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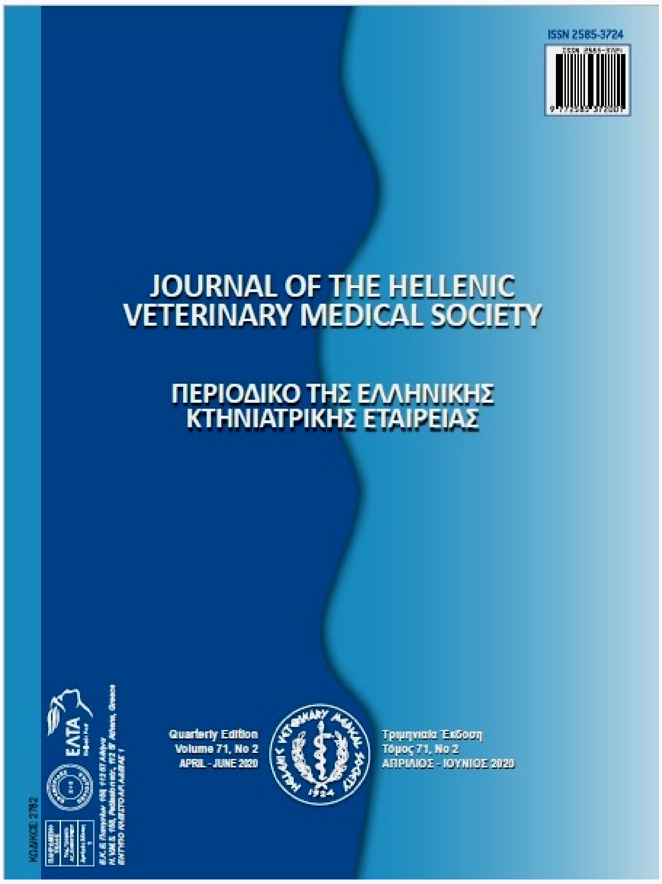

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Research article
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Effect of whey fat content on the properties and yields of whey cheese and serum

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ABSTRACT: The objective of this research was to study the effect of cheese whey fat content on the yield, physicochemical, textural and sensory properties of cheeses made from sheep's whey. Four types of whey cheese were made from skimmed whey (cheese A), whole whey (cheese B) and whey with added cream of 2.5% and 5% fat (cheeses C and D respectively) and evaluated. Significant differences in yield, sensory properties, total solids, moisture, fat, fat in dry matter, protein, calcium, hardness, modulus of elasticity, gumminess and chewiness were observed between the different types of cheeses. No significant differences were observed in pH, lactose, ash, lactic acid, citric acid, galactose, glucose, Mg, K, Na and cohesiveness. The increase in fat in whey cheeses improved yield, sensory and textural properties. Cheese D was the most preferred of all the experimental cheeses in sensory analysis: it had the highest level of fat in dry matter (77.3%) and the lowest moisture content (51.6%) and according to Greek Food Legislation is characterized as an excellent quality whey cheese. Cheese A had the lowest fat content (3.94%), scored of 61.2% overall in sensory analysis and was characterized as a new reduced-fat whey cheese, particularly suitable for customers who prefer reduced-fat cheese. Serum from whey cheese production should not be considered as a waste but might be exploited as a valuable source of carbohydrate, nitrogenous compounds and minerals. Serum resulting from whey cheese production indicates that it should not be treated as waste-pollutant but as a valuable source of carbohydrate, nitrogenous compounds and minerals from which usable products may be obtained.

Keywords: whey cheese, serum, biochemical characteristics, texture, sensory evaluation.

