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Manufacture of Kefalograviera cheese with less sodium by partial replacement of NaCl with KCl

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Kefalograviera cheeses (five trials) of different sodium content were made from split lots of curd by varying the salting processes, i.e. brine—and dry—salting with NaCl (control) or a mixture of NaCl/KCl (3:1 or 1:1, w/w basis). The results indicated that up to 50% reduction of sodium content in Kefalograviera cheese is feasible, with partial replacement of NaCl by KCl, without an adverse effect on its quality. It was also found that the cheeses made with the mixtures of NaCl/KCl did not exhibit any significant ($p > 0.05$) difference in compositional (moisture, fat, protein, salt), physico-chemical (pH, a_w), or textural (force and compression to fracture, hardness, cohesiveness, springiness, gumminess, chewiness) properties in comparison with the control cheese. Kefalograviera cheese of highly acceptable quality, which did not differ ($p > 0.05$) in sensory characteristics (appearance, body and texture, flavour, total score) from the control cheese, can be produced using a mixture of NaCl and KCl instead of NaCl alone. The Na:K ratio (molecular basis) decreased from 35.3 in the control cheese to 4.2 and 1.4 in the cheeses salted with 3:1 or 1:1 mixture of NaCl/KCl, respectively. The use of the 1:1 NaCl/KCl mixture in the salting of Kefalograviera cheese effectively brought its Na:K ratio close to the desired 1.0, while also greatly reducing the sodium content by about 50%.

INTRODUCTION

Salt (sodium chloride) has traditionally been used as a preservative. However, functional properties and nutritional considerations are now becoming more important in its use in food processing (Fitzgerald and Buckley, 1985).

The most frequent estimate of the minimum adult daily requirement for sodium is 200 mg (0.5 g of NaCl), while the average total daily sodium intake by most persons in developed countries is 4–5 g (10–12 g of NaCl) (IFT, 1980; Dillon, 1987). These quantities, which are 10–35-times greater than the minimum adult requirement (NAS/NRC, 1980*a*; Shank *et al*., 1982), are regarded as excessive, even dangerous, by many of those responsible for public health (Dillon, 1987). A sodium intake of 1100–3300 mg (2.8–8.3 g of NaCl) per day has been recommended as safe and adequate for adults (NAS/NRC, 1980*b*).

In many studies of various ethnic populations, there have been positive correlations between average salt consumption and the incidence of hypertension (Freis, 1976; Abernethy, 1979; Dillon, 1987). On the other hand, studies indicate that an increased intake of potassium via the diet can exert a protective effect in individuals with sodium-induced hypertension (Meneely, 1973; Fregly, 1981; Lecos, 1983; Haddy, 1991; Linas, 1991).

It should also be pointed out that increased dietary sodium increases urinary loss of calcium thereby raising the requirement for this mineral (Heaney, 1992; Massey, 1993; Nordin *et al*., 1993; Schaafsma, 1996); thus, salty foods are considered as a potential risk factor for osteoporosis (Goulding *et al*., 1993). In contrast, increasing potassium intake decreases urinary calcium excretion and potentially protects skeletal mass (Lemann *et al*., 1993).

For the above-mentioned reasons, there has been considerable pressure by consumer groups, some governmental agencies, and medical associations to reduce salt consumption (Olson, 1982). As a result, the dairy industry is seeking ways to reduce the sodium chloride content of cheeses which contain more sodium than do other dairy products (Reddy and Marth, 1993). When the salt concentration in cheese is simply reduced, proteolysis, water activity, acidity and bitterness all increase,

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while firmness and saltiness decrease (Editorial, 1993); abnormal fermentations may also occur (Olson, 1982; Petik, 1987). All of these factors make it difficult to lower sodium level substantially in cheese without affecting quality. However, replacing some of the NaCl with KCl helps to address some of the above problems (Editorial, 1993). KCl has been the most widely and successfully used partial replacement for NaCl in cheese (Reddy and Marth, 1991).

