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QUALITY OF WHEY FAT OBTAINED DURING THE PRODUCTION OF SOME RIPENING CHEESES

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Key words: milk fat, whey fat, Gouda cheese and Mazurski cheese

Cheese milk fat (treated as fat in the native state), whey fat and whey cream fat obtained during the production of some ripening cheeses were compared in the study.

No significant correlations were observed between cheese production technology and the quality of whey cream and whey cream fat obtained in the process. Whey cream showed differentiated quality. The range of changes in milk fat was related primarily to raw material quality. The proportions of fatty acids and their groups in the fat of particular types of whey cream and respective cheese milk samples were similar. The concentrations of free fatty acids and their groups in particular types of whey cream were relatively high and differentiated.

INTRODUCTION

Whey is one of by-products obtained during the production of ripening cheeses. Depending on the processing technology, whey contains 50% to 60% of milk dry matter components. Some of these components are highly valuable when in isolated form. One of the first technological steps during multidirectional whey processing (*e.g.* production of whey protein concentrates, lactose or lactic aid) is whey fat separation [Cheryan, 1998; Pedersen, 1990; Renner & Abd El-Salam, 1991; Timmer & Van der Horst, 1997]. The factor that determines, to a great extent, the possibility of further utilisation of whey fat is its concentration in the form of whey cream. Whey fat in this form, obtained during cheese production, is usually used as raw material for further processing.

The aim of the present study was to determine the effects of the technology of production of some ripening cheeses on changes in milk fat, by a comparative analysis of the composition and physicochemical properties of processing milk fat and whey cream fat obtained during cheese production.

MATERIALS AND METHODS

The study comprised a technological cycle in the production of Gouda cheese and Mazurski cheese. Determinations were made in seven replications on samples of bulk milk, processing milk, whey and whey cream. The analysis of milk fat and whey fat was preceded by collecting data on the main technological parameters of the production process. In all cases these parameters were consistent with the technological instructions for a given type of cheese. The same coagulating enzyme was applied in the experiments. The microbiological quality of milk met the requirement of relevant standards. The fat content of whey ranged from 0.3% to 0.6%, and the fat content of whey cream (obtained by double centrifugation of whey) – from 35.05% to 43.5%. All samples were collected on the same production line. The study was conducted from October to March.

The following analyses were performed: (i) in processing milk: dry matter content, fat content, potential acidity, fat acidity, concentrations of free fatty acids, composition of fatty acids and composition of free fatty acids; (ii) in whey: dry matter content, fat content, potential acidity, concentrations of free fatty acids; and (iii) in whey cream: dry matter content, fat content, potential acidity, fat acidity, composition of fatty acids, concentrations and composition of free fatty acids.

To determine the composition of fatty acids, fat was extracted by the Röse-Gottlieb method modified by Hankinson *et al.* [1958]. The instructions by Frankel & Tarassuk [1955], and McDowell [1974] were followed during fat extraction. Solvents were evaporated from the lipid extract at 50°C, and then fat was dried with odour-free sodium sulfate. Fatty acid methyl esters were prepared as described by De Mann [1968], and separated by gas chromatography.

Fatty acids were separated using a gas chromatograph (Anglia-Instruments Ltd.) with a flame-ionization detector and a glass column, 210 cm in length and 4 mm in diameter. Column packing (support): 15% DEGS (diethylene glycol succinate) plus orthophosphoric acid. Carrier gas: argon, flow rate 40 mL/min, oxy-hydrogen burner, hydrogen flow rate 40 mL/min, oxygen flow rate 200 mL/min. During the

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separation of fatty acid methyl esters temperature was programmed linearly from 60°C to 195°C; isothermal cycle began when a temperature of 195°C was achieved. The process was programmed at a gradient temperature range of 20°C/min. Detector temperature – 250°C, evaporator temperature – 250°C. The results are given as percentages of particular fatty acids in relation to total fatty acids.

To determine the composition of free fatty acids, esterification was carried out according to the method described by Kuzdzal-Savoie *et al.* [1971].

