Research in: Agricultural & Veterinary Sciences
Vol.2, No.2, 2018, pp.75-84

LIPOLYSIS PROFILE OF SOME GREEK PASTEURIZED MILK CHEESES: A REVIEW OF LITERATURE DATA OVER THE LAST TEN YEARS

Aikaterini Georgala[1*]

[1]Laboratory of Dairy Research, Department of Food Science & Human Nutrition, Agricultural University of Athens, Athens, Greece

Abstract. This paper reviews the last ten years' literature data on the lipolysis profile of some Greek pasteurized milk cheeses. Free fatty acids (FFAs) were found to be the main volatiles found in Feta Protected Designation of Origin (P.D.O.) cheese that was stored in wooden barrels or tins. FFAs were also the most abundant group of the volatile fraction of a white-brined goat's cheese made by a technology based on Feta cheese-making. The lipolysis level was not affected by the addition of starters used in the production of a soft Galotyri-type cheese. The application of different manufacturing processes on Galotyri-type cheese production showed a low lipolysis level. A low lipolysis level was observed during aerobic storage at 4^0C for 60 days, of soft Xinotyri cheese, an acid-curd cheese of Naxos Greek island of the Cycladic Aegean Sea complex, made from raw or pasteurized milk. Relatively high amounts of FFAs were found in grated Graviera hard cheese, especially when cheese was packed under aerobic conditions. In 'Myzithra Kalathaki' whey cheese, the packaging under different modified atmospheres showed that for a sampling day the FFA content was significantly higher in the control samples packed in air than in samples packed under $C0_2$ atmospheres.

Keywords: *Lipolysis, free fatty acids, Greek cheeses.*

Corresponding Author: *Aikaterini Georgala, Laboratory of Dairy Research, Department of Food Science & Human Nutrition, Agricultural University of Athens, 75 Iera Odos Str., 118 55, Athens, Greece. e-mail: georgala@aua.gr*

Received: *18 April 2018;* ***Accepted****: 25 June 2018;* ***Published:****31 August 2018*

1. Introduction

The numerous compounds involved in cheese aroma and flavor are derived from three major metabolic pathways; catabolism of lactate, protein and lipid. Lipolysis (lipid hydrolysis) is essential for flavor development in some mature cheeses. Lipolysis results in the formation of FFA, which may directly contribute to cheese flavor, especially short and intermediate chain FFA or act as precursors for other flavour compounds such as esters, methyl ketones and secondary alcohols which are also of importance (Fox *et al.*, 1993; Urbah, 1993; Urbach 1997; Molimard & Spinnler, 1996; Collins *et al.*, 2003).

Short and medium chain fatty acids have considerably lower perception thresholds than the long chain fatty acids and each with a characteristic flavor note have been found in many cheese varieties. Depending on their concentration and perception threshold, volatile fatty acids can either contribute positively to the aroma of the cheese or to a rancidity defect. Long-chain fatty acids (>12 carbon atoms) are considered to play a minor role in cheese flavor due to their high perception thresholds (Molimard & Spinnler, 1996).

Lipolysis level varies considerably among cheese varieties from slight in many internal, bacterially ripened varieties such as cheddar, gouda and Swiss cheeses to

extensive in hard Italian varieties, surface bacterially ripened (smear) cheeses and blue mould cheeses (Woo *et al*., 1984 a, b; Fox *et al.*, 1993; Fox & Wallace, 1997; McSweeney & Fox, 1993; Collins *et al.*, 2003).

For some cheese varieties, a specific group of compound is recognized as being the major contributor to flavor. In hard Italian cheese varieties FFAs are important contributors to cheese flavor, while in blue-mould ripened cheeses the impact of FFA to cheese flavour is less than that for Italian varieties due to the dominant influence of methyl ketones to the flavour of these cheeses (Woo *et al.*, 1984 a,b; Brennand *et al.*, 1989; Mollimard & Spinnler, 1996).

The kind and quality of milk, its heat treatment, lactic acid starter used, non-starter bacteria, ripening and storage temperature, milk lipase (if raw milk is used), lipases in the rennet and if used exogenous lipases are some of the main factors that affect lipolysis level in different cheese varieties (Nelson *et al.*, 1977, Driessen, 1989; Fox et al. 1993; Fox & Stepaniak, 1993; Urbach, 1993).