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INTRODUCTION

Cheese whey is the liquid portion that remains after milk coagulation and removal of the curd during the cheese-making process. Cheese whey is a major by-product of the dairy industry, produced in ever increasing quantities (Peter, 2006) and usually discarded, resulting in a loss of milk constituents of excellent nutritional value in addition to environmental pollution (Gonzalez, 1996). Cheese whey contains about half of milk dry matter and its chemical composition differs according to the types of cheese produced, in particular, the kind of milk used. Sheep's cheese whey is richer in fat, proteins and ash than cow's and goat's cheese whey (Anifantakis, 1991) and is of higher biological and nutritional value. Cheese whey is an exellent source of readily available proteins and essential amino acids comprise 37.6% of the total amino acids of sheep whey proteins (Hejtmankova *et al*., 2012). Whey cheeses are manufactured all over the world and bear distinct names depending on the country of origin. In the Mediterranean region whey cheese manufactured mainly from sheep's cheese whey, which contains high percent of the water soluble milk proteins β-lactoglobulin and α-lactalbumin. In Greece, approximately 250,000 tons of whey cheeses are produced, mainly from sheep's cheese whey. The best known traditional fresh Greek whey cheeses are Myzithra and two cheeses with a protected designation of origin (PDO) fresh Manouri and mature Xynomyzithra Kritis cheese.

The novelty and aims of this study were: (a) the effect of cheese whey fat content on the yield, physicochemical, textural and sensory properties of whey cheeses made from sheep's cheese whey, (b) the collection of data on the constituents of serum after the manufacture of whey cheese in relation to the fat content of the cheese whey.

MATERIALS AND METHODS

Whey cheese

Whey was obtained from sheep's milk after 'Graviera' cheese manufacture in the pilot plan of the Dairy Laboratory of the Agricultural University of Athens. The main constituents of whole whey (B-whole whey, control) determined by the Milkoscan apparatus (model 255 A/B, type 25700, Fosselectric, Denmark), were as follows (mean values ± the standard errors of the means): 6.73±0.12% total solids, 0.61±0.08% fat, 1.74±0.30% protein, 3.93%±0.14% lactose and 0.45±0.06% ash. The remaining whole whey was skimmed to a fat content of 0.19% (A-skimmed whey) from which two additional whey forms (samples C and D standardized to 1.65% and 3.15% fat content, respectively were produced by the addition of cream of 2.5% and 5% fat to whole whey). These, four types of sheep's whey with 0.19%, 0.61%, 1.65% and 3.15% fat content were then used to make whey cheeses A, B, C and D, respectively.

Cream

Sheep's cream with 50% fat was used.

Cheesemaking and sampling

Four types of whey cheese were produced at the Dairy Laboratory of the Agricultural University of Athens according to the following procedure:

-Collection of whey after the production of Graviera cheese from sheep milk.

- Filtration of the cheese whey in order to remove any existing curd grain.

- Whey standardization to 0.19%, 0.61%, 1.65% and 3.15% fat and transfer to four circular cheese vats.

-Heating of the whey gradually under continuous stirring to 65°C.

-At 65°C, cream was added to two vats of whey in the amounts stated in the experimental plan for C and D whey cheeses.

-Heating continued under gentle stirring up to 85°C. When small curd particles of whey proteins appeared, the temperature was increased to 90°C, and the rate of stirring reduced, finally stopping when a very thin layer of coagulum formed on the surface of the cheese whey.

-The curd was held at 90°C for 30 min; then transferred gradually by a perforated ladle to cheese cloth to facilitate drainage.

-Finally, the curd was transferred to a well-ventilated room at 20°C to drain until the next day.

Four replicates of each type of whey cheese were produced. The cheeses from each treatment were weighed, sampled and analyzed.

Physico-chemical analysis

The pH of all the whey cheeses was determined using a pH-meter (632 Metrohm, Herisau, Switzerland).

Total solids (TS) were determined according to IDF (1982). Fat was analyzed according to the volumetric method of Gerber- Van Gulic (Schneider, 1954). Ash was determined by drying at 550°C to constant weight (IDF, 1964). Total nitrogen (TN), was determined by the Kjeldahl method according to IDF (1993). Water-soluble nitrogen (WSN) was obtained by homogenizing 25g cheese with 100 ml H_2O according to the method for WSN extraction, cited in Butikofer and Ruegg (1993) and determined by the Kjeldahl method (IDF 1993). Lactose, galactose, glucose, lactic acid and citric acid were analyzed by high performance liquid chromatography (HPLC). An HPLC system, GBC (Scientific Equipment, Dandenorg, Victoria, Australia) equipped with a pump GBC, LC 1150 and refractive index detector (RI) GBC, LC 1240 was used. Separation was carried out in a column Aminex HPX-87H cation exchange 300 mm x 7.8 mm (Bio-Rad, Hercules, CA, USA) following the procedure described by Kaminarides *et al*., (2007). Ca, Mg, K and Na contents were determined by Atomic Absorption Spectrometry (IDF, 2007). All analyses were performed in triplicate.