Prior to the separation of volatile fatty acids, their soaps were treated as described by Roes *et al.* [1963]. The conditions of separation were as follows: a gas chromatograph with a flame-ionization detector and a glass column, 150 cm in length and 4 mm in diameter. Column packing (support): chromosorb WAIK 80/100 mesh. Liquid stationary phase: 10% DEGS (diethylene glycol succinate) plus orthophosphoric acid. Carrier gas: argon, flow rate 50 mL/min, oxy-hydrogen burner, hydrogen flow rate 50 mL/min, oxygen flow rate 200 mL/min. Detector temperature – 250°C, column temperature – 140°C, evaporator temperature – 225°C.

The conditions of separation of non-volatile fatty acids were as follows: a gas chromatograph with a flame-ionization detector and a glass column, 210 cm in length and 4 mm in diameter. Column packing (support): Gas-chrom 100/120 mesh. Liquid stationary phase: BGS5-x added in the amount of 10% in relation to the support. Carrier gas: argon, flow rate 60 mL/min, oxy-hydrogen burner, hydrogen flow rate 60 mL/min, oxygen flow rate 200 mL/min. During the separation temperature was programmed linearly from 65°C to 195°C; isothermal cycle began when a temperature of 195°C was achieved. The process was programmed at a gradient temperature range of 15°C/min. Detector temperature – 250°C, evaporator temperature – 225°C.

The concentrations of free fatty acids were determined by the Dole method modified by Deeth, Fitz-Gerald and Wood [Deeth *et al.*, 1975, 1976]. Fat content was determined by the Gerber method, active acidity was measured with a pH-meter, potential acidity was measured by the Soxhlet-Henkel method, and fat acidity was measured by the titration method, in fat obtained by the BDI method [Anderson *et al.*, 1962], protein content was determined by Kjeldahl method, and dry matter content – by drying at 102°C.

RESULTS AND DISCUSSION

The raw materials used for cheese production had differentiated physicochemical properties (Table 1) and various levels of particular fatty acids.

Certain changes in milk fat take place during the storage of milk, whey and whey cream [Eyer & Weeda, 1991; Fox & Stepaniak, 1993; Martley & Crow, 1993]. Also the process of re-pasteurization intensifies hydrolytic changes in fat [Batura *et al.*, 1991, Staniewski, 1998, Varnam & Sutherland, 1994]. In a way, elevated levels of free fatty acids are a consequence of the implementation of modern technologies of milk collection and processing [Banks, 1991; Cano-Ruiz & Richter, 1997; Fox & McSweeney, 1998; Horwood *et al.*, 1994; Sanchez *et al.*, 1994].

Milk fat used for the production of Gouda cheese, as compared with the raw material used for the production of Mazurski cheese, had higher concentrations of higher saturated and polyunsaturated fatty acids. The levels of the other fatty acids, mostly FFAs and monounsaturated fatty acids, were similar in both cases (Table 2).

Fat undergoes changes already at the initial stage of cheese production. These changes result in elevated levels

TABLE 1. Results of a physicochemical assessment of bulk milk, processing milk, whey, whey cream and cheese during the production of Gouda cheese and Mazurski cheese.

Type of cheese		Gouda		Mazurski	
Specification		$\bar{x}$	s	$\bar{x}$	s
			Processing milk		
Dry matter content	(%)	10.25	0.05	11.03	0.03
Fat content	(%)	2.86	0.05	3.51	0.04
Potential acidity	(°SH)	6.87	0.37	6.68	0.29
Fat acidity	(°)	2.49	0.39	2.14	0.19
Free fatty acid content	(μEq/cm^3)	2.66	0.33	2.20	0.18
Free fatty acid content	(μEq/g fat)	93.10	12.60	62.80	5.31
			Whey		
Dry matter content	(%)	6.19	0.15	6.06	0.33
Fat content	(%)	0.56	0.12	0.36	0.03
Potential acidity	(°SH)	4.94	0.44	4.45	0.19
Free fatty acid content	(μEq/cm^3)	1.72	0.64	1.77	0.21
Free fatty acid content	(μEq/g fat)	347.00	101.94	483.18	58.90
			Whey cream		
Dry matter content	(%)	39.11	2.59	45.90	5.93
Fat content	(%)	35.71	2.80	41.57	5.21
Potential acidity	(°SH)	6.68	0.91	4.47	0.65
Fat acidity	(°)	2.91	0.47	2.25	0.29
Free fatty acid content	(μEq/cm^3)	18.39	4.80	10.23	1.78
Free fatty acid content	(μEq/g fat)	51.24	12.86	24.65	3.61

TABLE 2. Proportions of fatty acids by groups (% of total fatty acids) in processing milk fat and whey cream fat during the production of Gouda cheese and Mazurski cheese.