There is a long cheese-making tradition in Greece and a large number of cheeses are mainly made from ewe's or goat's milk or a mixture of them. Cheeses made from ewe's and goat's milk are greatly appreciated in many countries due to their organoleptic characteristics. The Greek cheeses are generally classified as soft cheeses, semi-hard cheeses, hard cheeses, very hard and whey cheeses. Concerning cheese lipolysis, it has been shown that the use of ewes' milk in Greek cheeses manufacture lead to the production of higher levels of short-chain FFAs. Also, lipases found in the rennet paste from kids and lamb's abomasa, which is often used in the production of Greek cheeses, are known to have a preference for the release of short-chain FFAs, C4:0-C8:0 (Nelson *et al.*, 1977; Anifantakis, 1991; Abd El-Salam *et al.*, 1993; Collins *et al.*, 2003).

The aim of this work was to review the literature data over the last ten years on the lipolysis profile of some Greek pasteurized milk cheeses.

2. Lipolysis profile of Greek pasteurized milk cheeses

2.1. Soft-White brined cheeses

Feta cheese

Feta cheese is known to be the most famous traditional soft white-brined and Protected Designation of Origin (P.D.O.) Greek cheese. Feta cheese is produced in Greece since Homeric times. It is made from pure ewes' milk or mixtures of ewes' and goats' milk, in which the proportion of latter is not higher than 30%. Due to the availability of ewes' milk, Feta cheese is mainly produced from January to May. Feta cheese must be exclusively produced in the Greek areas of Macedonia, Thraki, Ipiros, Thessalia, Sterea Ellada, Peloponnissos and Lesvos island.

Feta cheese is ripened and kept in brine (10-12% NaCl) and the ripening time should be at least two months. The maximum moisture value must not exceed 56%, nor fat in dry matter (FDM) be lower than 43% (Codex Alimentarius, 2003 b).

Feta cheese has always a natural white color due to the kind of milk, ewes' milk or a mixture of it with goats' milk, which is used for its manufacture. Feta cheese has a pleasant salty, slightly acid taste and a strong flavour. Its pleasant organoleptic characteristics make it widely accepted. Feta cheese is smooth and creamy, but with a firm body and texture which makes it sliceable. No gas holes should be present but irregular small mechanical openings are desirable.

Traditionally, Feta cheese was made from raw milk in small family units. However, nowadays most Feta cheese is produced from pasteurized milk in well-organized cheese dairies by using commercial (mesophilic and thermophilic) lactic acid cultures. Also, some modifications with respect to the traditional technology have been applied to the cheese making process of Feta cheese (Anifantakis, 1991; Law 1999; Abd El-Salam & Alichanidis, 2004).

In the industrial cheese making of Feta cheese it is packaged in rectangular tins filled with brine. Traditional feta is also packaged in wooden barrels with the addition of brine (Anifantakis, 1991; Anonymous, 1993). Feta cheese is marketed in barrels, in tinned boxes or as plastic-wrapped pieces.

Table 1. Free fatty acids of Feta cheese (μg.g^{-1}), Galotyri-type cheese (μg.g^{-1}) and soft Xinotyri cheese (mg.kg^{-1}) during ripening/storage.

Cheese type	Ripening time	Treatment	C2:0	C3:0	C4:0	C6:0	C8:0	C10:0	C12:0	C14:0	C14:1	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1	C4:0-C20:1	Total	References
Feta cheese	60	1	193.8	n.d.	65.70	64.10	30.64	147.69	100.38	110.92	5.2	134.19	4.13	50.26	84.18	nd					991.21	
	60	2	164.29	n.d.	51.38	52.70	28.81	148.63	100.18	105.53	5.87	156.73	4.11	44.38	74.78	n.d.					937.43	[I]
Feta cheese	180	1	284.53	16.39	77.16	77.71	41.98	299.03	138.74	159.78	7.06	226.27	12.72	55.32	123.75	17.51					1537.99	
	180	2	184.87	n.d.	56.31	59.61	39.22	253.92	134.25	129.20	7.07	207.48	14.32	68.82	131.93	14.63					1301.66	
Galotyri-type cheese	1	3	62.0		17.5	23.6	27.7	18.4	151	40.5	23.2	46.0	23.9	32.6	37.4	17.9	20.8	20.0	19.1	520	582	[II]
	1	4	70.4		18.0	24.4	25.9	18.4	102	37.2	21.2	52.3	22.9	35.6	47.5	17.4	22.9	21.7	18.2	485	556	
	1	5	419		16.8	24.8	27.2	19.2	127	39.9	24.3	48.9	24.1	39.8	40.5	9.33	21.3	20.1	19.1	502	921	
	1	6	78.7		17.7	23.9	27.9	19.0	121	36.0	25.0	50.4	24.5	30.9	35.2	14.8	21.2	19.8	19.5	486	565	
Galotyri-type cheese	15	3	70.7		17.5	23.8	28.3	19.0	183	44.4	25.3	52.2	30.4	37.4	53.0	19.8	22.5	20.7	20.3	597	668	[II]
	15	4	90.3		18.1	26.0	26.0	27.6	131	39.1	22.8	59.5	24.3	35.8	52.5	24.9	23.6	22.2	18.4	551	641	
	15	5	429		17.8	24.0	28.9	20.0	144	41.6	25.0	52.9	26.6	41.4	51.6	13.6	22.4	20.9	19.9	551	980	

