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S. KAMINARIDES

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■ Comparison of two methods of making reduced-fat ovine Halloumi type cheese

S. Kaminarides¹

¹Laboratory of Dairy Science and Technology, Department of Food Science and Human Nutrition,
Agricultural University of Athens, Athens, Greece

■ Σύγκριση δύο μεθόδων παρασκευής τυριού Χαλούμι με μειωμένο λίπος από πρόβειο γάλα

Σ. Καμινάριδης^{1x}

¹Εργαστήριο Γαλακτοκομίας, Τμήμα Επιστήμης Τροφίμων και Διατροφής του Ανθρώπου, Αθήνα

ABSTRACT. Halloumi is a popular cheese in Cyprus where reduced-fat Halloumi cheese is manufactured solely from bovine milk. In this study, two methods of making reduced-fat Halloumi type cheeses from ovine milk containing 1.8% fat were compared. Ovine milk was used because it has a greater biological and nutritional value than bovine milk. The first method used traditional technology (T) as a control whereas the second method was a modified technology (M), as described in material and methods. The M cheese had a significantly ($P < 0.05$) higher yield, moisture content, protein in dry matter, pH value and lower content of fat, lactose, ash, Ca and Mg, acidity, hardness, adhesiveness, elasticity, gumminess and chewiness than the T cheese. The assessment panel suggested that the M technology was superior and can be used to produce a reduced-fat ovine Halloumi type cheese.

Keywords: Reduced-fat cheese, Ovine Halloumi cheese, physicochemical characteristics, texture profile, sensory attributes.

Corresponding Author:

Stelios Kaminarides, Laboratory of Dairy Science and Technology Department of Food Science and Human Nutrition Agricultural University of Athens 75, Iera Odos - 118 55 Athens - Greece, E-mail: skamin@aua.gr

Αλληλογραφία:

Στέλιος Καμινάριδης, Εργαστήριο Γαλακτοκομίας, Τμήμα Επιστήμης Τροφίμων και Διατροφής του Ανθρώπου, Γεωπονικό Πανεπιστήμιο Αθηνών, Ιερά Οδός 75 - 118 55 Αθήνα, ΤΗΛ.: 210-5294641, E-mail: skamin@aua.gr

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ΠΕΡΙΛΗΨΗ. Το Χαλλούμι είναι ένα δημοφιλές τυρί στην Κύπρο. Τα τελευταία χρόνια στην αγορά της Κύπρου κυκλοφορεί Χαλλούμι με μειωμένο λίπος που παράγεται αποκλειστικά από αγελαδινό γάλα. Στην παρούσα μελέτη, έγινε σύγκριση δύο μεθόδων παρασκευής τυριού τύπου Χαλλούμι από πρόβειο γάλα που μειώθηκε το λίπος του στο 1,8%. Χρησιμοποιήθηκε πρόβειο γάλα γιατί είναι μεγαλύτερης βιολογικής και θρεπτικής αξίας από το αγελαδινό. Στην πρώτη, χρησιμοποιήθηκε ως μάρτυρας η παραδοσιακή τεχνολογία (Τ), ενώ στη δεύτερη, η τροποποιημένη τεχνολογία (Μ), όπως περιγράφεται στα υλικά και μέθοδοι. Το τυρί Μ είχε υψηλότερη απόδοση, περιεκτικότητα σε υγρασία και πρωτεΐνη υπολογισμένη σε ξηρή ουσία, υψηλότερη τιμή pH και χαμηλότερη περιεκτικότητα σε λίπος, λακτόζη, τέφρα, Ca, Mg, οξύτητα, σκληρότητα, συνάφεια, ελαστικότητα, πολτοποιητικότητα και μασητικότητα από το τυρί Τ. Η ομάδα οργανοληπτικής αξιολόγησης πρότεινε ότι η τεχνολογία Μ είναι καλύτερη και μπορεί να χρησιμοποιηθεί για την παραγωγή πρόβειου τυριού τύπου Χαλλούμι με μειωμένο λίπος.

Λέξεις κλειδιά: Τυρί με μειωμένο λίπος, τυρί Χαλλούμι, φυσικοχημικά χαρακτηριστικά, ρεολογικά, χαρακτηριστικά, οργανοληπτικά χαρακτηριστικά.