Textural evaluation

The textural properties of the whey cheese were measured with an Instron Universal Machine (Angstrom 1011, Buckingham HP 12 3SY, UK). A plunger with a diameter of 6 mm was attached to the moving crosshead. The speed of the crosshead was set at 2.5 cm min^{-1}. The cheese sample was placed on a flat holding plate at 15°C and the plunger inserted 20 mm below the cheese surface. Two bites were taken per sample. The following textural characteristics were calculated from the resulting force-deformation curve obtained:

Hardness: Perception of required force (N) to achieve a deformation in the first bite.

Modulus of elasticity: The modulus of elasticity was also calculated at the part of the force-deformation curve and defined as the ratio of stress to strain and is the slope of the force-deformation curve.

Cohesiveness: Defined as the ratio of the positive area under the curve during the second compression to that during the first compression.

Gumminess: Is the product of hardness X cohesiveness and is the energy required to disintegrate a cheese to a state ready for swallowing.

Chewiness: Is the product of gumminess X elasticity and is the energy required to masticate a cheese to a state ready for swallowing.

Sensory evaluation

The cheese sensory characteristics were graded by a ten-member taste-panel of the Dairy Laboratory of the Agricultural University of Athens. Panel members, who were familiar with this type of cheese, evaluated each sample 1 day after its manufacture for appearance, texture and flavour on a 10-point scale, from one signifying the worst to ten signifying the best quality. More importance was given to flavour and to texture than appearance of the cheese, as advised by the IDF Standard 99C (1997), by multiplying their scores by 5 and 4 respectively. The total score was obtained by adding the scores based on the three attributes. An excellent cheese obtained a total score of 100. The panel was asked to note any defects.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using the statistical program Statgraphics Plus for Windows v. 5.2 (Manugistics, Inc., Rockville, MO, USA). Paired comparisons of means were made using the Duncan test with a 95% confidence level and 5% significance ($P \leq 0.05$).

RESULTS AND DISCUSSION

Physicochemical characteristics of whey cheeses

The physicochemical characteristics of the experimental whey cheeses A, B, C and D are shown in Table 1. There were statistically significant differences ($P>0.05$) in moisture content, which decreased as the percentage of fat in whey increased. The moisture content ranged from 51.57 to 75.27% (w/w) and in the experimental cheeses B, C and D remained within the upper limit (maximum 70%) set for whey cheese by the Greek Codex Alimentarius (2014). In contrast, the moisture content of A-cheese (75.27%) was significantly higher than that of whey cheeses B, C and D ($P < 0.05$). In the present study, as expected, the fat content of the four types of whey cheese differed significantly ($P>0.05$) and it was observed that the increase in fat content in cheeses B,C and D compared with that of A resulted in a decrease in moisture content. This could be due to the presence of fat globules in the network protein creating wider pores in the curd (Walstra *et al.,* 1999) and thus facilitating drainage. Lteif *et al.* (2009) reported a similar finding for Haloumi cheese where low fat content resulted in a higher moisture level. The total solids content followed a trend that was the reverse of that relating to moisture.

The fat content of whey cheeses was highest (37.33%) in D-cheese produced from whey + 5.0% cream, followed by 24.61% in C-cheese produced from whey + 2.5% cream. Cheese B made from whole whey without the addition of cream had a significantly lower fat content (11.79%) than C and D, while A-cheese (made from skimmed whey had the lowest fat content of all (3.94%). Overall whey cheeses produced from whey with 4 different fat contents (0.19- 3.15), contained from 3.94 to 37.33% fat or 15.80-77.48% fat in dry matter (FDM). We classify A as a new reduced-fat whey cheese, while the cheeses B and C are classified as Myzithra cheese on the basis of maximum moisture 70% (Greek Codex Alimentarius, 2014). Type Cheese-D is characterized as an excellent quality whey cheese based on maximum moisture content of 60% and minimum fat in dry matter 70% and is classified as Manouri cheese (Greek Codex Alimentarius, 2014).