Treatments: 1: Feta cheese ripened and stored in wooden barrels; 2: Feta cheese ripened and stored in tin vessels; 3: Cheese made with starter culture CH-1 (cheese named A); 4: Cheese made with starter culture MA011 (cheese named B); 5: Cheese made with starter culture Probat 222 (cheese named C); 6: Cheese made with starter culture CHOOZIT MT 1 (cheese named D); 7: SC, cheese made with starter culture, no rennet and dry salting of curd after draining; 8: SC+R, cheese made with starter culture, rennet and dry salting of curd after draining; 9: SM+R, cheese made from salted milk with starter culture and rennet; 10: Soft Xinotyri cheese made from raw milk (RMC); 11: Soft Xinotyri cheese made from pasteurized milk (PMC).References: [I] Kondyli *et al.* (2012); [II] Katsiari*et al.* (2009); [III] Kondyli*et al.* (2013); [IV]Pappa*et al.* (2017).

Kondyli *et al.* (2012) examined the effect of package type on the lipolysis of Feta cheese. Feta cheese was made by using artisanal rennet from kids and lamb's abomasa and was ripened and stored either in tin vessels or in wooden barrels. The level of lipolysis (total free fatty acids) was found to be similar among the examined Feta cheeses and was not affected by the package type used. Free fatty acids were found to be the major group of compounds determined in the volatile fraction of all Feta cheeses

with acetic, butyric, hexanoic, octanoic and decanoic acids to be the most abundant. At day 60 cheese, the feta cheese stored in wooden barrels had significantly ($P<0.05$) higher levels of butyric, heptanoic, nonanoic and decanoic acids than Feta cheese stored in tins (Table 1). However, in 180 days of storage, Feta cheese stored in tins had significantly ($P<0.05$) higher amounts of octanoic and dodecanoic acids than Feta cheese stored in wooden barrels (Table 1). Also, at 180 days' cheese, Feta cheese stored in tins had significantly ($P<0.05$) lower levels of decanoic acid than Feta cheese stored in wooden barrels (Table 1). Short-chain fatty acids are known to be the main contributors to the cheese flavor of soft brined cheeses such as Feta cheese. Acetic acid and butyric acid are known to have a very important effect on the flavour and piquant taste of these cheeses. Although acetic acid is not entirely produced by lipolysis, it contributes greatly to the final flavor and sensory characteristics of these cheeses. Acetic acid is formed during the early stages of cheese ripening and it is probably a product of citrate or lactate fermentation or of amino acids catabolism by bacteria (Abd-El-Salam & Alichanidis, 2004). Butyric acid (C4:0) is also known to contribute greatly to the piquant taste of feta cheese (Georgala *et al.*, 1999).

White-brined goat cheese

The preference of consumers for traditional made cheeses and the special sensorial and nutritional properties of goat's milk make goat milk cheeses to be popular between the consumers. In Greece, white brined goat milk cheeses are produced in a small scale but gradually these cheeses become more and more popular. White-brined goat milk cheeses are produced by a technology almost similar to that used for Feta cheese manufacture.

Kondyli *et al.* (2016) studied the volatile compounds of a white-brined cheese made from goat milk that was taken from the Greek native breed *Capra Prisca*. This breed is the 85% of goat population found in Greece. The white-brined cheese was made by a technology based on Feta cheese-making. Free fatty acids were found to be the main group of volatile compounds determined in this cheese. Hexanoic acid, butanoic acid and decanoic acid were the predominant free fatty acids determined (Table 2).