INTRODUCTION

Obesity has become a very important danger for the population's health mainly in the United States and Europe, but also in developing countries. Obesity causes serious health problems, such as arteriosclerosis, cardiovascular damage, coronary heart disease, diabetes in adults, as well as being implicated in some forms of cancer in the breast and colon (Ritvanen *et al.*, 2005). Nowadays, more and more consumers buy foods with reduced-fat and energy, as part of a diet to reduce their weight (Ritvanen *et al.*, 2005).

The production of reduced-fat cheeses has increased considerably recently, reflecting the increasing demand of consumers for lower-fat products (Molinaa *et al.*, 2000). The cheeses with reduced fat, however, frequently present various negative characteristics, such as a very hard texture, the yield reduce, the crystallization of calcium salts with lactic acid, a lack of good flavour. These can be attributed to the important role of fat in determining the characteristic texture and flavour of cheese. However, other parameters that are altered by the reduction of fat, e.g. moisture, pH, salts etc., may play a role. Thus, a series of modifications of cheese technology have been proposed for the improvement of low-fat or reduced-fat cheese quality (Ritvanen *et al.*, 2005).

Halloumi cheese is a traditional and distinctive cheese of Cyprus. Traditionally, raw ovine and caprine milks, or a mixture of the two, were used for the

manufacture of Halloumi cheese. However, increased production of cow's milk in Cyprus has promoted the manufacture of Halloumi cheese from cow's milk alone or mixed with that of sheep or goat milk. It is widely popular in Cyprus and other countries of the Eastern Mediterranean and, more recently, the product has gained international acceptance and recognition. It is a semi-hard rindless cheese. The Committee for Standards of the Cyprus Ministry of Commerce and Industry (1985) established the definition and standards for 'fresh' and 'mature' Halloumi cheese. Two categories of Halloumi cheese with reduced-fat from cow's milk have been circulated in the Cypriot market in the past few years by the brand names of Light and Slim (Papademas *et al.*, 2000). Attempts to produce reduced fat versions of the cheese are poorly documented. Theophilou and Wilbey (2007) reported the production of a low-fat Halloumi cheese from bovine milk, where bovine whey protein concentrate (Simplese®) incorporated into the milk as replacement of milk fat. It should be noted that cow's milk contains more than 20 allergenic proteins, of which β -lactoglobulin and casein are reported to cause the most allergenic effects (El-Agamy, 2007), while for sheep's milk there are no scientific reports that it causes allergies. Furthermore, whey proteins in sheep's and goat's milk are increasingly recognized for their bioactivity or health-promoting benefits, such as their immunomodulatory and anti-microbial activities (Hernandez-Ledesma *et al.*, 2011).

Ovine milk is richer in fat, proteins, ash, calcium, iron, manganese, phosphorus, zinc, medium-chain fatty acids, monounsaturated fatty acids, linolenic acid, all essential amino acids and most vitamins (except for carotene) than bovine milk and caprine milk (Park *et al.*, 2007). Indeed, ovine milk is of high biological and nutritional value with high digestibility and hypoallergenicity (Park *et al.*, 2007). Thus, from a nutritional, and health point of view, ovine milk and its dairy products excel cow's milk (Kaminarides and Anifantakis, 2004; Kaminarides *et al.*, 2007).

Today, there are not data about the technology and quality of the production reduced-fat Halloumi type cheese from ovine milk. So, the objectives of this work were to determine differences between reduced-fat Halloumi type cheeses from ovine milk made by the traditional technology and by modified technology with six changes, especially by the step of incorporation of denatured ovine serum proteins, which are more than those of bovine milk, into the casein matrix during the heat treatment of milk (75°C/10min). The cheeses produced by two technologies were compared