Numerous attempts have been made by the scientific community and cheese industry to develop an acceptable low-sodium cheese using NaCl/KCl mixtures (Martens *et al.*, 1976; Lindsay *et al.*, 1982; Taylor, 1983; Demott *et al.*, 1984; Karahadian and Lindsay, 1984; Kindstedt and Kosikowski, 1984; Fitzgerald and Buckley, 1985; Jameson, 1987; Rapacci *et al.*, 1990; Zorrilla, 1993; Reddy and Marth, 1994; Aly, 1995; Iwanczak *et al.*, 1995; Ramadan, 1995; Rampilli *et al.*, 1995).

Kefalograviera cheese, a traditional hard Greek cheese, has a high salt content of 3.4% (Anifantakis, 1991); this is equivalent to 1338 mg Na per 100 g of cheese, since salt consists of about 39% sodium (IFT, 1980). No research has been conducted on the manufacture of Kefalograviera cheese with less than the normal sodium content. Thus, the objectives of the present study were: (i) to investigate the feasibility of reducing the sodium content in Kefalograviera cheese, using mixtures of NaCl and KCl (3:1 or 1:1, w/w) in the salting processes, without adversely affecting the quality; and (ii) to determine and compare the compositional, physico-chemical, sensory, and textural properties of Kefalograviera cheeses made with mixtures of NaCl and KCl to those of cheese made with NaCl (control).

MATERIALS AND METHODS

Cheese manufacture

Bulk ewes' milk was obtained from the herd of the Agricultural Research Station at Ioannina and standardized by separation. The composition and physico-chemical properties of cheese milk were: fat 6.0%, casein 4.8 %, casein: fat 0.8, pH 6.62 and titratable acidity 24° D. Kefalograviera cheese was made on five occasions at the pilot plant of the Institute (in a 150 litre open vat) on a 100 kg scale according to the conventional procedure (Katsiari and Voutsinas, 1994*b*) with the following modifications: (a) the cheese milk was inoculated with 0.5% starter culture, consisting of 4:1 *Streptococcus salivarius* subsp. *thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* (Visbyvac Joghurt 709, Laboratorium Wiesby GmbH and Co. KG, Niebull, Germany); and (b) the cheeses were salted with fine-grain iodized cooking NaCl (Kalas, Athens, Greece) or a mixture of NaCl and food grade KCl (Merck, Darmstadt, Germany).

The following salting treatments were applied to the cheeses derived from the same lot of curd: (A) immersion of cheese for 2 days in a 20% (w/w) NaCl brine followed by dry salting the cheese with NaCl (control cheese); (B) immersion of cheese for 2 days in a 20% (w/w) brine made with a 3:1 (w/w) mixture of NaCl/KCl followed by dry salting the cheese with the same mixture; and (C) immersion of cheese for 2 days in a 20% (w/w) brine made with a 1:1 (w/w) mixture of NaCl/KCl followed by dry salting the cheese with the same mixture. The ratio of cheese weight to brine volume was 0.5. After brine-salting, the cheeses were transferred to a clean board in the ripening room, where they remained for 2 days. Then, dry salt (20 g) was applied to each cheese nine times, every second day; each time, the cheese was inverted and the side was rubbed with a cheese-cloth soaked in the corresponding brine. Twenty-three days after manufacture, the cheeses were washed with a weak brine (14% NaCl or NaCl/KCl mixture), wiped with a dry cheese-cloth, and left to dry. The dry cheeses were packaged in Cryovac plastic bags and ripened up to 90 days at 10–12°C. Afterwards, the cheeses were transferred to a cold room (2–3°C) for storage.

Samples from each cheese were taken at 5, 25, 60, 90 and 180 days after manufacture for assessment of the compositional and physico-chemical properties. The results reported are the mean values ± S.E. (standard error) of the five cheesemaking trials.

Chemical analysis

Samples of cheese milk were analysed for pH (Metrohm, Model 605 pH-meter, Switzerland), titratable acidity (Dornic method), fat (Gerber method; BSI, 1955) and casein (IDF, 1964). All cheeses were analysed for fat (Gerber method; BSI, 1955), protein (Kjeldahl method; IDF, 1986), moisture (IDF, 1958), salt (Kosikowski, 1978), pH (Metrohm, model 605 pH-meter, Switzerland), and calcium (Pearce, 1977). Samples for mineral analysis were dried overnight at 102°C and ashed at 550°C for 6 h; the ash was analysed for Na and K as described by Egan *et al.*, (1981) using a Corning model 410 Flame Photometer (Ciba Corning Diagnostics Scientific Instruments, Essex, England). Water activity (a_w) was determined at 25°C using a Novasima instrument (Thermoconstanter HUMIDAT, model TH-2, Novasima AG, Zurich, Switzerland) as described by Labuza *et al.* (1976).