Table 2. Free fatty acids (AU=peak area $x10^3$ isolated from goat white-brined cheese at different stages of storage

Free fatty acids	60 days	180 days
Butanoic acid (C4:0)	22195.50±4421.30	88215.50±19317.00
Hexanoic acid (C6:0)	81922.00±17827.30	191968.00±30777.50
Octanoic acid (C8:0)	45741.40±1996.75	84405.30±16577.90
Nonanoic acid (C9:0)	2534.90±433.80	1322.75±321.25
Decanoic acid (C10:0)	27969.90±1539.65	49956.50±10148.90
Dodecanoic acid (C12:0)	1823.75±146.05	2775.90±704.80

Reference: Kondyli *et al.* (2016).

2.2. Soft cheeses

Galotyri-type cheese

Galotyri cheese is one of the oldest traditional Greek cheeses with a Protected Designation of Origin (P.D.O.) (Anifantakis, 1991) and it is made in many regions of

Greece, in many ways, from ewe's or goat's milk or mixtures of both of these milks. The milk that is used for Galotyri cheese production should be of good quality, whole raw or pasteurized, coming from the regions of Epirus and Thessaly.

Galotyri cheese has a spreadable texture and pleasant organoleptic characteristics. Modifications on the traditional cheese making process of Galotyri P.D.O. cheese, such as salting with less than 2% NaCl and very short or no ripening time, lead to the production of a Galotyri-type cheese. Several Galotyri-type fresh cheeses are found in Greek market which different compositional and sensorial characteristics.

Katsiari *et al.* (2009) examined the lipolytic characteristics of a Galotyri-type cheese (a traditional acid/rennet-curd cheese) that was made with four different commercial starter cultures. The starter cultures used in making Galotyri-type cheese were two mesophilic cultures (MA011 and Probat 222), a thermophilic culture (CH-1) and a mixed mesophilic/thermophilic (CHOOZITMT1) culture. The Galotyri-type cheeses were all made under the same conditions, expect of the use of different cultures. The above study showed that the extent of lipolysis (total C4:0-C20:1 free fatty acid content) was not affected by the type of the starter culture used for the cheese making of the Galotyri-type cheese production. However, significant differences for some of the individual FFAs (e.g. C10:0, C12:0, C18:0, C18:1 and C18:2 FFAs) were observed.

Acetic acid and lauric acid were found to be the main free fatty acids in all Galotyri-type cheeses throughout storage (Table 1). Acetic acid is known to be an important flavor compound in many acid-heat coagulated cheeses (Centeno *et al.*, 1999; Lucey, 2003). Acetic acid is not a product of lipolysis and it is known to be produced from lactose fermentation and degradation of amino acids and also from the fermentation of citrate (Law, 1984). The Galotyri-type cheese made by the mesophilic starter culture Probat 222 (cheese named C) was found to have significantly higher levels of acetic acid than the rest cheeses at all sampling ages. This was due to the fact that the culture used for making this cheese contained two citrate-fermenting lactic acid bacteria the *Lc.lactis* subsp. *lactis biovar diacetylactis* and the *Leuconostoc mesenteroides* subsp. *cremoris*. However, the amount of capric acid was significantly higher in cheese made with the mesophilic starter culture MA011 (cheese named B) than in the rest cheeses but only for the day 15 and day 30 cheeses (Table 1). Lauric acid was found to be significantly higher in cheese made with the starter culture CH-1 (cheese named A) than in cheese made with the starter culture MA011 (cheese named B), at day 1 and day 15 cheeses (Table 1). However, at 30 days of cheese storage the amount of lauric acid was significantly higher in cheese A than in cheeses B and C, but similar to that of cheese D (Table 1). At 30 days of storage, all cheeses had similar levels of oleic acid. At 15 days of cheese storage, cheeses A, B and C had similar amounts of oleic acid while significantly lower amount of oleic acid was found in cheese D (cheese made with the starter CHOOZITMT1) (Table 1). No significant differences in linoleic acid content were found among the 30 days' cheeses (Table 1). The amount of all individual FFA increased during cheese storage. The total (C2:0-C20:1) free fatty acid content was significantly higher in cheese C than in the rest cheeses at all cheese ages (Table 1). Nevertheless, the total C4:0-C20:1 free fatty acid content, which is known to be considered as the actual index of cheese lipolysis, did not differ significantly among cheeses throughout the whole storage period (Table 1).Finally, the results of the study of Katsiari *et al*. (2009) showed that an excellent quality Galotyri-type cheese can be produced by using any of the starter cultures A, B, C or D.