The protein content ranged from 11.37% to 15.77% (w/w) and decreased as the amount of fat in the whey increased. According to Sánchez-Macías et al. (2010), in traditional cheese produced from fresh cow's milk fat reduction resulted in increased protein.

The mean lactose content among the different types of whey cheese ranged from 4.06% (cheese-A) to 3.56% (cheese D) which was similar to that reported by Kalantzopoulos (1993) for Myzithra and Riccotta cheese. Although the lactose content did not differ to a statistically significant level between the cheeses, the lower value for cheese D is likely to have been resulted from due to the addition of 5% cream, which had lower lactose content than that of the whole whey itself.

The percentage of ash among cheeses did not differ (P> 0.05), but appeared to be highest in cheese A, which had the highest Ca content (Table 1). The concentrations of the inorganic elements in whey cheeses are shown in Table 1. Ca content ranged between 61.43 mg/100g cheese in cheese D and 162.40 mg/100g cheese in cheese A. The high Ca content of cheese A was probably due to its high percentage of serum proteins (Table 1), including α-lactalbumin (α-La), in each molecule of which 2 mole Ca is strongly bound (Walstra and Jenness 1984). The Mg, K and Na content of the cheese samples ranged from 11.31-24.31, 85.84-139.44 and 39.38-112.69 mg/100g cheese respectively without statistically significant differences between them.

Galactose and glucose, the monomers of lactose, produced via lactose catabolism by the starter cultures used, ranged from 0.15% to 0.23% and 0.03% to 0.05%, respectively. The greater proportion of galactose in relation to glucose can be attributed to the fact that *Streptococcus thermophilus,* present in the starting culture used in the production of Graviera cheese, does not metabolize galactose. A correspondig result was observed in Mozzarella cheese where *Streptococcus thermophilus* and *Lactobacillus bulgaricus* were used and the whey content of galactose and glucose was 0.12% and 0.01%, respectively (Gernigon et al., 2009). Citric acid was detected at low concentrations in the whey cheeses, ranged from 0.17% to 0.27, and did not differ significantly between the four types of cheese. There were also no significant differences ($P>0.05$) in pH values and lactic acid. Lactic acid, which ranged from 0.15–0.20 %, constitutes the main metabolic product of lactose by starter cultures and lowers the pH of whey cheese (Table 1).

Texture profile analysis of whey cheeses

Table 1 shows the data obtained from texture profile analysis carried out on cheese made from sheep's whey with different fat percentages. Statistically significant differences were recorded for hardness ($P<0.05$), which decreased as fat content increased. The increase in fat globules within the network protein creates wider pores in the curd (Walstra *et al.,* 1999), which weaken the protein matrix and give a softer texture to the cheese (Walstra and Jenness, 1984). Also, this phenomenon related to the protein and Ca content of the samples, since cheese-A with a high protein and Ca content exhibited greater hardness than cheese-D with a low percentage of these constituents (Kaminarides and Stachriaris, 2000). The calcium lever acts as cement within the cheese body and the increase of cheese protein leads to a harder texture (Adda *et al.,* 1982). Statistically significant differences were also found ($P<0.05$) in modulus elasticity. Elasticity decreased with fat content and was lowest in cheese-A, produced from skimmed whey. According to Adda *et al.* (1982), a higher fat content in cheese leads to a less elastic body. No significant difference ($P > 0.05$) was observed in cohesiveness between the different types of whey cheese. Cheese-A, produced from skimmed whey, exhibited the highest values for gumminess and chewiness due to its greater hardness. As the fat content increased, less strength was required to chew because the body became softer.

