Original scientific paper - Izvorni znanstveni rad UDK: 637.352

Comparative study of white brined cheeses obtained from whole milk and milk-olive oil emulsion: Physicochemical and sensory properties

doi: 10.15567/mljekarstvo.2016.0406

Imène Felfoul[1, 2], Ali Sahli[3], Olfa Samet-Bali[1], Hamadi Attia[1], Salwa Bornaz[2]*

[1]Laboratoire Analyses, Valorisation et Sécurité des Aliments (LAVASA), Ecole Nationale d'Ingénieurs de Sfax, Université de Sfax, Route de Soukra, 3038 Sfax, Tunisie
[2]Ecole Supérieure des Industries Alimentaires de Tunis, Université de Carthage, 58 Rue Alain Savary, 1003 Tunis, Tunisie
[3]Institut National Agronomique de Tunisie, Université de Carthage, 43, Av Charles Nicolle, 1082 Tunis, Tunisie

Received - Prispjelo: 27.01.2016.
Accepted - Prihvaćeno: 20.10.2016.

Abstract

The present paper is focused on the physicochemical and sensory parameters of low-fat white brined cheese-like product obtained from the substitution of milk fat by milk-olive oil emulsion, in comparison with full and low-fat control cheeses. Formulated milk samples were initially pasteurized at 63 °C for 30 min, cooled down to 35 °C, and subsequently 0.35 mL L^{-1} of microbial rennet were added. The obtained cheeses were stored at 4 °C during 24 hours and then analyzed for physico-chemical and sensory properties. The replacement of milk fat in white brined cheese resulted in a lower total solids content due to the higher water-binding capacity of fat replacers used. Fat content was significantly higher for low-fat white brined cheese-like product than in low-fat control cheese. This result was attributed to fat retention capacity of the fat replacers used. Lipolysis index was the highest in the case of low-fat white brined cheese-like product due to changes in cheese microstructure after fat replacers incorporation in low-fat products. Milk-olive oil emulsion showed the lowest cheese-making yield compared to its full and low-fat counterparts. The cheese like- product sample received a significantly lower overall impression score by the panelists than full and low-fat cheeses.

Key words: milk-olive oil emulsion, cheese-like product, fat replacers, lipolysis, overall impression

Introduction

Fat content is an important food component with high sensory and physiological benefits. Fat is a source of fat-soluble vitamins mainly fatty acids, which contributes to the development of flavor, appearance, aroma, odor and texture of foods. Fat is the most concentrated source of energy in the human diet compared to proteins and carbohydrates with 9 kcal/g. However, high fat intake is associated with increased risk of some types of cancer and obesity. Saturated fat intake is associated with coronary heart disease and high blood cholesterol (AHA, 1996; USDHHS, 1988). Therefore, it is recommended to limit the total fat intake to no more than 30 % of daily energy intake (USDA and USDHHS, 1995).

The consumer health interest in decreasing fat intake led producers to develop low-fat food products (Bullens, 1994). However, making reduced-fat products with similar properties and functionalities

*Corresponding author/Dopisni autor: Phone/Tel.: 0021622048253; E-mail: imenef@gmail.com, imene.felfoul@enis.rnu.tn

as full-fat constitutes a very difficult task. Indeed, low and reduced-fat cheeses are generally identified as soft, firm, rubbery and defective in colour (Sipahioglu et al., 1999). In low-fat cheeses, fewer fat globules are incorporated within the protein matrix and the globules are usually smaller than in full fat cheese (Mistry and Anderson, 1993). Therefore, the use of fat replacers is a good alternative to improve the properties of reduced-fat cheeses (Drake and Swanson, 1995).

The attempts to produce a low-fat white-brined cheese containing fat replacers are very scarce. Katsiari and Voutsinas (1994) investigated low-fat Feta-type cheese made from ewe's milk by reducing the fat content of cheese milk. Acceptable sensory attributes of low-fat Feta cheese were obtained from milk containing 1.5 % fat. Sipahioglu et al. (1999) studied Feta cheese made with tapioca starch and lecithin as fat mimetics. Significant increase in moisture content and yield were obtained for low-fat cheeses containing fat mimetics compared to full-fat cheese. Romeih et al. (2002) reported on low-fat white brined cheese made from bovine milk and two commercial fat mimetics. Cheeses containing fat replacers showed higher moisture and yield values than low-fat products without fat replacers' addition.