Sensory analysis

Samples of Kefalograviera cheese were cut into pieces about 3×3×2 cm in size and placed on white plates coded with three-digit random numbers. The cut samples were tempered by holding at ambient temperature (18 ± 2°C) and then presented to the panellists in a random order for testing. Water was provided for mouth washing between samples.

The cheeses were evaluated organoleptically after 90 and 180 days of ripening by a five-member trained panel familiar with Kefalograviera cheese according to the IDF (1987) quide for the sensory evaluation of cheese as analytically described by Katsiari and Voutsinas (1994*b*).

Texture evaluation

Compression testing was performed on the cheeses after 90 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. Cylindrical samples (diameter 14 mm, height 15 mm) of each cheese (4°C) were prepared from a 4-cm-thick slab of cheese, cut at least 30 mm from the cheese surface, using a cork borer. The long cylindrical samples were cut with a thin-bladed sharp knife to the desired height. Once the samples were cut, they were placed in airtight plastic boxes and allowed to equilibrate to assay temperature (19 ± 1°C). The operating conditions were: crosshead speed 30 mm/min, chart speed 60 mm/min and chart recording range 0–20 kg. From each force-distance curve, obtained by compression of the sample to 80% in two bites, the following texture-profile parameters were determined as described by Bourne (1978, 1982): (i) 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 (a lower numerical value indicates greater fracturability or brittleness; Fedrick and Dulley, 1984); (ii) the compression (%) at which the sample fractured, as a measure of cheese shortness; (iii) the compressive force (kg) recorded at maximum compression during the first bite, i.e. the force recorded at 80% compression of the sample, as a measure of cheese hardness; (iv) the ratio of the positive-force area under the curve during the second compression (bite) to that during the first compression (A_2/A_1), as a measure of cohesiveness; (v) the height (mm) that the sample recovered during the time that elapsed between the end of the first bite and the start of the second bite, as a measure of springiness (elasticity); (vi) the product of hardness × cohesiveness (kg), as a measure of gumminess; and (vii) the product of gumminess × springiness (kg.mm), as a measure of chewiness. At least five replicate measurements were made for each cheese and the average values ± S.E. for the five cheese-making trials are reported.

Statistical analysis

The data were subjected to an 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 and Torrie, 1960).

RESULTS AND DISCUSSION

Compositional and physico-chemical properties

The mean values for moisture, fat, moisture in the non-fat substance (MNFS) and fat in dry matter (FDM) of Kefalograviera cheeses at different sampling ages are given in Table 1. The moisture and FDM contents of ripened cheeses met the Greek legal specifications of a maximum of 38% and a minimum of 40%, respectively, for 'first quality' Kefalograviera cheese (Greek Ministry of Economics, 1987). There were no significant ($p > 0.05$) differences in the moisture, fat or FDM contents of cheeses made with NaCl or NaCl/KCl mixtures. These results are in agreement with those found by

Table 1. Moisture, fat, moisture in the non-fat substance (MNFS) and fat in dry matter (FDM) values of Kefalograviera cheese[a,b] made with NaCl or mixtures of NaCl and KCl during aging