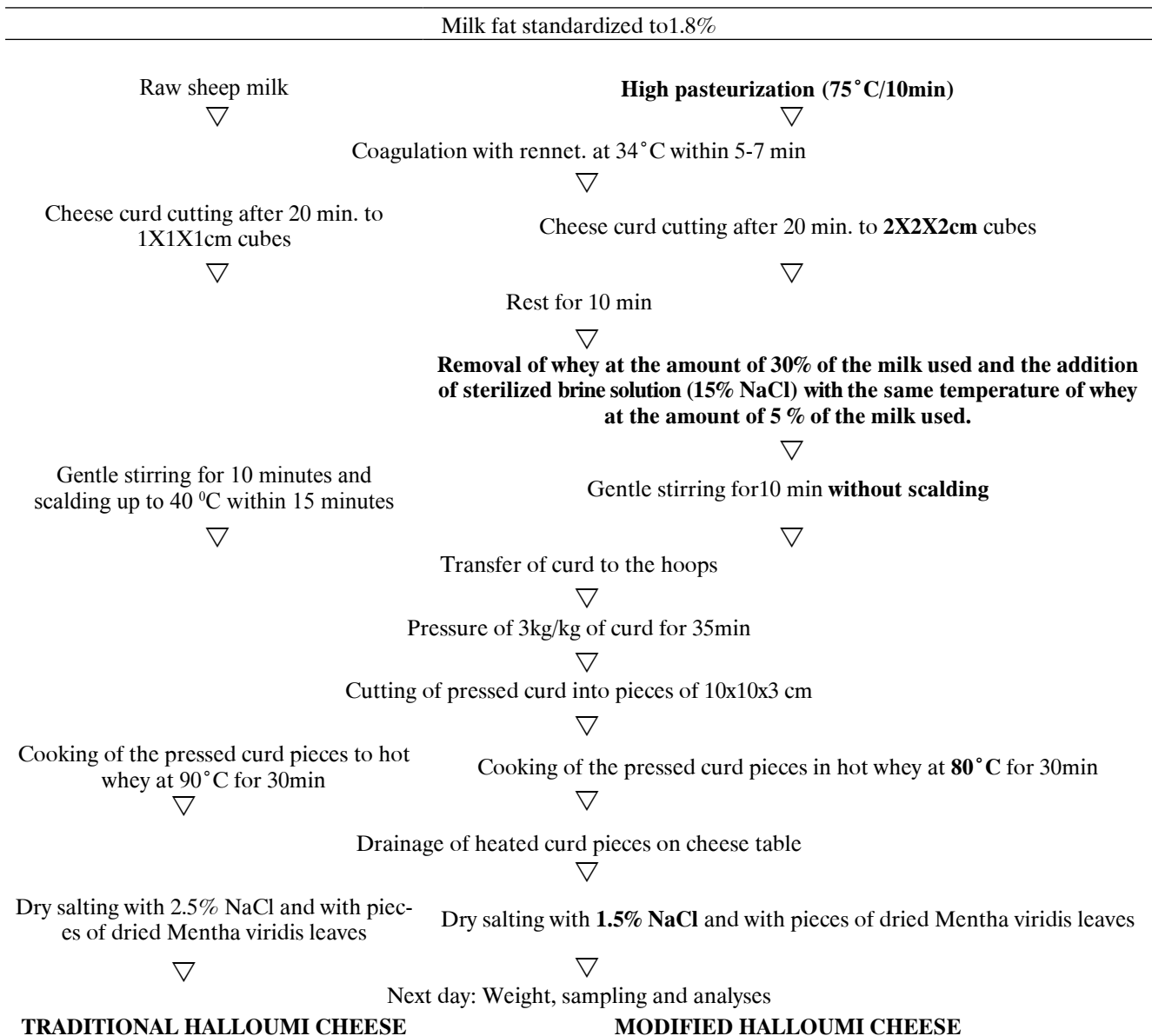


Figure 1: Flow chart for the production of reduced fat Halloumi type cheeses by traditional and modified technology. Bold letters indicate the modifications to the traditional technology.

for yield, recovery of milk solids, physicochemical, microbiological, rheological and sensory properties.

MATERIALS AND METHODS

Milk

Fresh ovine milk, without antibiotics, was obtained from the farm of the Agricultural University of Athens and standardized to 1.8% fat by separation. The standardized milk was separated into two batches and used as cheese milk for the production of reduced-fat Halloumi type cheese by two different technologies in two different vats.