Milk fat substitution by emulsified vegetable oils in milk is an option to obtain cheeses with healthier saturated/unsaturated fat balance (Yu and Hammond, 2000). However, the incorporation of emulsified vegetable oils alters the content, the type and the distribution of the fat droplets into the protein's network, thus causing changes in cheese microstructure and textural behavior (Lobato-Calleros et al., 2002; 2003).

Previous investigations were focused on milk fat substitution by canola oil (Lobato-Calleros et al., 2001; 2003). Few data were available in the literature about milk fat substitution by emulsified olive oil (Felfoul et al., 2013; 2015). The aim of this paper was to evaluate the physicochemical and sensory attributes of low-fat white brined cheese-like product obtained from the substitution of milk fat by emulsified olive oil in comparison with low and full-fat control cheeses.

Materials and methods

Materials

Olive oil (OO) (Chaal Oil, SOCOHUILE, Sfax., Tunisia) was used as the oil phase of the $W_1/O/W_2$ emulsion. The hydrophilic emulsifier (WE) (P4780, SIGMA-ALDRICH, St Louis, USA, esters of monoglycerides and diglycerides of diacetyltartaric acid) and the hydrophobic emulsifier (OE) (85548, SIGMA-ALDRICH, Chemie Gmbh, CH9471 Buchs, Spain, esters of polyglycerol and polyricinoleate fatty acids) were purchased from SIGMA-ALDRICH France. The biopolymers used were gellan gum (GG) (P8169, SIGMA-ALDRICH, St Louis, USA) and carboxymethylcellulose (CMC) (GA 20529, SIGMA-ALDRICH, CH-9471 Buchs, Steinheim, the Netherlands). The water used in all of the experiments was double-distilled.

Formulation and preparation of the $W_1/O/W_2$ emulsions

$W_1/O/W_2$ emulsions were prepared at room temperature using a two-stage emulsification procedure (Dickinson and McClements, 1996; Felfoul et al., 2015). In the first stage, a W_1/O emulsion was made having a 20% (w/w) dispersed aqueous phase, a GG concentration of 0.1 % (w/w) and a total emulsifiers concentration of 8 % (w/w) (one part of WE to four parts of OE). The aqueous inner phase (W_1) (distilled water + WE + GG) was added drop-wise to the oil phase (O) (OO+OE) using an Ultra-Turrax homogenizer (Ultra-Turrax H 500 SLT, Service Trade Laboratory Equipment, Germany) at 5800 rpm for 5 min. In the second stage the W_1/O primary emulsion was re-emulsified in the biopolymer aqueous solution (0.5 % w/w CMC), at 5200 rpm for 10 min using the Ultra-Turrax homogenizer, yielding the following $W_1/O/W_2$ emulsion. The $W_1/O/W_2$ emulsion had a dispersed phase fraction of 0.2.

Milk samples

Cow milk used in this study originated from a certain breeding spot in northern Tunisia (Holstein breed, BICHE farm, Nabeul region) and was transported at 4 °C. Once arrived at the laboratory, pH measurement was realized. Subsequently, 0.06 % (w/v) potassium dichromate was added to 10 L of milk in order to prevent all bacterial growth and milk was immediately frozen at -10 °C. Milk samples were divided into three equal volumes: a) Control full-fat milk, b) Low-fat milk which was made by blending skimmed milk, obtained by centrifugation at 3600 g/15 min of full-fat milk, with whole milk (v/v) and c) Milk-olive oil emulsion obtained by mixing skimmed milk with X amount of an emulsified olive oil. X is equal to milk fat content in control full-fat milk.

Milk composition

The milk pH was measured using a pH meter (Model pH 315i /SET, WTW Inc., Weilheim, Germany) according to NF V 04-281 (1968). Dry matter content was determined by drying 5 g of milk sample at 103 °C for 7 h in a capsule containing sand according to an IDF method (21 B, 1987). Ash content of milk was determined according to NF V04-208 (1989). Protein content was determined by Kjeldhal method (IDF 20 B, 1993). Fat, calcium and phosphorous contents were measured by Gerber method and atomic absorption spectrophotometer respectively (AOAC, 1995).