Age of cheese (days)	Salting treatment[c]	Moisture (%)	Fat (%)	MNFS (%)	FDM (%)
5	A	42.70 ± 0.25	26.83 ± 0.60	58.38 ± 0.67	46.84 ± 1.13
	B	42.92 ± 0.35	26.67 ± 0.44	58.53 ± 0.54	46.72 ± 0.77
	C	42.61 ± 0.24	27.17 ± 0.44	58.51 ± 0.54	47.34 ± 0.84
25	A	39.19 ± 0.22	28.83 ± 0.33	55.06 ± 0.08	47.41 ± 0.37
	B	39.27 ± 0.37	28.50 ± 0.29	54.92 ± 0.31	46.93 ± 0.21
	C	39.31 ± 0.29	28.83 ± 0.44	55.39 ± 0.22	47.51 ± 0.50
60	A	37.31 ± 0.36	29.33 ± 0.17	52.80 ± 0.59	46.79 ± 0.46
	B	37.30 ± 0.29	29.25 ± 0.25	52.73 ± 0.59	46.66 ± 0.61
	C	37.22 ± 0.39	29.25 ± 0.25	52.61 ± 0.66	46.60 ± 0.60
90	A	37.81 ± 0.09	29.45 ± 0.12	53.59 ± 0.22	47.36 ± 0.26
	B	37.94 ± 0.11	29.35 ± 0.15	53.70 ± 0.17	47.29 ± 0.24
	C	37.66 ± 0.21	29.45 ± 0.20	53.39 ± 0.34	47.24 ± 0.37
180	A	37.99 ± 0.21	29.70 ± 0.12	54.03 ± 0.36	47.90 ± 0.33
	B	37.98 ± 0.11	29.80 ± 0.12	54.11 ± 0.20	48.05 ± 0.23
	C	37.88 ± 0.23	29.45 ± 0.17	53.73 ± 0.41	47.41 ± 0.38

[a]Means in each column and at the same age without a superscript did not differ significantly ($p > 0.05$).
[b]Mean values ± S.E. of five trials.
[c]Salting treatment: A, salting with NaCl (control); B, salting with 3:1 (w/w) mixture of NaCl and KCl; C, salting with 1:1 (w/w) mixture of NaCl and KCl.

others (Fitzgerald and Buckley, 1985; Rapacci *et al.*, 1990; Reddy and Marth, 1993; Aly, 1995; Ramadan, 1995; Rampilli *et al.*, 1995) in their studies on the effect of partial substitution of NaCl by KCl on various cheese varieties (Cheddar, Prato, UF Feta-type, Caciotta and Domiati). It can also be seen from Table 1, that all cheeses had similar ($p > 0.05$) MNFS values.

Table 2 shows the mean values for protein, salt, salt in moisture (S/M), pH and water activity (a_w) of various Kefalograviera cheeses during aging. As may be seen, no significant ($p > 0.05$) differences in the protein and salt contents were observed among the cheeses. This finding is in accordance with the results of other investigators (Fitzgerald and Buckley, 1985; Aly, 1995; Ramadan, 1995). Moreover, the S/M values of the cheeses were not significantly ($p > 0.05$) affected by the type of the salt used. Similar results have been reported by Fitzgerald and Buckley (1985) and Ramadan (1995) for Cheddar and Domiati cheeses, respectively. Table 2 also shows that the mean pH values of all cheeses were similar ($p > 0.05$), although the ripened cheeses salted with the NaCl/KCl mixtures had consistently slightly higher pH values than the control cheese containing NaCl alone. Lindsay *et al.* (1982) and Aly (1995) found similar results for Cheddar and UF Feta-type cheeses, respectively. The salting treatment did not affect ($p > 0.05$) the a_w of cheeses, which continuously decreased throughout aging (Table 2). It is well known that low molecular weight compounds, notably peptides and amino acids, that are formed during ripening, are involved in lowering the a_w of the cheese (Fox, 1987; Malthlouthi *et al.*, 1981).

The observation in this study, that the cheeses salted with NaCl/KCl mixtures exhibited similar physico-chemical properties to the control cheese, can be attributed to the fact that, as stated by Kosikowski (Taylor, 1983), technically, the potassium ion has the same effects as the sodium ion in the cheese-making process.