Cheese Making and Sampling

In a series of five parallel pilot plant experiments, reduced-fat Halloumi type cheese was manufactured over 5 successive weeks, using two different technologies. The first trial employed traditional Halloumi cheese making technology (T) but with the milk fat standardized at 1.8% and was used as a control. The second trial utilized modified technology (M) that differed from the traditional technology as shown in Figure 1. Based mainly on bibliographic data, these modifications are indicated in bold and aimed at increasing the yield, the moisture (Rodriquez, 1998; Lo and Bastian, 1998) and improving the texture of reduced-fat Halloumi type cheese. The weight of milk and cheese produced from each trial were measured. Samples of milk and cheese from each treatment and replication were analyzed 1 day after manufacture

Physicochemical Analyses of Milk Samples

The main constituents (fat, protein, lactose, ash and total solids) of the standardized ovine milk used for the production of reduced-fat Halloumi-type cheeses were determined by the Milkoscan apparatus (model 255 A/B, type 25700, Fosselectric, Denmark). Acidity was measured by the Dornic method and pH recorded using a pH meter (model 632, Metrohm, Herisau, Switzerland). All analyses were performed in triplicate and the results are presented as the average of fifteen analyses from five trials.

Enumeration of Microorganisms

Samples (50 g) of cheese curd were transferred under aseptic conditions to Petri dishes and analyzed on the day of sampling. A sample (5g) was suspended

in 20 g L⁻¹ trisodium citrate (45 ml) to give a 1:10 dilution. Further decimal dilutions were prepared in 1/4 strength Ringer's solution. The total microbial flora was enumerated by the pour-plate method of the American Public Health Association (APHA, 1967) using Plate Count Agar (Difco, Michigan, USA) with incubation at 30°C for 2 days. Yeast and mould counts were enumerated using Yeast Extract Glucose Chloramphenicol Agar (IDF, 1991) with incubation at 25°C for 4 days. Coliforms were enumerated according to IDF (1985) using Macconkey broth (Oxoid, Hampshire, England) and incubation at 37°C for 2 days.

Physicochemical Analyses of Cheese Samples

Samples of reduced-fat Halloumi type cheese were analyzed for total N by the method of Kjeldahl (TN; IDF, 1964), total solids (TS; IDF, 1982), NaCl content (IDF 1972), fat by the method of Gerber-Van Gulic (Schneider, 1954) ash as specified in the AOAC (1975), pH was measured with a pH-meter (model 632, Metrohm, Herisau, Switzerland), acidity was measured by the method of Dornic, as specified in the AOAC (1975). Calcium, sodium, potassium and magnesium contents were determined according to procedure 119 of the IDF (2007) using a Varian spectrAA-200HT atomic absorption spectrophotometer (Varian, Victoria, Australia). Phosphorus content was determined according to spectrometric method 42: B of the IDF (1990). All analyses were performed in triplicate and the results are given as the average of 15 analyses from five trials.

Textural Evaluations

The textural properties of cheeses were measured with a Shimadzu testing instrument, model AGS-500 NG (Shimadzu Corporation, Kyoto, Japan), as described by Kaminarides and Stachtariis (2000).

Sensory Evaluation

The Halloumi type cheese sensory characteristics were evaluated by a ten-member panel of the Dairy Laboratory of the Agricultural University of Athens, which was familiar with Halloumi cheese. Panel members evaluated each cheese for appearance, texture and flavour (odour and taste) using a 10-point scale, scoring 1 for worst and 10 for best quality. Results are expressed as a mean score for the whole panel for each cheese. Also, the panel of judges were requested to record their perception of elasticity and softness on a scale from 1 to 5. Elasticity

ty (the degree to which the cheese sample deforms) was assessed by pressing a piece of cheese between the forefinger and thumb [1= inelastic, 5= elastic]. Softness was estimated as the force required to penetrate the cheese sample with the molar teeth [1= very hard, 5= very soft].

Statistical analysis

Statistical analysis was performed using the general linear model (proc GLM) statistical program S.A.S. (SAS Institute, 2005), with independent variable the technology of cheese production. The level of significance was fixed at $P = 0.05$. The comparisons of means were made with the Duncan method. The results are presented as means \pm standard error of mean.