Cheese making process

A control white brined cheese (Full-fat cheese) was prepared from milk containing 33.23±1.11 g of milk-fat L^{-1}. A low–fat white brined cheese was prepared by blending full fat milk with skim milk (1±0.1 g of milk fat L^{-1}). A low-fat white brined cheese-like product was elaborated from skim milk added with 33.23 g of the $W_1/O/W_2$ emulsions L^{-1}. Cheeses were prepared from 10 L batches of formulated milk in a completely randomized design. The formulated milks were vat-pasteurized at 63±0.1 °C for 30 min, cooled to 35±0.5 °C, and 0.35 mL L^{-1} of microbial rennet was added (*M. miehei*, strength 1:10 000, Laboratoires ARRAZI, PARACHIMIC, Sfax., Tunisia). After coagulation time (app. 60 min.), the curd was cut into 1 cm^3 cubes. About 30 % of the whey was drained, and salting was carried out by adding 6.3 g of table salt L^{-1} of milk. The curds were transferred to 1 kg round polyvinylchloride containers, kept at room temperature (20±2 °C) for 2 h, and then placed in a cooling chamber (12±0.5 °C, 80-90 % RH), for 24 h. Cheeses were stored at 4 °C during 24 hours and then analyzed.

The cheeses were analyzed for protein, fat, dry matter and ashes by Kjeldahl method, Gerber method and oven drying, respectively (AOAC, 1995) and for lipolysis degree (Gallois and Langlois, 1990). Composition results were expressed in dry basis. Cheese yield (g/L) was expressed as the quantity of cheese obtained from a given mass of milk (g/L) after 4 h of drainage (Felfoul et al., 2013).

Sensory evaluation

After 24 h of storage (4±0.1 °C, 80-90 % RH), cheese samples were sensory evaluated by a 100-member panel recruited among staff and students of the Laboratoire Central d'Analyses et d'Essai (Tunis, State of Tunisia) who stated that they were cheese lovers and users. Each of the three

Table 1. Physicochemical parameters of milk

Parameters	Milk samples		
	Full-fat	Low-fat	Olive oil-milk emulsion
pH	6.65±0.01[a]	6.61±0.05[a]	6.62±0.01[a]
Dry matter (g/L)	129.75±2.33[a]	119.12±2.03[b]	105.53±1.21[b]
Fat (g/L)	33.23±1.11[a]	15.22±1.65[b]	15.65±0.11[b]
Protein (g/L)	34.09±0.05[a]	30.97±0.97[c]	33.92±0.07[b]
Ash (g/L)	8.54±0.17[a]	7.98±0.41[a]	9.71±0.54[b]
Ca (g/L)	1.17±0.05[a]	1.28±0.01[b]	1.11±0.09[a]
P (g/L)	0.744±0.12[a]	0.851±0.11[b]	0.801±0.09[b]

Means±standard deviation (SD) of three separate determinations
[a,b,c]Values sharing lowercase letter within a column are not significantly different by Duncan's multiple-range test (p<0.05)

cheese samples were cut into 1 cm^3 cubes, were coded with three-digit random numbers, and randomly presented to the panel. Panel members evaluated cheeses for appearance, body texture, odour, taste (bitterness, acidity and saltiness) and overall impression using scores from 0 to 5, with 0 being the worst and 5 being the best quality.

Statistical analysis

Analysis of variance (ANOVA) was carried out by using the software SPSS statistics 19. Significant differences ($p<0.05$) among treatments were detected using Duncan's multiple range tests. Values expressed are means ± standard deviation of triplicate measurements.

Results and discussion

Physicochemical characterization of milk

Table 1 showed the average physicochemical characteristics of the different milk samples. It is clear that pH was not significantly different between milk samples ($p<0.05$). This result confirmed those found by Romeih et al. (2002) and Felfoul et al. (2013) who showed that fat content reduction combined with fat replacers' addition had no effect on milk pH.