Elemental data and nutritionally related calculations for Na and K in the cheeses are given in Table 3. For comparative purposes, data for commercial ewes' milk Kefalograviera cheese are also given. The calcium content of all cheeses was similar ($p > 0.05$). The Ca, Na and K contents found in this study for the control cheese compare closely with the corresponding values found for the commercial Kefalograviera sample. The desired Na:K ratio is 0.5 on a gravimetric basis or 1.0 on a molecular basis (Hansen and Wyse, 1980; Shank, 1980). As may seen from Table 3, the use of the 3:1 and 1:1 NaCl/KCl mixtures effectively reduced the Na:K ratio of Kefalograviera cheese to 4.2 and 1.4, respectively, while the Na content decreased by 23.7 and 49.4%, respectively, compared to the control cheese. Therefore, the cheese salted with the 1:1 NaCl/KCl mixture had an acceptable Na:K ratio. This cheese had a Na content of 189 mg per 28.4 g serving, and thus, it can not be labelled as 'low sodium' food because it does not meet the requirement that the sodium content must be 140 mg or less per 28.4 g serving (Anon, 1984). The K content in cheeses salted with the 3:1 or 1:1 NaCl/KCl mixture was about 6.3 and 12.7 times higher, respectively, as compared with the control cheese (Table 3).

Sensory evaluation

The results of the taste panel's assessment of cheese quality after aging for 90 and 180 days are shown in Table 4. The mean scores for appearance, body and texture, flavour, and overall quality (total score) of cheeses salted with the NaCl/KCl mixtures were not significantly ($p > 0.05$) different from those of the control cheese at both sampling ages, although the control cheese received slightly higher flavour scores than the NaCl/KCl-salted cheeses. The cheese salted with the 3:1 NaCl/KCl mixture also received a somewhat higher flavour score than the cheese salted with the 1:1 NaCl/KCl

Table 2. Protein, salt, salt in moisture (S/M), pH and water activity (a_w) values of Kefalograviera cheese[a,b] made with NaCl or mixtures of NaCl and KCl during aging

Age of cheese (days)	Salting treatment[c]	Protein (%)	Salt (%)	S/M (%)	pH	a_w
5	A	25.63 ± 0.33	0.82 ± 0.01	1.92 ± 0.04	5.44 ± 0.04	0.956 ± 0.00
	B	25.69 ± 0.25	0.75 ± 0.05	1.76 ± 0.12	5.42 ± 0.02	0.959 ± 0.00
	C	25.88 ± 0.09	0.78 ± 0.05	1.83 ± 0.12	5.45 ± 0.02	0.961 ± 0.00
25	A	26.48 ± 0.16	2.36 ± 0.16	6.02 ± 0.43	5.38 ± 0.02	0.924 ± 0.01
	B	26.31 ± 0.17	2.43 ± 0.12	6.18 ± 0.33	5.41 ± 0.03	0.926 ± 0.00
	C	26.54 ± 0.15	2.41 ± 0.12	6.13 ± 0.27	5.45 ± 0.03	0.929 ± 0.00
60	A	26.52 ± 0.39	3.41 ± 0.18	9.13 ± 0.44	5.35 ± 0.04	0.902 ± 0.00
	B	26.43 ± 0.33	3.46 ± 0.10	9.27 ± 0.26	5.34 ± 0.05	0.909 ± 0.00
	C	26.54 ± 0.20	3.35 ± 0.19	9.00 ± 0.47	5.37 ± 0.06	0.906 ± 0.00
90	A	26.41 ± 0.30	3.50 ± 0.08	9.25 ± 0.23	5.42 ± 0.03	0.902 ± 0.01
	B	26.33 ± 0.24	3.46 ± 0.11	9.11 ± 0.29	5.44 ± 0.04	0.900 ± 0.01
	C	26.62 ± 0.21	3.42 ± 0.07	9.08 ± 0.23	5.49 ± 0.05	0.902 ± 0.00
180	A	26.30 ± 0.36	3.51 ± 0.05	9.25 ± 0.15	5.45 ± 0.03	0.894 ± 0.00
	B	25.97 ± 0.34	3.55 ± 0.07	9.34 ± 0.18	5.50 ± 0.03	0.894 ± 0.00
	C	26.20 ± 0.30	3.51 ± 0.15	9.28 ± 0.41	5.52 ± 0.03	0.894 ± 0.00

[a]Means in each column and at the same age without a superscript did not differ significantly ($p > 0.05$).
[b]Mean values ± S.E. of five trials.
[c]Salting treatment: symbols as in Table 1.