RESULTS AND DISCUSSION

Milk Composition

The main constituents of the standardized ovine

milk used for the production of reduced-fat Halloumi-type cheeses were as follows (mean values (\pm) the standard errors of the means): 1.80 \pm 0.01% fat, 5.29 \pm 0.18% total protein, 5.02 \pm 0.17% lactose, 0.91 \pm 0.03% ash and 13.10 \pm 0.35% dry matter.

Yield and Recovery of Milk Constituents in Reduced-fat Halloumi type Cheese

Cheese yield is one of the most economically important aspects of cheese manufacture. The cheese yield depends on the composition and quality of the milk used, the technology applied during cheese production and the conditions of cheese storage. A total reduction of cheese yield is inevitable during the production of cheese from milk with a low fat content, provided that the fat in the milk is one of the main components determining cheese yield (Romeih *et al.*, 2002). The yield of the experimental cheeses T and M, 1 day after preparation, differed significantly ($P < 0.05$). From the results (Table 1), it appears that the av-

Table 1. Yield and physicochemical characteristics of reduced-fat Halloumi type cheeses produced from ovine milk by traditional (T) and modified (M) technology. (Means of 5 trials \pm standard error of mean).

Yield and physicochemical characteristics	Reduced-fat ovine Halloumi type cheeses	
	Traditional technology (T)	Modified technology (M)
Cheese yield (%)	12.86 ^a \pm 0.57	15.95 ^b \pm 0.64
pH	5.9 ^a \pm 0.09	6.3 ^b \pm 0.06
Acidity (%)	0.38 ^b \pm 0.05	0.19 ^a \pm 0.03
Moisture (%)	48.70 ^a \pm 1.14	54.51 ^b \pm 1.21
Dry matter (%)	51.30 ^b \pm 1.14	44.79 ^a \pm 1.21
Fat (%)	12.58 ^b \pm 0.27	10.66 ^a \pm 0.32
Fat in dry matter (%)	24.46 ^a \pm 0.53	24.10 ^a \pm 0.54
Protein (%)	30.74 ^b \pm 0.95	27.86 ^a \pm 1.09
Protein in dry matter (%)	59.66 ^a \pm 0.44	61.17 ^b \pm 0.59
Lactose (%)	2.62 ^b \pm 0.14	1.91 ^a \pm 0.05
Ash (%)	4.97 ^b \pm 0.11	4.32 ^a \pm 0.08
NaCl (%)	1.62 ^a \pm 0.19	1.39 ^a \pm 0.19
Ca (mg/100g)	1104.10 ^b \pm 34.13	894.32 ^a \pm 63.44
Mg (mg/100g)	56.02 ^b \pm 1.74	48.58 ^a \pm 2.61
Na (mg/100g)	715.46 ^a \pm 61.04	609.08 ^a \pm 50.12
K (mg/100g)	87.3 ^a \pm 5.43	86.52 ^a \pm 4.47

^{a, b}: Means in the same row with the same superscript did not differ significantly ($P > 0.05$)

erage yield of reduced-fat cheese by the M technology was 15.95% compared with 12.86% for the T technology. This significant difference is mainly attributed to the higher moisture content of reduced fat cheese made by the M technology (54.51%) compared to that by T technology (48.70%) and secondly to the fact that in the case of M technology more proteins are transferred to the cheese (proteins in dry matter 61.17%) compared to that by T technology (proteins in dry matter 59.66%). The latter can be attributed to the incorporation of denatured serum proteins (mainly the β -lactoglobulin) with κ - and α_{s2} -caseins in casein micelles via sulphur bridges (Walstra and Jenness, 1984) during the heat treatment of milk (75°C/10min) in M technology.

The recovery of milk constituents (i.e. the percentage of milk constituents converted into cheese) was computed from the following equation:

$$Z \text{ component recovery (\%)} = \frac{\text{Cheese weight (kg)} \times \% Z \text{ content in cheese} \times 100}{\text{Milk weight (kg)} \times \% Z \text{ content in milk}}$$

The recovery of fat, protein and total solid residue were 89.64, 74.58 and 50.21% respectively for T technology and 93.86, 84.00 and 54.50% respectively for M technology. Fat recovery was the highest of the three main solid components because milk fat is transferred almost entirely to the cheese mass. In contrast, the total solids recovery was the lowest of the three main solid components because a significant part of the water-soluble ingredients of the solids (lactose, soluble salts and serum proteins) were transferred to whey. No significant ($p > 0.05$) differences were observed between the two types of cheese concerning the recovery of fat and total solids. In contrast, protein recovery was significantly higher in reduced-fat cheese made by M technology (84%) than in that made by T technology (74.58%). The higher protein recovery in reduced-fat cheese made by M technology can be attributed to increased retention of serum proteins during high pasteurization of milk than in reduced-fat cheese made from raw milk by T technology.