Cheese yield and recovery of whey constituents in cheese

Cheese yield is one of the most economically important aspects of cheese manufacture and the factor that most affects cheese yield is its chemical composition, especially the fat and protein content, which accounts for more than 90% of the solid ingredients. The yield of whey cheeses affected significantly by the whey fat content: The more fat within the whey higher the yield. From the results (Table 1), it appears that average yield was highest in cheese D (7.09%) derived from whey to which 5% cream was added, followed in decreasing order by the types C (5.02%) derived from whey to which 2.5% cream was added, B (4.27%) derived from whole whey and A (2.73%) derived from skimmed whey. The mean yield of cheese B was similar to that reported by Kaminarides *et al.* (2013) for Myzithra whey cheese (4.30%with 68.04% moisture) produced from sheep's whole whey without the addition of milk or cream to the whey.

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

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

Table 1. Yield, physicochemical and textural characteristics of whey cheese made from whey differing in fat content. (Means of 4 trials ± standard error of mean).

Parameters	Whey cheeses			
	A	B	C	D
Moisture (%)	75.27^{d}± 1.99	69.07^{c}± 2.67	57.50^{b}± 3.02	51.57^{a}± 3.62
Total solids (%)	24.73^{a}± 1.99	30.93^{b}± 2.67	42.50^{c}± 3.02	48.43^{d}± 3.62
Fat (%)	3.94^{a}± 1.00	11.79^{b}± 1.20	24.61^{c}± 4.67	37.33^{d}± 0.58
Fat in dry matter (%)	15.80^{a}± 2.78	38.15^{b}± 2.83	58.14^{c}± 11.65	77.48^{d}± 6.90
Total protein (%)	15.77^{b}± 0.39	14.21^{b}± 1.34	13.87^{b}± 1.75	11.37^{a}± 1.45
Lactose (%)	4.06^{a}± 0.36	3.68^{a}± 0.31	3.62^{a}± 0.32	3.56^{a}± 0.10
Ash (%)	0.71^{a}± 0.12	0.65^{a}± 0.10	0.57^{a}± 0.07	0.55^{a}± 0.06
Lactic acid (%)	0.15^{a} ± 0.06	0.20^{a} ± 0.05	0.19^{a} ± 0.06	0.16^{a} ± 0.07
pH	6.00^{a} ± 0.09	5.36^{a} ± 0.81	5.69^{a} ± 0.67	5.88^{a} ± 0.88
Galactose (%)	0.15^{a}± 0.11	0.23^{a}± 0.11	0.19^{a}± 0.15	0.17^{a}± 0.09
Glucose (%)	0.03^{a}± 0.01	0.05^{a}± 0.04	0.05^{a}± 0.04	0.05^{a}± 0.03
Citric acid (%)	0.27^{a}± 0.07	0.21^{a} ± 0.04	0.23^{a} ± 0.04	0.17^{a} ± 0.01
Ca (mg/100g cheese)	162.40^{b}± 54.03	95.52^{ab}± 10.46	69.80^{ab}± 7.93	61.43^{a}± 51.68
Mg (mg/100g cheese)	24.31^{a}± 5.98	17.81^{a}± 3.86	14.68^{a}± 4.85	11.31^{a}± 1.05
K (mg/100g cheese)	139.44^{a} ± 34.34	133.01^{a} ± 18.00	100.66^{a} ± 47.66	85.84^{a}± 6.69
Na (mg/100g cheese)	81.13^{a}± 34.05	112.69^{a} ± 49.34	58.55^{a}± 17.01	39.38^{a}± 14.57
Hardness (**N**)	7,60^{c} ±0,40	5,73^{b} ±0,45	5.30^{b}± 0.30	4.40^{a}± 0.14
Modulus of elasticity (N/mm)	1.17^{b} ±0.08	0.84^{a} ±0.12	0.83^{a} ±0.13	0.79^{a} ±0.12
Cohesiveness (**N** mm)	0.56^{a} ±0.01	0.60^{a} ±0.05	0.61^{a} ±0.10	0.55^{a} ±0.13
Gumminess (**N** mm)	4.27^{b} ±0.27	3.19^{a} ±0.47	2.67^{a} ±0.35	3.10^{a} ±0.53
Chewiness ((**N** mm)	4.95^{b} ±0.01	2.63^{a} ±0.02	2.07^{a} ±0.01	2.61^{a} ±0.80
Yield cheese (%)	2.73^{a}± 0.27	4.27^{b}± 0.70	5.02^{b}± 0.73	7.09^{c}± 0.63
Coefficient of recovery:				
-of whey total solids into cheese (%)	10.55^{a}± 0.98	19.72^{b}± 1.54	27.66^{b}± 2.39	38.26^{c}± 1.56
-of whey fat into cheese (%)	59.57^{a}± 2.14	62.53^{a}± 3.00	75.07^{b}± 6.95	84.23^{b}± 7.58
-of whey protein into cheese (%)	24.78^{a}± 2.93	34.28^{ab}± 7.94	39.39^{b}± 3.05	43.54^{b}± 6.82
-of whey lactose into cheese (%)	2.52^{a}± 0.13	4.04^{b}± 0.77	4.46^{b}± 0.91	4.81^{b}± 0.87