Full-fat milk had a higher dry matter content, 129.75 g/L, followed by low-fat milk, 119.12 g/L, and milk-olive oil emulsion, 105.53 g/L. Fat content of milk-olive oil emulsion was significantly lower that of full-fat milk (15.65 g/L for milk olive oil emulsion *vs* 33.23 g/L for full-fat milk) but significantly similar to that of low-fat milk without fat replacers' addition (15.22 g/L) as shown in Table 1. This result was attributed to the high amount of water added to the previously prepared $W_1/O/W_2$ emulsion. Besides, Lobato-Calleros et al. (2003) investigated on Mexican Manchego cheese-like products containing canola oil and emulsifier blends. These authors demonstrated that the Hydrophilic-Lipophilic Balance (HLB) value of this mixture affected the fat content in milk. The difference between the fat content of the three milk samples affected the dry matter content. Protein content was significantly higher for full-fat milk than for milk-olive oil emulsion (Table 1). Ash content is lower in the case of full-fat milk than for milk-olive oil emulsion. These results confirmed those obtained previously in the literature (Felfoul et al., 2013).

Physicochemical characterization of the cheeses

Table 2 showed the main physicochemical characteristics of the cheeses. As shown in Table 2, there is no significant difference in pH between full and low-fat cheeses and cheese like-product ($p<0.05$). This result was in accordance with those reported by Michaelidou et al. (2003). The dry matter content of full-fat cheese was significantly higher than those of low-fat sample and low-fat white brined cheese like-product. Dry matter content decreased with the reduction of milk fat content (Table 2). Besides, basing on a significantly equal initial fat content in low-fat milk and milk-olive oil emulsion (Table 1), low-fat cheese presented a significantly higher dry

Table 2. Physicochemical parameters of the cheeses

Parameters	Cheese samples		
	Full-fat	Low-fat	Cheese-like product
pH	5.06±0.02^a	5.07±0.02^a	4.98±0.04^a
Dry matter (%)	43.24±0.04^c	38.92±0.22^b	37.89±0.02^a
Fat (%)	44.55±5.24^c	37.68±4.36^a	41.36±1.31^b
Protein (%)	31.98±0.09^a	36.84±0.77^b	39.25±0.05^c
Ashes (%)	8.17±0.01^a	9.21±0.17^b	8.25±0.09^a
Lipolysis	1.24±0.34^b	0.89±0.13^a	1.67±0.00^c
Cheese yield (g/L)	221.22±0.88^c	157.18±4.02^b	139.58±3.38^a

Means±standard deviation (SD) of three separate determinations
^{a,b,c}Values sharing lowercase letter within a column are not significantly different by Duncan's multiple-range test ($p<0.05$)

matter content than that of low-fat white brined cheese-like product (Table 2). This result showed that the addition of 3 % of $W_1/O/W_2$ emulsion to skimmed milk produced the decrease of dry matter content of white brined cheese-like product. Differences between full-fat and low-fat cheeses could be attributed to their protein contents. Furthermore, fat replacers are known for their water-binding capacity, which might in return explain the lower total solids content found in low-fat cheese than in full and low-fat control cheeses (Table 2).

Both the reduction and the substitution of milk fat had a significant effect on dry matter content of different cheese samples. Previous studies reported many significant differences in moisture content due to milk fat reduction and replacement ($p<0.05$). Indeed, McMahon et al. (1993) explained this by the fact that water acts as a lubricant, at low viscosity, between fat globules and casein molecules, and fills then the gaps between these particles. As for Lobato-Calleros et al. (2007), they demonstrated that moisture content is mainly influenced by the emulsifier blends as well as fat content and they indicated that the increase in fat and in emulsified canola oil contents produce a wide interruption of the protein network, resulting in more interspaces.

Fat content was significantly higher in the case of low-fat white brined cheese like-product than for low-fat control cheese ($p<0.05$) despite the same initial fat content (Table 1). Thus, it can be concluded that fat replacers could play a very important role in fat retention. This result was in accordance with those reported by Romeih et al. (2002) and Felfoul et al. (2015). With regard to Lobato-Calleros et al. (2003), they indicated that full-fat cheese has a significantly higher fat content than that of the obtained cheeses with canola oil having a high initial fat content. These authors explained that fat loss could be attributed to the emulsifier blends characteristics (HLB values of the emulsifiers, the interaction of some emulsifiers).