Physicochemical Properties of Reduced-fat Cheeses

Significant differences ($P < 0.05$) in acidity (Ta-

ble 1) between the two types of reduced-fat Halloumi were observed, with acidity being higher in the cheeses made by T technology than in those made by M technology. This difference is attributed to the partial reduction of lactic acid and lactose contents in cheese made by the modified technology, where part of the whey was replaced with brine. Drake and Swanson (1995) reported that the washing of curd decreases and limits the acidity of cheese.

Similar differences ($P < 0.05$) in the pH of the reduced-fat Halloumi-type cheeses were observed (Table 1) with T- cheeses having a lower pH than M-cheeses due to the increased acidity of the former.

The moisture content of the cheeses differed significantly ($P < 0.05$). The cheeses made by M technology had a higher moisture content (54.51%) than those made using T technology (48.70%). This difference

was due to the six modifications (bold letters in Figure 1) made for the production of reduced-fat Halloumi type cheese by the modified technology, which enhanced the cheese moisture content. The mean moisture content of reduced-fat Halloumi type cheese made by the M technology was approaching to that reported by Economides (2004) in the Lite bovine Halloumi cheese (56.06%) and was similar to that reported by Leif et al. (2009) in the reduced-fat Halloumi cheese (53.93%).

The dry matter content of each type of reduced-fat Halloumi cheese followed a trend that was the reverse of that relating to moisture. The cheeses made using T technology had a higher dry matter content (51.30%) than that made by M technology (44.79%). This difference arose from the higher temperature used to heat the curd in T-cheese (90°C for 30min compared with 80°C for 30min for M-cheese), which increased water evaporation from the open vat, resulting in a significantly higher concentration ($P < 0.05$) of total solids in the T-cheese. The mean fat content of reduced-fat Halloumi type cheese made by the M technology (10.66%) was approaching to that reported by Economides (2004) in the Lite bovine Halloumi cheese (9.75%) and the mean fat content of reduced-fat Hal-

louni type cheese made by the T technology (12.58%) was similar to that reported by Leif *et al.* (2009) in the reduced-fat Halloumi cheese (12.83%).

Although the two types of cheese were produced from milk with the same fat content (1.8%), the cheese made by M technology had a lower fat content than that made by T technology (Table 1). This is attributed to the difference in moisture content between the two types of cheese. However, when fat was expressed on a dry matter basis, no statistically significant differences were observed (Table 1).

Similarly, the lower protein content of reduced-fat Halloumi type cheese produced by M technology (Table 1) compared with that of cheese produced by T technology is attributed to the difference in moisture content of the two cheeses (Table 1). In contrast though, when protein was expressed on a dry matter basis, we observed that the protein in dry matter of the reduced-fat M-Halloumi cheese was statistically significantly higher than that of T- cheese (Table 1). This difference could be attributed to denatured serum proteins in the pasteurized milk, since heating of the milk at high pasteurization denatured some β -lactoglobulin, which may have associated with κ - and α_{s2} -casein in the milk through disulfide bond formation (Walstra and Jenness, 1984), thus coagulating with casein during cheese making.

The lactose and ash content (Table 1) of reduced-fat Halloumi type cheese produced by M technology was statistically less than that produced by T technology. On the one hand, this difference could be attributed to the higher moisture content of this cheese, while on the other hand to the partial removal of water soluble lactose and salts during the replacement of part of the whey by brine in the M technology (Fig. 1).

No statistically significant differences ($P > 0.05$) in the NaCl content of the two types of reduced-fat Halloumi cheese were observed despite the different methods of salting. In the modified technology, NaCl was added as 10% sterilized brine containing 15% NaCl plus 1.5% dry salt to the cheese surface, whereas in the traditional technology dry salt only (2.5%) was added to the cheese surface.

