cheeses decreased as the concentration of culture increased throughout the ripening period upto 2 months. The chewiness of cheeses also decreased as the rate of addition of culture increased for cheese making. The yield of buffalo milk *Feta* type cheese increased with the increase in rate of addition of starter culture. In addition to this, moisture, fat, FDM, protein, salt and S/M increased with the increase in rate of addition of starter culture. However, TS of experimental cheeses decreased.

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