Low-fat white brined cheese-like product was characterized by significantly higher protein content than low-fat control cheese. Indeed, protein contents were 39.25 %, 36.84 % and 31.98 % for low-fat white brined cheese-like product, low and full-fat control cheeses, respectively (Table 2). Low-fat white brined-cheese like product was positively affected by the emulsifiers blend used as well as milk fat content. However, their contribution was indirect since they are naturally lipids. Moreover, protein content of different white brined cheese samples was inversely proportional to dry matter content as shown in Table 2. This could be due to water-binding capacity of fat replacers used in this study (Clark, 1994; Kavas et al., 2004). These results confirmed those of Michaelidou et al. (2003) and Felfoul et al. (2015) who showed that milk fat content reduction and substitution resulted in protein content increases in low-fat Feta-type and low-fat Gouda-type cheeses, respectively.

Table 2 indicated that ash content was significantly higher for low-fat control cheese than for low-fat white brined cheese-like product and full-fat cheese. This result was in disagreement with those reported by McGregor and White (1990), Rudan et al. (1999) and Romeih et al. (2002) for Cheddar-type cheese and Mozzarella cheese and white brined cheese, respectively. These authors showed that ash content is particularly important when milk fat content increases.

The lipolysis extent in full, low-fat cheeses and low-fat white brined-cheese like product, as assessed by the acid-degree value (ADV), was shown in Table 2. Lipolysis indexes of full and low-fat cheeses and white brined cheese-like product were equal to 1.24, 0.88 and 1.67 meq of acid per 100 g of fat, respectively. Cheese like products showed free acidity values significantly higher compared to low-fat cheese without fat replacers' addition. The increase in lipolysis index values could be due to the formation of simple nitrogen compounds, particularly free amino acids, which could serve as precursors for the formation of volatile fatty acids (Aly, 1994). Such results could also be attributed to significantly higher moisture content of cheese like products compared to low-fat cheese, which generally promote enzymatic activity and microbial growth. Moreover, cheese microstructure changes after fat replacers incorporation in low-fat products could also contribute to their high lipolysis degrees (Romeih et al., 2002). The manipulation of milk fat during $W_1/O/W_2$ emulsion preparation might also be one of the reasons for the increase in the lipolysis index. These results were in accordance with those previously reported in the literature. Indeed, Romeih et al. (2002) showed the reduction of free acidity values with fat content decrease for Cheddar (Dulley and Grieve, 1974) and Feta cheese prepared from sheep's milk (Katsiari and Voutsinas, 1994).

Low-fat milk had a cheese yield significantly lower than that of full-fat milk. The more the fat content was important, the more the cheese yield was increased. This result confirmed those reported by Lou and Ng-Kwai-Hang (1992) and Rudan et al. (1999) who showed that the yield of Mozzarella cheese containing 5 % fat was 30 % lower than in cheeses containing 25 % fat. Cheese yield was significantly greater in the case of low-fat milk (157.18 g/L) than that of milk-olive oil emulsion (139.58 g/L). The type of the fat incorporated into the milk to obtain the white brined cheese-like product affected significantly the cheese yield. The reduction in cheese yield during low-fat cheeses production was inevitable, since milk casein and fat as the main components determining the cheese yield, were reduced (Table 2). However, cheese-like products showed decreased cheese yields compared to low-fat cheeses. This result was in disagreement with those reported by Drake et al. (1996) and Sipahioglu et al. (1999) for Cheddar and Feta cheeses, respectively. The higher cheese yield of white brined cheese-like product compared to low-fat cheese without fat-replacers addition could be attributed to their low dry matter content.

Sensory evaluation of the cheeses

The panel's scores for the different cheese samples are presented in Table 3. No significant effect was noticed on appearance and odor scores between experimental cheeses ($p<0.05$). This result is opposite to our previous findings on low-fat Gouda cheese-like product (Felfoul et al., 2015). These differences could be attributed to the difference in the studied cheese types as well as the higher moisture content found in white brined cheese compared to that of Gouda cheese which might influence positively the mouthfeel attributes. There was no significant effect ($p<0.05$) on flavour scores of milk fat substitution between low-fat white brined cheese-like product and low-fat cheeses except for salty taste scores. Low-fat control cheese was characterized by a very salty taste score compared to all other cheese samples. This could be due to the significant high ash content in the low-fat cheese (Table 2). In addition, significantly higher bitterness scores were attributed to both cheese-like product and low-fat cheese samples in comparison to full-fat control cheese (Table 3). The obtained values are lower than those found by Felfoul et al. (2015) for Gouda cheese.