There were statistically lower percentages ($P < 0.05$) of Ca, Mg and K in the reduced-fat type Halloumi cheese produced by the M technology compared

with that produced by T technology. These differences suggest that the cheese production process plays a key role in the distribution of these elements (Kandarakis *et al.*, 2004); for example, the removal of some of the whey (amounting to 30% of the milk used and the addition of sterilized brine solution (15% NaCl) to an amount of 5 % of the milk used and at the same temperature. A similar reduction in Ca was observed by realised also the researcher Rodríguez (1998), who reported that discarding the wastewater of the curd decreased the levels of soluble Ca in the cheeses with a decreased fat content. Economides (2004) also reported that reduced-fat Halloumi cheese has less Ca than traditional Halloumi. Furthermore, the increase in Ca content observed in reduced-fat Halloumi type cheese produced by T technology (heating the curd at 90°C for 30 min) compared with that in reduced-fat Halloumi type cheese produced by M technology (heating the curd at 80°C for 30 min) may result from more colloidal calcium phosphate at the higher cooking of the curd (Walstra and Jenness, 1984).

In these experiments, reduced-fat Halloumi type cheese produced from ovine milk by both M and T technologies is considered to be a rich source of calcium, 894 mg/100 g cheese and 1104 mg/100 g cheese, respectively. These amounts compare favourably with the lower calcium level present in reduced-fat Halloumi type cheese produced from bovine milk, 738 mg/100 g (Lteif *et al.*, 2009), as well as in Slim Halloumi cheese, 690 mg/100 g cheese, and Lite Halloumi cheese, 320 mg/100 g cheese, on the Cyprus market (Economides, 2004). Similarly, the magnesium content of reduced-fat Halloumi type cheeses produced from ovine milk by M and T technology (49 mg/100 g cheese and 56mg/100 g cheese, respectively) was richer than that recorded for Slim Halloumi cheese (30 mg/100 g cheese) and Lite Halloumi cheese (20 mg/100 g cheese) from the Cyprus market (Economides, 2004).

No statistically significant differences ($P > 0.05$) in Na content between the two types of cheese were recorded, since the concentration of Na depended mainly on the amount of NaCl added to cheese.

Enumeration of Microorganisms in Reduced-fat Cheeses

The T reduced-fat Halloumi type cheese had a lower total bacterial count of 3.81 log cfu/g cheese

than that the M reduced-fat Halloumi cheese, which had a total bacterial count 4.40 log cfu/g cheese. This could be attributed to the higher temperature of curd cooking in the former (93-95°C for 30 min) compared with the lower temperature (80°C for 30 min) used for the production of M- reduced-fat Halloumi type cheese. The microorganisms that survived the high heat treatment could be thermotolerant microorganisms such *Lactobacillus brevis*, *Lactobacillus pentosus*, *Lactobacillus plantarum*, *Enterococcus faecium* and *Lactobacillus cypricasei* (Lawson et al., 2001). Coliforms and yeasts -moulds were not detected in either cheese since these are susceptible to the heating time of 30 minutes.

Textural Assessment of Reduced-fat Cheeses

The results of the textural assessment are presented in Table 2. Statistical analysis of the data showed that the reduced-fat Halloumi type cheese made by T technology exhibited higher hardness, elasticity adhesiveness, gumminess and chewiness than M-reduced-fat Halloumi type cheese.

In this study, the higher hardness of T-reduced-fat Halloumi type cheese was due to the higher total solids and ash content, the lower pH value and lower moisture content compared with that of M-reduced-fat Halloumi type cheese (Table 1). It is already known that a low pH results in the hardest cheese (Creamer and Olson, 1982).

The reduction of cohesiveness observed in cheese prepared by M technology could be attributed to se-

rum proteins incorporated into it after the high pasteurization of the milk. Intense heat treatment of milk (M-cheese) has the effect of creating a weak cheese curd and looser paracasein network.

The lower elasticity observed in reduced-fat Halloumi cheese prepared by M technology could be attributed to serum protein incorporation after high pasteurization and their retention by caseins to form a more inelastic gel. Also, calcium content influenced positive the cheese elasticity. This appears to be in agreement with Prentice et al. (1993) that the rheological role of casein in cheese is to provide a continuous elastic framework for the individual cheese granules.