Kondyli *et al.* (2013) examined the effect of different manufacturing processes on the free fatty acid (FFA) profile of a Galotyri-type cheese. Three cheese-making processes were applied depending on whether the milk or the curd was salted and if rennet was used or not. In the procedure named SM+R the cheese was made from salted milk with commercial starter culture and rennet. In the procedure named SC the cheese was made using starter culture, no rennet and dry salting of the curd after draining. Finally, in the procedure named R+SC the cheese was made with starter culture and rennet and dry salting of the curd after draining.

Low levels of lipolysis (total FFA content) were found in all Galotyri-type cheeses that were produced using the different cheese-making procedures. At all sampling ages the content of most FFAs did not differ significantly among the examined cheeses. Lauric, palmitic and acetic acids were the main FFAs determined in all cheeses during storage. At 30 days of storage, the cheese named SC+R had a significantly lower content of total FFA than the rest ones (Table 1).

Soft Xinotyri cheese

Soft Xinotyri cheese is an acid-curd goat's milk cheese variety that is produced traditionally on the island of Naxos in the Cycladic complex of Greek islands. Soft Xinotyri cheese is not shaped and is consumed as fresh or ripened and it is cold-stored. Although soft Xinotyri cheese is typically made at Naxos Island from raw milk, however due to safety reasons an increase in making soft Xinotyri cheese from pasteurized milk is observed.

Pappa *et al.* (2017) studied the lipolysis profile of soft Xinotyri cheese, a traditional Greek acid-curd cheese (pH 4.4, moisture 65%, salt 1%) that was made from raw or pasteurized milk without the addition of starter cultures, during its aerobic storage at 4^0C for 60 days. Generally, no significant differences in individual as well as in total FFA content were found between raw milk soft Xinotyri cheese and pasteurized milk soft Xinotyri cheese. This is probably due to the fact that the time of 60 days' cold storage of soft Xinotyri cheese is short enough so that great differences could be found in lipolysis level between raw and pasteurized milk cheese samples. Regardless the use of raw or pasteurized milk in soft Xinotyri cheese production, the most abundant free fatty acids determined were oleic (C18:1), palmitic (C16:0), myristic (C14:0), capric (C10:0) and caprylic (C8:0) acids (Table 1). Also, a low lipolysis level (low total FFA content) was found in raw milk as well as in pasteurized milk soft Xinotyri cheese during storage (Table 1).

2.3. Hard cheeses

Graviera cheese

Greek graviera is a popular yellow hard gruyere-type cheese produced in different regions of Greece belonging to the gruyere group of Swiss-type cheeses that are produced in other European countries (Switzerland, France, Italy) and also in Australia (e.g. Heidi gruyere). Greek graviera is made either from cows' milk with starters or from ewe's milk and mixtures of it with goat's milk without the addition of starters. Generally, Greek graviera has a more intense flavour than the typical gruyere cheese that is imported from other European countries. It has a hard elastic texture with propionic fermentation holes on its mass. Greek graviera was initially produced seasonally in small dairies from unpasteurized milk. Nowadays due to public health reasons it is produced from pasteurized milk in well-organized dairies. Graviera cheese

has a high fat content (30-33%, w/w) and a relatively low salt content (2-3.5%, w/w). The maximum moisture value must be 38% while the minimum fat in dry matter 40%. The ripening time is minimum 3 months (Codex Alimentarious, 2003a).

Numerous substances have been reported as aroma and flavour components of Greek graviera cheese. Among them the most important are the short chain fatty acids acetic, propionic and butyric (Zerfirides *et al.*, 1984; Vangtal &Hammond, 1986). Propionic acid generally characterizes gruyere-type cheeses. It is produced through propionic acid fermentation of lactate by the action of propionibacteria (Frohlich-Wyder & Bachmann, 2004). Butyric acid is also an important component of gruyere-type cheeses but large amounts of butyric acid, which may originate from butyric acid fermentation of lactose by the action of butyric acid bacteria, are nevertheless undesirable (Bosset & Liardon, 1984).