Table 3. Calcium, sodium and potassium contents of 90-day old Kefalograviera cheese[d] made with NaCl or mixtures of NaCl and KCl

Parameter	Salting treatment[e]			Commercial sample
	A	B	C	
Ca (mg per 100 g)	988 ± 22	992 ± 21	983 ± 25	990
Na (mg per 100 g)	1312 ± 50[a]	1001 ± 45[b]	664 ± 28[c]	1340
K (mg per 100 g)	64 ± 2[c]	404 ± 33[b]	814 ± 58[a]	60
Na:K ratio (gravimetric basis)	20.5[a]	2.5[b]	0.8[c]	22.3
mg Na per 28.4 g serving	373[a]	284[b]	189[c]	381
mg K per 28.4 g serving	18[c]	115[b]	231[a]	17
meq Na per 28.4 g serving[f]	16.22[a]	12.35[b]	8.22[c]	16.6
meq K per 28.4 g serving[g]	0.46[c]	2.95[b]	5.92[a]	0.44
Na : K ratio (molecular basis)	35.3[a]	4.2[b]	1.4[c]	37.7

[a,b,c]Means in each row without a superscript or bearing a common superscript did not differ significantly ($p > 0.05$).
[d]Mean values ± S.E. of five trials.
[e]Salting treatment: symbols as in Table 1.
[f]meq Na = mg Na/23.
[g]meq K = mg K/39.

mixture. A similar trend was observed by Reddy and Marth (1994), Aly (1995), and Ramadan (1995) in their studies on the effect of partial substitution of NaCl by KCl on the flavour of Cheddar, UF Feta-type and Domiati cheese, respectively.

The lower flavour scores of the cheese salted with the 1:1 NaCl/KCl mixture observed in the present study was due to a slightly burning-metallic aftertaste, typical of KCl, noted in four of the five trials by some (1–2) panellists, mainly after aging for 180 days. It should be pointed out, however, that, despite this minor flavour defect, this cheese was very acceptable (Table 4). The fact that the cheese salted with the 3:1 NaCl/KCl mixture did not exhibit a metallic off- flavour could be attributed to the masking effect of NaCl. According to Charteris and Keogh (1991), sodium chloride may mask metallic-chemical off-notes but this effect is dependent on the concentration of NaCl added and the type of chemical compounds produced during shelf-life. It is worth noting that, in one trial, two panellists perceived a slightly burning aftertaste even in the control cheese.

The results in Table 4 clearly demonstrate the successful manufacture of Kefalograviera cheeses using the NaCl/KCl mixtures studied. Similar positive results have also been reported by other investigators for various cheese varietes, such as Cheddar (Lindsay *et al.*, 1982; Taylor, 1983; Kindstedt and Kosikowski, 1984; Fitzgerald and Buckley, 1985; Reddy and Marth, 1994), Gouda (Martens *et al.*, 1976; Iwanczak *et al.*, 1995), Prato (Rapacci *et al.*, 1990), Process American (Karahadian and Lindsay, 1984), Swiss (Jameson, 1987), Cottage (Demott *et al.*, 1984), Feta-type (Aly, 1995), Caciotta (Rampilli *et al.*, 1995), Fynbo (Zorrilla, 1993), Colby (Taylor, 1983), Domiati (Ramadan, 1995) and Camembert, Camping and Tilsit (Iwanczak *et al.*, 1995). Low-sodium Cheddar and Colby cheeses made with KCl as a salt substitute are already commercially available (Taylor, 1983). It should be reported, however, that Sieber and Schar (1993) found that partial substitution of NaCl by KCl had a negative effect on the quality of Appenzell-type semi-hard cheese.