Low-fat white brined cheese-like products received significantly similar scores for body texture compared to full-fat cheese. These findings are in agreement with data reported by Drake et al. (1996) for Cheddar, Katsiari and Voutsinas (1994) for Feta and Felfoul et al. (2015) for Gouda cheeses.

According to the panelists, full-fat cheese showed a significantly higher overall impression with a score equal to 3.4 compared to low-fat white brined cheese-like product with 2.8 (Table 2). Fat substitution had a significant effect on the overall assessment of the cheeses. However, all cheeses were appreciated as acceptable by the panelists. This result was in agreement with our previous finding on low-fat Gouda cheese-like product (Felfoul et al., 2015).

Table 3. Sensory attribute ratings of the cheeses (scores from 100 panelists)

Attributes	Full-fat	Low-fat	Cheese like-product
Appearance	3.7 ± 0.95^{a}	3.9 ± 0.74^{a}	3.4 ± 1.07^{a}
Odour	2.9 ± 1.37^{a}	3.0 ± 0.82^{a}	2.3 ± 0.95^{a}
Bitterness	1.1 ± 1.29^{a}	1.6 ± 1.78^{b}	1.6 ± 1.58^{b}
Acidity	1.1 ± 0.99^{a}	2.6 ± 1.71^{b}	1.7 ± 1.57^{ab}
Saltiness	1.9 ± 1.10^{a}	4.0 ± 1.05^{b}	1.8 ± 1.23^{a}
Body texture	2.9 ± 0.74^{a}	3.2 ± 1.23^{a}	3.0 ± 0.94^{a}
Overall impression	3.4 ± 0.97^{a}	3.2 ± 1.14^{a}	2.8 ± 0.92^{b}

Means±standard deviation (SD) of three separate determinations
^{a,b}Values sharing lowercase letter within a column are not significantly different by Duncan's multiple-range test ($p<0.05$)

Conclusion

This study was carried out to evaluate the physicochemical and sensory attributes of white brined cheese-like product obtained from milk-olive oil emulsion in comparison with full and low-fat control cheeses. The obtained data have shown that it is possible to make acceptable cheese-like products with milk-olive emulsion and fat replacers. Total solids content was significantly lower for cheese-like product compared to full-fat control cheeses due to water-binding capacity of the fat replacers used. Besides, protein content was significantly higher in the case of low-fat white brined cheese-like product compared to full and low-fat control cheeses. Moreover, low-fat cheese-like products showed free acidity values significantly higher compared to low-fat cheese without fat replacers' addition. Cheese like-product showed a significantly lower overall impression score by the panelists compared to full and low-fat control cheeses.

Acknowledgment

This work was funded by the Ministry of Higher Education and Scientific Research - Tunisia.

Usporedba fizikalno-kemijskih i senzorskih svojstava sireva u salamuri proizvedenih od mlijeka i mješavine mlijeka i maslinovog ulja

Sažetak

Cilj ovog rada bio je usporediti fizikalno kemijska i senzorska svojstva posnih zamjena za sireve u salamuri proizvedenih od mješavine mlijeka i maslinovog ulja u odnosu na posne i punomasne sireve tog tipa. Pripremljeni uzorci mlijeka odnosno smjesa mlijeka i ulja pasterizirani su na 63 °C/30 min, ohlađeni na 35 °C te im je dodano 0,35 mL L^{-1} sirila mikrobnog porijekla. Proizvedeni uzorci sira čuvani su na 4 °C tijekom 24 sata te je potom provedena analiza fizikalno kemijskih i senzorskih svojstava. Zamjena mliječne masti uljem rezultirala je nižim udjelom suhe tvari uslijed veće sposobnosti vezanja vode od strane zamjenske masti. Udio masti je bio značajno viši u sirnim zamjenama nego u kontrolnom uzroku posnog sira, što se može povezati s kapacitetom zadržavanja masnoća od strane korištene zamjene za mliječnu mast. Najveći indeks lipolize zabilježen je u posnoj zamjeni za sir i to zbog promjena u mikrostrukturi sira koje su nastupile dodatkom zamjena za mliječnu mats i njihove ugradnje zamjenski proizvod. Mješavina maslinovog ulja i mlijeka odlikovala se najnižim prinosom sira, a tako proizvedena zamjena za sir dobila je značajno niže ocjene prilikom senzorskog ispitivanja u odnosu na punomasni i posni sir.