In order to cover the consumer demands hard cheeses are sold not only as cuts/blocks but also as sliced or grated. Grated Graviera cheese that is packaged in transparent containers has a relative short shelf life of about 2-3 weeks under refrigeration accordingly to its salt content. The fat content of the cheese is responsible for the cheese to be more or less susceptible to light-induced oxidative deterioration in correlation with the development of off-flavors and discoloration (Hong *et al.*, 1995; Trobetas *et al.*, 2008).

Trobetas *et al.* (2008) studied the light-induced changes in grated Graviera cheese that was packaged under modified atmospheres in order to increase the self-life of this cheese. The volatile acids of grated Graviera cheese packaged under various atmospheres on day 0 (0 week) and on day 63 (9 weeks) of storage for both light exposed and light protected samples are shown in Table 3. The results of Trobetas *et al.* (2008) showed that mainly, under aerobic cheese packaging, relatively high amounts of FFAs were determined. This was due to the enhanced oxidation in the presence of oxygen. In cheeses packaged under N_2, the FFA amount was less than the FFA amount found in cheeses packaged under CO_2. Nevertheless, for a given atmosphere, the concentration of FFAs was similar in light exposed samples as compared to that of light protected samples (Table 3). This showed that lipolysis was not substantially affected by light. The amount of acetic acid ranged from 0.228 μmg^{-1} (0 week) to 0.663 μmg^{-1} (9 weeks' storage) under 100% $C0_2$ and light (Table 3).

Table 3. Volatile acids (μgg^{-1} grated Gaviera cheese as a function of light exposure, modified atmosphere and storage time at 4^0C

	0 week	9 weeks					
Acids		Air-dark	Airlight	100%N_2-dark	100%N_2-light	100%$C0_2$-dark	100%$C0_2$-light
Propanoic acid, 2-methyl	0.014	0.369	0.378	0.080	0.117	0.121	0.154
Acetic acid	0.228	0.615	0.634	0.238	0.275	0.343	0.663
Butanoic acid	0.557	7.117	7.261	0.703	0.805	0.872	1.239
Hexanoic acid	0.730	12.931	14.455	1.037	1.177	1.257	2.743
Octanoic acid	0.229	8.689	9.685	0.393	0.473	0.641	0.870
Decanoic acid	0.106	3.734	4.010	0.173	0.202	0.205	0.267
Butanoic acid, 3-methyl or pentanoic acid	0.093	0.973	1.168	0.110	0.162	0.210	0.250

Reference: Trobetas *et al.* (2008).

2.4. Whey cheeses

'Myzithra Kalathaki' cheese

Whey is the watery portion of milk remaining after milk coagulation, cutting and removal of the curd. The whey contains about the half of milk dry matter. Whey proteins have a higher nutritive value than cheese casein as they contain all the essential amino acids and in a greater ratio than casein. The production of whey cheeses is based on denaturation and coagulation of the water soluble milk proteins present in the whey when it is heated at temperatures above 85^0C. In Greece there are produced about 250,000 tons of whey cheeses mainly from ewes' whey. The most known traditional Greek whey cheeses are Myzithra, Anthotyros and two cheeses with a protected designation of origin (P.D.O.), the Manouri cheese and the Xynomyzithra Kritis cheese (Kalantzopoulos, 1995; Samelis *et al.*, 2003).

Dermiki *et al.* (2008) studied the effect of the modified atmosphere packaging (MAP) on the quality characteristics and the self-life extension of the whey cheese 'Myzithra Kalathaki'. Myzithra cheese was packaged into four different atmospheres: vacuum, 20% CO_2/80% N_2 (sample named M1), 40% CO_2/60% N_2 (sample named M2) and 60% CO_2/40% N2 (sample named M3). Also, 'Myzithra Klathaki' cheeses were packaged in air and were considered as controlsamples. The degree of lipolysis that was expressed as ml of 0.01N KOH required to neutralize the FFA present in cheese samples, was higher in the samples packaged under vacuum than in the samples packaged under CO_2 atmospheres. For a given sampling day, the samples packed under vacuum showed a lower lipolysis than the control ones (samples packed in air). Additionally, the FFA content was significantly higher in control samples that were packed in air than in samples packed under CO_2 atmospheres. Finally, the lipolysis level did not differ significantly with the type of packaging treatment applied to the 'Myzithra Kalathaki' cheese samples.