Means in the same row followed by different letters are significantly different (Duncan test, P<0.05).
A: skimmed whey; B: 100% whole whey; C: 97.5% whole whey + 2.5% cream; D: 95% whole whey + 5% cream.

Fat recovery was the highest of the four main solid components because milk fat is transferred almost entirely to the cheese mass. Protein recovery was lower than fat recovery because the proteose-peptone is a fraction of the whey proteins which is not rendered insoluble by heating the whey during whey cheese manufacture and is therefore not transferred to the cheese mass. Total solids recovery was lower than protein recovery because a significant part of the water-soluble ingredients of the solids such as lactose, soluble salts, the proteose-peptone fraction and other soluble constituents remained in serum. Lactose recovery was still lower because the bulk of the water-soluble lactose remained in serum. There were statistically significant differences ($P<0.05$) in the recovery of fat, protein, total solids and lactose from the different types of whey used to whey cheeses production and this significantly affected whey cheese yield. Cheese D, produced from 95% whole whey + 5% cream, had the highest cheese yield as it had the highest recovery of total solids, fat and protein this led to better incorporation of each main whey constituent into cheese.

Physicochemical characteristics of different serums

Serum is the liquid residue that remains after whey cheese production. Since to our knowledge the composition of serum after whey cheese production of whey components and the rate of transfer of whey components to the serum has not been previously published, a second objective of this study was to examine the physicochemical characteristics of serum after the preparation whey cheese varying in fat content and to calculate the coefficients of total solids, fat, protein and lactose of remain in the liquid residue following removal of whey cheese. The results obtained are shown in Table 2. Serum is composed of 5.88-6.25% total solids, of which around 69.9-75.5% is lactose, 18.2-19.7% is crude proteins and 7.7-8.5% is ash. The remaining constituents determined quantitatively were lactic acid, citric acid, galactose, glucose and the elements Ca, Mg, K and Na. The coefficient of lactose transfer into serum was particularly high and ranged from 88.66% in the serum D to 93.7% in the serum A. These compositional characteristics render whey serum a serious pollutant if disposed of as waste. On the other hand, with appropriate treatment serum but might be exploited as a valuable source of carbohydrate suitable for incorporation into products for animal feed (biomass), human food (alcohol, other organic chemicals, lactose extraction, glucose-galactose syrup) and as an industrial fuel (methane).

Table 2. Physicochemical characteristics of serum after the manufacture of whey cheese from whey differing in fat content. (Means of 4 trials ± standard error of mean).