Table 4. Sensory properties of Kefalograviera cheese[a,b] made with NaCl or mixtures of NaCl and KCl during aging

Age of cheese (days)	Sensory property	Salting treatment[c]		
		A	B	C
90	Appearance (10)[d]	9.07 ± 0.13	8.93 ± 0.09	8.93 ± 0.09
180		9.32 ± 0.26	9.25 ± 0.21	9.32 ± 0.15
90	Body and texture (40)[d]	36.60 ± 0.60	35.53 ± 0.47	35.72 ± 0.44
180		36.92 ± 0.75	36.96 ± 0.64	36.34 ± 0.92
90	Flavour (50)[d]	44.35 ± 0.78	44.07 ± 1.07	43.37 ± 0.63
180		43.33 ± 0.87	43.05 ± 1.12	42.65 ± 0.67
90	Total score (100)[d]	90.02 ± 1.15	88.53 ± 1.48	88.03 ± 1.03
180		89.56 ± 1.79	89.26 ± 1.70	88.31 ± 1.69

[a]Means in each row without a superscript did not differ significantly ($p > 0.05$).
[b]Mean values ± S.E. of five trials.
[c]Salting treatment: symbols as in Table 1.
[d]Values in parentheses are maximum attainable scores.

Table 5. Textural properties of Kefalograviera cheese[a,b] made with NaCl or mixtures of NaCl and KCl during aging

Age of cheese (days)	Textural property	Salting treatment[c]		
		A	B	C
90	Force to fracture (kg)	3.07 ± 0.43	2.79 ± 0.33	2.72 ± 0.27
180		2.45 ± 0.17	2.41 ± 0.12	2.29 ± 0.20
90	Compression to fracture (%)	31.22 ± 1.91	31.30 ± 1.93	31.28 ± 1.92
180		26.73 ± 1.45	27.36 ± 1.68	26.49 ± 1.44
90	Hardness (kg)	12.37 ± 1.69	11.28 ± 1.63	11.14 ± 1.61
180		9.99 ± 0.74	9.61 ± 0.59	9.33 ± 0.61
90	Cohesiveness	0.13 ± 0.01	0.13 ± 0.01	0.13 ± 0.01
180		0.12 ± 0.00	0.11 ± 0.00	0.12 ± 0.00
90	Springiness (mm)	3.75 ± 0.26	3.41 ± 0.21	3.29 ± 0.27
180		2.86 ± 0.12	2.82 ± 0.19	2.74 ± 0.16
90	Gumminess (kg)	1.67 ± 0.28	1.42 ± 0.24	1.39 ± 0.13
180		1.23 ± 0.09	1.08 ± 0.11	1.10 ± 0.09
90	Chewiness (kg.mm)	6.13 ± 0.88	4.72 ± 0.64	4.43 ± 0.59
180		3.50 ± 0.26	2.99 ± 0.20	2.99 ± 0.17

[a]Means in each row without a superscript did not differ significantly ($p > 0.05$).
[b]Mean values ± S.E. of five trials.
[c]Salting treatment: symbols as in Table 1.

Texture evaluation

The results of the objective evaluation of cheese texture after 90 and 180 days of aging are given in Table 5. Generally, the cheeses salted with the NaCl/KCl mixtures were slightly more fracturable, softer, springier, gummier and more chewy than the control cheese. However, no significant ($p > 0.05$) differences in the textural properties were observed among the three cheeses at either sampling age. This finding is in accordance with the results of Fitzgerald and Buckley (1985) who reported no significant differences in the physical characteristics (hardness, cuttability, firmness and shortness) of Cheddar cheese salted with KCl or a NaCl/KCl mixture (1:1) and the control cheese. Table 5 also indicates that the values of all textural properties of various Kefalograviera cheeses decreased with aging. This observation is in agreement with the results of Katsiari and Voutsinas (1994*b*) for Kefalograviera cheese and of Creamer and Olson (1982), Zaki (1990) and Katsiari and Voutsinas (1994*a*) for Cheddar, Domiati and Feta cheeses, respectively. During the aging of many types of cheese, the protein matrix is converted to a smoother structure and softening occurs (Creamer and Olson, 1982). These changes are probably due to proteolysis of a_{s1}-casein, mainly by residual coagulant.

CONCLUSIONS

Kefalograviera cheeses of very acceptable quality can be produced using a 3:1 or 1:1 (w/w) mixture of NaCl with KCl instead of NaCl alone. These cheeses did not differ significantly ($p > 0.05$) from the control cheese in any respect, but contained about 25 and 50% lower sodium, respectively. The Na:K ratio of the cheese salted with the 1:1 NaCl/KCl mixture was close to that recommended by nutritionists.

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