3. Conclusion

This paper reviewed the last ten years' literature data on the lipolysis profile of some Greek pasteurized milk cheese varieties and gave a more complete knowledge on these cheeses. The lipolysis level differed among the Greek cheeses referred in this study, indicating that lipolysis could be a useful index for characterizing these cheeses. The applied technology and the cheese age influenced the level of lipolysis of these cheeses. F.F.A.s were found to be the main volatiles in the Feta (P.D.O.) cheese stored in wooden barrels or tins. Also, F.F.A.s were the most abundant chemical group of a white-brined goat cheese that was manufactured by a technology based on Feta cheese-making. The extent of lipolysis of Galotyri-type cheese was not affected by the addition of starters. However, significant differences for some of the FFAs were observed among cheeses. Low total free fatty acid content was found in the Galotyri-type cheese produced by different manufacturing processes. A low lipolysis level was found in soft Xinotyri cheese made from raw or pasteurized milk with oleic, palmitic, capric and caprylic acids to be the main free fatty acids determined. In grated Graviera hard cheese, relatively high amounts of FFAs were found, especially under aerobic packaging. The FFA content was significantly higher in control samples of 'Myzithra Kalathaki' cheese than in samples packed under CO_2 atmospheres.

References

Abd El-Salam, M.H., Alichanidis, E., & Zerfiridis, G.K. (1993). Domiati and Feta type cheeses. In: *Cheese: Chemistry, Physics and Microbiology,* Vol. 2. (Ed. P.F. Fox). Chapman and Hall, London, 301-335.

Abd El-Salam, M.H. & Alichanidis, E. (2004). Cheese varieties ripened in brine. In *Cheese: Chemistry, Physics and Microbiology,* Vol. 2. (Eds P.F. Fox, P.L.H. McSweeney, T.M. Cogan and T.M. Guinee). Elsevier, Amsterdam, 227-249.

Anifantakis, E. (1991). Traditional Feta cheese. In *Feta and Related cheeses* (Eds R.K. Robinson and A.Y. Tamime), Ellis Horwood Limited, England, pp. 49-69.

Anonymous (1993). Recognition of Feta as protected denomination of origin cheese. Off. J. Hellenic Republ. (1) (No 36, Articles 1, 2, National Printing Office, Athens, Greece).

Brennand, C.P., Ha, J.K. & Lindsay, R.C. (1989). Aroma properties and thresholds of some branched-chain and other minor volatile fatty acids occuring in milkfat and meat lipids. *Journal of Sensory Studies*, 4, 105-120.

Bosset, J.O. & Liardon, R. (1984). The aroma composition of Swiss Gruyere cheese. II. The neutral volatile components. *Lebensmittel Wissenschaft and Technologie,* 17, 359-362.

Centeno, J.A., Menendez, S., Hermida, Ma. & Rodriguez-Otero, J.L. (1999). Effects of the addition of Enterococcus faecalis in Cebreiro cheese manufacture. *International Journal of Food Microbiology,* 48, 97-111.

Codex Alimentarius (2003 a), Vol. 4, Graviera cheese, National Printing Office, Athens, Greece, pp 914-917.

Codex Alimentarius (2003 b), Vol. 4, Feta cheese, National Printing Office, Athens, Greece, pp 943-946.

Collins, Y.F., McSweeney, P.L.H. &Wilkinson, M.G. (2003), Lipolysis and free fatty acid catabolism in cheese: a review of current knowledge. *International Dairy Journal,* 13, 841-866.

Dermiki, M., Ntzimani, A., Badeka, A., Savvaidis, I.N. & Kontominas, M.G. (2008). Shelf-life extension and quality attributes of the whey cheese ‘‘Myzithra Kalathaki’’ using modified atmosphere packaging. *LWT*, 41, 284-294.

Driessen, F.M. (1989). Heat-induced changes in milk. *Bulletin 238*, Int. Dairy Federation, Brussels.

Frohlich-Wyder, M.T. & Bachmann, H.P. (2004). Cheeses with propionic acid fermentation. In Cheese: Chemistry, Physics and Microbiology, Vol. 2 (Eds. Fox, P.F., McSweeney, P.L.H., Cogan, T.M. and Guinee, T.P.). 3rd ed., Elsevier, Amsterdam, 141-156.