Parameters	Serum			
	A	B	C	D
Total solids (%)	6.13 ^{a} ±0.41	5.88 ^{a} ±0.42	5.97 ^{a} ±0.42	6.25 ^{a} ±0.43
Fat (%)	0.02 ^{a} ±0.02	0.07 ^{a} ±0.02	0.13 ^{ab} ±0.04	0.25 ^{b} ±0.16
Crude protein (%)	1.21 ^{a} ±0.05	1.12 ^{a} ±0.14	1.15 ^{a} ±0.10	1.14 ^{a} ±0.12
Lactose (%)	4.63 ^{b}± 0.20	4.21 ^{a}± 0.09	4.18 ^{a} ± 0.07	4.37 ^{ab} ± 0.21
Ash (%)	0.47^{a}± 0.02	0.48^{a}± 0.05	0.51^{a}± 0.02	0.49^{a}± 0.03
Lactic acid (%)	0.10 ^{a} ± 0.05	0.21^{a} ± 0.07	0.15 ^{a} ± 0.09	0.15 ^{a} ± 0.05
pH	6.18 ^{a} ± 0.25	6.03 ^{a} ± 0.46	6.12 ^{a} ± 0.40	6.10 ^{a} ± 0.47
Galactose (%)	0.16^{a}± 0.08	0.31^{a}± 0.11	0.27^{a}± 0.13	0.22 ^{a}± 0.09
Glucose (%)	0.02^{a}± 0.01	0.05^{a}± 0.04	0.05^{a}± 0.03	0.06^{a}± 0.03
Citric acid (%)	0.21^{a}± 0.03	0.21^{a} ± 0.01	0.19^{a} ± 0.04	0.22^{a} ± 0.01
Ca (mg/100g)	49.67^{a}± 1.58	48.41^{a}± 8.78	45.25^{a}± 5.20	49.03^{a}± 9.96
Mg (mg/100g)	13.61^{a}± 1.58	14.41^{a}± 2.67	12.86^{a}± 0.67	13.01^{a}± 1.15
K (mg/100g)	153.54^{a} ± 44.23	133.53^{a} ± 11.47	180.72^{a} ± 29.02	172.33^{a}± 41.03
Na (mg/100g)	79.83^{a}± 17.40	86.98^{a} ± 33.36	83.31^{a}± 22.46	78.36^{a}± 14.22
Coefficient of transfer :				
-of whey total solids into serum (%)	85.84^{d}± 1.51	76.93^{c}± 3.07	68.75^{b}±4.96	56.57 ^{a} ± 2.89
-of whey fat into serum (%)	9.67^{a}± 2.53	7.29^{a}± 9.83	7.01^{a}± 4.85	6.47^{a}± 4.11
-of whey protein into serum (%)	61.49^{a}± 2.88	56.10^{a}± 7.09	54.88^{a}± 5.35	50.31^{a}± 5.69
-of whey lactose into serum (%)	93.70^{a}± 11.83	93.11^{a}± 1.92	90.07^{a}± 2.67	88.66^{a}± 3.53

Means in the same row followed by different letters are significantly different (Duncan test, $P<0.05$).
A: skimmed whey; B: 100% whole whey; C: 97.5% whole whey + 2.5% cream; D: 95% whole whey + 5% cream.

Table 3. Sensory evaluation of whey cheese made from whey differing in fat content. (Means of 4 trials ± standard error of mean).

Sensory characteristics	Whey cheeses			
	A	B	C	D
Appearance (1-10)	7.04[a] ±0.63	8.05[b] ±2.56	8.73[bc] ±2.68	9.25[c] ±2.64
Texture (1-40)	23.72[a]±0.89	31.76[b] ±2.48	33.36[bc] ±2.50	35.40[c] ±2.56
Flavour (1-50)	30.4[a] ±0.82	37.45[b] ±2.37	40.55[bc] ±2.43	42.55[c] ±2.45
Total (1-100)	61.16[a] ±8.25	77.26[b] ±1.97	82.63[bc] ±0.49	87.21[c] ±4.98

Means in the same row followed by different letters are significantly different (Duncan test, P<0.05).
A: skimmed whey; B: 100% whole whey; C: 97.5% whole whey + 2.5% cream; D: 95% whole whey + 5% cream.

The lactose content of the serum varied significantly between 4.18 and 4.63% and it is necessary either to develop an effective method to recover lactose by evaporation, crystallization, washing, centrifuging and drying for crystalline lactose, or by fermentation of serum lactose by different microorganisms and the production of valuable products such as: a) ethyl alcohol and single cell protein (SCP) using yeast strains (e.g. *Saccharomyces fragilis*, *Kluyveromyces marxianus, Torula cremoris*, *Candida pseudotropicalis*), b) microbial lipid that contains "rare" poly-unsaturated fatty acids (PUFAs) of nutritional and pharmaceutical importance, e.g. g-linolenic acid (GLA–D6,9,12C18:3) by various oleaginous microorganisms, c) lactic acid by lactic acid bacteria such as *Lactobacillus bulgaricus*, d) butyric acid by butyric bacteria such as *Clostridium butyricum*, e) propionic acid by propionic bacteria such as *Propionibacterium shermanii*, f) the enzyme β-galactosidase or lactase by *Kluyveromyces marxianus* or *Candida pseudotropicali and g)* methane, vitamins, amino acids, penicillin, polysaccharides as food gums, hydrolysed lactose syrup, beverages etc.