Ključne riječi: emulzija mlijeko-maslinovo ulje, zamjena za sir, zamjena za mliječnu mast, lipoliza, ukupan dojam

References

1. AHA (1996): Dietary guidelines for healthy Americans. *Circulation* 94: 1795-1800.
2. Aly, M.E. (1994): Flavour enchancement of low-fat Kashkaval cheese using heat or freeze-shocked *Lactobacillus delbrueckii* var. *helveticus* cultures, *Nahrung 38*, 504-510. doi: 10.1002/food.19940380506
3. AOAC (1995): Official methods of analysis, 16th edn. Association of Official Analytical Chemists, Washington, DC.
4. Bullens, C. (1994): Reduced-fat Cheddar: Aspects of process and ingredient, *World of Ingredients 1*, 28-31.
5. Clark, D. (1994): Fat replacers and fat substitutes, *Food Technology 48*, 86.
6. Dickinson, E., McClements, J.D. (1996): Advances in food colloids. London: Blackie Academic & Professional, *Journal of Food Science 61*, 1267-1271.
7. Drake, M.A., Swanson, B.G. (1995): Reduced- and low-fat cheese technology: A review, *Trends in Food Science and Technology 6*, 366-369. doi: 10.1016/S0924-2244(00)89192-X
8. Drake, M.A., Boylston, T.D., Swanson, B.G. (1996): Fat mimetics in low-fat Cheddar cheese, *Journal of Food Science 61*, 1267-1270. doi: 10.1111/j.1365-2621.1996.tb10976.x
9. Dulley, J.R., Grieve, P.A. (1974): Volatile fatty acid production in Cheddar cheese, *Australian Journal of Dairy Technology 29*, 120-123.
10. Felfoul, I., Bornaz, S., Baccouche, A., Sahli, A., Attia, A. (2015): Low-fat Gouda cheese made from bovine milk-olive oil emulsion: physicochemical and sensory attributes, *Journal of Food Science and Technology 52*, 6749-6755. doi: 10.1007/s13197-015-1736-0