Fox, P.F. & Stepaniak, L. (1993). Enzymes in cheese technology. *International Dairy Journal*, 3, 509-530.

Fox, P.F., Law, J., Mc Sweeney, P.L.H. & Wallace, J. (1993). Biochemistry of cheese ripening. In *Cheese: Chemistry, Physics and Microbiology*, Vol. 1. (Ed. P.F. Fox). Chapman and Hall, London, 389-439.

Fox, P.F. & Wallace, J.M. (1997). Formation of flavor compounds in cheese. *Advances in Applied Microbiology*,45, 17-85.

Georgala, A.K., Kandarakis, I.G., Kaminarides, S.E. & Anifantakis, E.M. (1999), Volatile free fatty acid content of Feta and white-brined cheeses. *Australian Journal of Dairy Technology*, 54, 5-8.

Hong, C.M., Wendorff, W.L., & Bradley, R.L. (1995). Effects of packaging and lighting on pink discoloration and lipid oxidation of annatto-coloured cheese. *Journal of Dairy Science,* 78, 1896-1902.

Kalantzopoulos, G. (1995). Cheeses from ewes’ and goats’ milk. In P. F. Fox (Ed.), Cheese: Chemistry, physics and microbiology: Major cheese groups (2nd ed., pp. 507–550). Gaithersburg: Aspen Publishers Inc.

Katsiari, M.C., Kondyli, E. & Voutsinas, L.P. (2009). The quality of Galotyri-type cheese made with different starter cultures. *Food Control*, 20, 113-118.

Kondyli, E., Pappa, E.C. &Vlachou, A.M. (2012). Effect of package type on the composition and volatile compounds of Feta cheese. *Small Ruminant Research*, 108, 95-101.

Kondyli, E., Massouras, T., Katsiari, M.C. & Voutsinas, L.P. (2013). Lipolysis and volatile compounds of Galotyri-type cheese made using different procedures. *Small Ruminant Research*, 113, 432-436.

Kondyli, E., Pappa, E.C. & Svarnas, Ch. (2016). Ripening changes of the chemical composition, proteolysis, volatile fraction and organoleptic characteristics of a white-brined goat milk cheese. *Small Ruminant Research*, 145, 1-6.

Law, B.A. (1984). Flavour development in cheese. In F. L. Davies & B. A. Law (Eds.), Advances in the microbiology and biochemistry of cheese and fermented milk (pp.187–208). London: Elsevier Applied Science Publishers.

Law, B.A. (1999). Cheese ripening and cheese flavour technology. In *Technology of Cheesemaking*, (Ed B.A. Law). Sheffield Academic Press Ltd., Sheffield, England, pp. 163-192.

Lucey, J.A. (2003). Acid and acid/heat coagulated cheese. In: Roginski, H., Fuquay, J.W., Fox, P.F. (Eds.), Encyclopedia of Dairy Sciences, vol. 1. Academic Press, Amsterdam, Netherlands, pp. 350-356.

Molimard, P. & Spinnler, H.E. (1996). Review: Compounds involved in the flavor of surface mould-ripened cheeses: origins and properties. *Journal of Dairy Science*, 79, 169-184.

McSweeney, P.L.H. & Fox, P.F. (1993), Cheese: Methods of Chemical Analysis. In Cheese: Chemistry, Physics and Microbiology, Vol. 1. (Ed P.F. Fox), Chapman and Hall, London, 368-388.

Nelson, J.H., Jensen, R.G. & Pitas, R.E. (1977). Pregastric esterase and other oral lipases-a review. *Journal of Dairy Science*, 60, 327-362.

Pappa, E., Bontinis, Th., Margari, M.T. & Samelis, J. (2017). Microbial quality and biochemical changes in fresh soft, acid-curd Xinotyri cheese made from raw or pasteurized goat's milk. *Food Technology and Biotechnology*, 55, 496-510.

Samelis, J., Kakouri, A., Rogga, K.J., Savvaidis, I.N. & Kontominas, M.G. (2003). Nisin treatments to control Listeria monocytogenes post-processing contamination on Anthotyros, a traditional Greek whey cheese, stored at 4 1C in vacuum packages. *Food Microbiology*, 20, 661-669.

Trobetas, A., Badeka, A. & Kontominas, M.G. (2008). Light-induced changes in grated Graviera hard cheese packaged under modified atmospheres. *International Dairy Journal*, 18, 1133-1139.