Crude protein transfer rates from cheese whey to serum were low and varied from 1.12- 1.21% with no significant differences in relation to the fat content of the whey. The term 'crude protein' in Table 2 indicates that the nitrogen content is converted to protein content using the conversion factor 6.38. However, nitrogen in serum consists mainly of non-protein nitrogen and true proteins are mainly proteose-peptones, which are heat-resistant (Walstra and Jenness, 1984) and remain soluble by heating the whey during the cheese-making process, and fine casein granules which were not incorporated in the cheeses during drainage. Salvatore *et al.* (2014) reported that the crude protein content of serum after the manufacture of Ricotta cheese was about 1%, which was similar to that in our experiments.

Fat content of the sera varied significantly between 0.02-0.25%. The highest fat transfer from cheese whey to serum occurred in serum A (9.67%) and the lowest in serum D (6.47%).

Other serum components, which did not differ significantly in relation to the fat content of the whey were: 0.47-0.51 % ash; 0.10-0.21 % lactic acid; 0.16-0.31 % galactose; 0.02-0.06% glucose; 0.19-0.22 % citric acid; 133.53- 180.72 mg/100g K; 78.36-86.98 mg/100g Na; 45.25-49.67 mg/100g Ca; 12.86- 14.41 mg/100g Mg.

3.5. Sensory characteristics of whey cheeses

Table 3 shows the results for the sensory evaluation of the four cheeses. The highest total scores were received by D-cheese, which was characterized as the most flavorful, soft and aromatic, possibly due to its increased fat content resulting from the greater amount of cream added to the whey during cheese production. D-cheese is characterized by the Greek Codex Alimentarius (2014) as Manouri, which is a PDO cheese and is considered the most delicious of whey cheeses with higher fat content (>70% of its dry substance) and lower moisture content than other types of whey cheese. C-cheese, which contained less fat than D-cheese, was considered better than A and B cheeses which were produced from whey without added cream. C and B cheeses are characterized by the Greek Codex Alimentarius (2014) as Myzithra. B-cheese, produced from whole whey, it was frangible and had a slightly granular texture. Finally, A-cheese, which was made by skimming the cheese whey to 0.2% fat, was hard, frangible and granular, due to it having the lowest fat and highest protein and calcium content (Table 1): Cheese-A is characterized as a new reduced-fat whey cheese. The above are in agreement with Sanchez-Macias et al. (2012) who stated that the fat content positively modifies sensory properties and consumer acceptance.

CONCLUSION

The fat content significantly influenced physico-chemical parameters such as moisture content, protein, Ca and cheese yield. The increase in fat in the cheese whey affected the physico-chemical composition and improved the rheological, sensory characteristics and yield of whey cheese. The addition of cream reduced hardness, modulus of elasticity and led to higher yield and cheese quality (soft texture and rich flavor) compared to cheese made from whey without the addition of cream. Also, the use of cream in the production of whey cheese will help the valorization of cream. In contrast, the skimming of whey caused a significant deterioration in whey cheese quality. The recovery of fat, protein, total solids and lactose in whey cheeses was proportional to the fat content of cheese whey and was significantly higher in D-cheese. In serum, during the manufacture of whey cheese 90-93% of cheese whey lactose, 50-61.49% of crude protein and 6.47-9.67% of fat was transferred and if this serum is irresponsibly disposed of, it will cause environmental pollution due to its high organic load. In contrast, we propose that serum from whey cheese production can be processed in various ways to obtain usable products or be used as a substrate by microbial species to produce metabolic compounds of added value.

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CONFLICT OF INTEREST STATEMENT

We have no conflict of interest to declare.

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