As shown in Table 2, the M-reduced-fat Halloumi type cheese had a lower adhesiveness value than T-reduced-fat Halloumi type cheese. The M-reduced-fat Halloumi type cheese had a lower gumminess value than T-reduced-fat Halloumi type cheese. The M-reduced-fat Halloumi type cheese had a lower chewiness value than T-reduced-fat Halloumi type cheese.

Organoleptic Evaluations

The results of the taste panel assessment (Table 3) showed that the reduced-fat Halloumi type cheese made by M technology received significantly ($P < 0.05$) higher scores for taste and flavour, texture and appearance than the reduced-fat Halloumi type cheese made by traditional technology. M- reduced-fat Halloumi type cheese had a softer texture, whiter color and was liked more. The stronger white coloring of cheese made by M technology is due to the coagulation of the serum proteins and their incorporation into

Table 2. Rheological characteristics of reduced-fat Halloumi type cheeses produced from ovine milk by traditional (T) and modified (M) technology. (Means of 5 trials \pm standard error of mean).

Rheological characteristics	Reduced-fat ovine Halloumi type cheeses	
	Traditional technology (T)	Modified technology (M)
Hardness (N)	21.65 ^b \pm 2.18	13.71 ^a \pm 1.44
Cohesiveness (N.mm)	0.51 ^a \pm 0.014	0.47 ^a \pm 0.015
Elasticity (mm)	0.96 ^b \pm 0.007	0.92 ^a \pm 0.010
Adhesiveness (N.mm)	37.89 ^b \pm 4.76	21.83 ^a \pm 2.48
Gumminess (N.mm)	11.09 ^b \pm 1.79	6.36 ^a \pm 0.65
Chewiness (N.mm)	10.66 ^b \pm 1.80	5.87 ^a \pm 0.63

^{a, b}: Means in the same row with the same superscript did not differ significantly ($P > 0.05$)

Table 3. Organoleptic evaluation of reduced-fat Halloumi type cheeses produced from ovine milk by traditional (T) and modified (M) technology. (Means of 5 trials \pm standard error of mean).

Organoleptic characteristics	Reduced-fat ovine Halloumi type cheeses	
	Traditional technology (T)	Modified technology (M)
Taste and flavour(10)	7.02 ^a \pm 0.72	7.86 ^b \pm 0.24
Texture (10)	6.67 ^a \pm 0.24	7.86 ^b \pm 0.11
Appearance (10)	7.09 ^a \pm 0.32	8.42 ^b \pm 0.24

^{a,b}Means in the same row bearing a common superscript did not differ significantly ($P > 0.05$).

the cheese curd. In contrast, the reduced-fat Halloumi type cheese made by T technology it was very hard and more yellowish in appearance.. The application of high temperatures (90°C for 30 min) during the cheese curd cooking in T technology resulted in the formation of compounds that darken the colour of the cheese as a result of the Maillard reaction due to lactose reacting with its amino compounds, and cause increased evaporation of water from the open vat.

CONCLUSION

The results obtained enable us to draw the following conclusions: The novel reduced-fat ovine Halloumi type cheese produced by M technology had a higher yield due to higher moisture content and a higher percentage recovery of milk constituents in cheese. Also, M-reduced-fat ovine Halloumi type cheese had a softer texture, whiter color, higher sensory scores, and protein (caseins & serum proteins) in dry matter content, increasing the quality of this type of cheese compared with the T-reduced-fat ovine Halloumi type cheese.

Therefore, it is proposed to utilise the M technology for the manufacture of good quality ovine Halloumi cheese with reduced-fat content. In contrary, T-reduced-fat ovine Halloumi type cheese had a higher acidity, calcium and phosphorus concentrations compared with the M-reduced-fat ovine Halloumi type cheese.

Further in this study the ovine cheeses obtained by these both technologies had a higher nutritional value (Ca and Mg content) than those of reduced-fat bovine Halloumi cheese currently available in the Cyprus market than that recorded for Slim Halloumi cheese and Lite Halloumi cheese from the Cyprus market (Economides, 2004).

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CONFLICT OF INTEREST STATEMENT

I have no conflict of interest to declare.

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