11. Felfoul, I., Bornaz, S., Belhadj Hmida, W., Sahli, A., Attia, H. (2013): Effect of milk fat substitution of rennet milk induced coagulation on physicochemical properties, *E- Journal of Chemistry 2013*, 1-8. doi: 10.1155/2013/732024
12. Gallois, A., Langlois, D. (1990): New results in the volatile odorous compounds of French cheeses, *Lait 70*, 89-106. doi: 10.1051/lait:199028
13. International Dairy Federation (1987): Lait. Crème et lait concentré non sucré. Détermination de la matière sèche, International Standard FIL-IDF 21B.
14. International Dairy Federation (1993): Lait. Détermination de la teneur en azote. 4. Détermination de la teneur en azote non protéique, International Standard FIL-IDF 20B.
15. Katsiari, M.C., Voutsinas, L.P. (1994): Manufacture of low-fat Feta cheese, *Food Chemistry 49*, 53-60. doi: 10.1016/0308-8146(94)90232-1
16. Kavas, G., Oysun, G., Kinik, O., Uysal, H. (2004): Effect of some fat replacers on chemical, physical and sensory attributes of low-fat white pickled cheese, *Food Chemistry 88*, 381-388. doi: 10.1016/j.foodchem.2004.01.054
17. Lobato-Calleros, C., Ramírez-Santiago, C., Osorio-Santiago, V.J., Vernon-Carter, E.J. (2002): Microstructure and texture of manchego cheese-like products made with canola oil, lipophilic, and hydrophilic emulsifiers, *Journal of Texture Studies 33*, 165-182. doi: 10.1111/j.1745-4603.2002.tb01343.x
18. Lobato-Calleros, C., Reyes-Hernandez, J., Beristain, C.I., Hornelas-Uribe, Y., Sanchez-Garcia, J.E., Vernon-Carter, E.J. (2007): Microstructure and texture of white fresh cheese made with canola oil and whey protein concentrate in partial or total replacement of milk fat, *Food Research International 40*, 529-537. doi: 10.1016/j.foodres.2006.10.011
19. Lobato-Calleros, C., Robles-Martínez, J.C., Caballero-Pérez, J.F., Aguirre-Mandujano, E., Vernon-Carter, E.J. (2001): Fat replacers in low-fat mexican manchego cheese, *Journal of Texture Studies 32*, 1-14. doi: 10.1111/j.1745-4603.2001.tb01030.x
20. Lobato-Calleros, C., Velazquez-Varela, J., Sanchez-Garcia, J., Vernon-Carter, E.J. (2003): Dynamic rheology of Mexican Manchego cheese-like products containing canola oil and emulsifier blends, *Food Research International 36*, 81-90. doi: 10.1016/S0963-9969(02)00111-4
21. Lou, Y., Ng-Kwai-Hang, K.F. (1992): Effects of protein and fat levels in milk on cheese and whey compositions, *Food Research International 25*, 445-451. doi: 10.1016/0963-9969(92)90169-6
22. McGregor, J.U., White, C.H. (1990): Effect of enzyme treatment and ultra-filtration on the quality of low-fat Cheddar cheese, *Journal of Dairy Science 73*, 571-579. doi: 10.3168/jds.S0022-0302(90)78704-8
23. McMahon, D.J., Youssif, B.H., Kalab, M. (1993): Effect of whey protein denaturation on structure of casein micelles and their rennetability after ultra-high temperature processing of milk with or without ultrafiltration, *International Dairy Journal 3*, 239-256. doi: 10.1016/0958-6946(93)90067-A
24. Michaelidou, A., Katsiari, M.C., Voutsinas, L.P., Kondyli, E., Alichanidis, E. (2003): Effect of a commercial adjunct culture on proteolysis in low-fat Feta-type cheese, *International Dairy Journal 13*, 743-753. doi: 10.1016/S0958-6946(03)00099-2
25. Mistry, V.V., Anderson, D.L. (1993): Composition of microstructure of commercial full-fat and low-fat cheeses, *Food Structure 12*, 259-266.
26. Norme Française (1968): Détermination du pH du fromage, NF V 04-281.
27. Norme Française (1989): Lait - Détermination des cendres - Méthode de référence, NF V04-208, Ed. AFNOR, Paris : Association Française de Normalisation.
28. Romeih, E.A., Michaelidou, A., Biliaderis, C.G., Zerfiridis, G.K. (2002): Low-fat white brined cheese made from bovine milk and two commercial fat mimetics, physical and sensory attributes, *International Dairy Journal 12*, 525-540. doi: 10.1016/S0958-6946(02)00043-2
29. Rudan, M.A., Barbano, D.M., Kindstedt, P.S. (1998): Effect of fat replacer (Salatrims) on chemical composition, proteolysis, functionality, appearance, and yield of reduced fat Mozzarella cheese, *Journal of Dairy Science 81*, 2077-2088. doi: 10.3168/jds.S0022-0302(98)75782-0
30. Sipahioglu, O., Alvarez, V.B., Solano-Lopez, C. (1999): Structure, physico-chemical and sensory properties of Feta cheese made with tapioca starch and lecithin as fat mimetics, *International Dairy Journal 9*, 783-789. doi: 10.1016/S0958-6946(99)00150-8
31. USDA, USDHHS (1995): Nutrition and your health: Dietary guidelines for Americans. 4th ed., Home and Garden Bulletin, No. 232., U.S. Dept. Agriculture and U.S. Dept. Health and Human Services, Washington, D.C.
32. USDHHS (1988): The Surgeon General's Report on Nutrition and Health. Publ. No. 88-50210. U.S. Govt. Print. Office, Washington, D.C.
33. Yu, L., Hammond, E.G. (2000): Production and characterization of a swiss cheese-like product from modified vegetable oils, *Journal of the American Oil Chemists' Society 77*, 917-924. doi: 10.1007/s11746-000-0145-y