Proportions of fatty acids by groups (%)	Gouda cheese		Mazurski cheese	
	processing milk	whey cream	processing milk	whey cream
Volatile	11.48	15.56	11.74	12.38
Higher saturated	60.79	53.97	56.93	53.92
Monounsaturated	24.28	26.91	29.15	31.58
Polyunsaturated	3.45	3.56	2.18	2.12

TABLE 3. Proportions of free fatty acids by groups (% of total fatty acids) in processing milk fat and whey cream fat during the production of Gouda cheese and Mazurski cheese.

Proportions of fatty acids by groups (%)	Gouda cheese		Mazurski cheese	
	processing milk	whey cream	processing milk	whey cream
Volatile	16.46	5.8	20.67	5.79
Higher saturated	48.32	53.15	46.37	58.05
Monounsaturated	33.68	37.89	31.14	32.77
Polyunsaturated	1.54	3.16	1.82	3.39

of FFAs, including low-molecule acids in whey cream (from C_4 to C_{10}, and $C_{10:1}$). Horwood *et al.* [1994] demonstrated that milk aeration intensified the processes of milk fat hydrolysis, which caused a considerable increase in the FFA content of cheese curd. Milk fat oxidation was also studied by Chen & Nawar [1991]. Free amino acids and their analogues acted as antioxidants, both in aqueous solutions and in the acid medium.

In comparison with processing milk, whey cream obtained during Gouda cheese production contained slightly larger amounts of the acids C_{12}, $C_{12:1}$, $C_{17:1}$, $C_{18:1}$ and $C_{18:2}$, and whey cream obtained during Mazurski cheese production had higher levels of the acids $C_{12:1}$, $C_{16\ ISO}$, C_{17}, $C_{17:1}$, C_{18}, $C_{18:1}$ and $C_{18:2}$. Whey cream obtained during the production of both types of cheese contained more volatile and monounsaturated fatty acids than milk. The concentrations of polyunsaturated fatty acids in whey cream and milk were similar. The levels of saturated fatty acids were somewhat higher in milk than in whey cream obtained during the production of Gouda cheese and Mazurski cheese (Table 2).

The composition of whey cream fat obtained during Gouda cheese production was more differentiated than the composition of whey cream fat obtained during Mazurski cheese production. These differences included: slightly higher concentrations of FFAs during Gouda cheese production, and a higher decrease in the levels of isotetradedecanoic acid ($C_{14\ ISO}$) and isohexadecanoic acid ($C_{16\ ISO}$), compared with processing milk. Whey cream obtained during Mazurski cheese production contained significantly higher amounts of 9-heptadecanoid acid ($C_{17:1}$) and isohexadecanoid acid ($C_{16\ ISO}$), and lower quantities of isotetradecanoid acid ($C_{14\ ISO}$) and linolenic acid ($C_{18:3}$) than milk fat. Changes in the concentrations of higher saturated and unsaturated fatty acids were similar in both types of whey cream.

Certain differences in FFA content were observed in all products in both production processes. The milk used for Mazurski cheese production had a higher content of volatile and polyunsaturated fatty acids, and a lower content of higher saturated and monounsaturated fatty acids than processing milk used for Gouda cheese production. Despite their low levels, more distinct differences were recorded in the concentrations of the acids C_2, C_4, C_8, C_{12}, $C_{18:1}$, which were higher in the milk used for Mazurski cheese production, and in the concentrations of the acids $C_{10:1}$, $C_{12:1}$, $C_{16\ ISO}$, $C_{16:1}$, C_{17}, $C_{17:1}$, which were slightly higher in the milk used for Gouda cheese production. Whey cream fat contained lower amounts of volatile free fatty acids than milk. Whey cream obtained as a result of cheese production contained higher levels of polyunsaturated free fatty acids (Table 3). This increase was identical in both linoleic acid ($C_{18:2}$) and linolenic acid ($C_{18:3}$). A certain, but much lower, increase in monounsaturated free fatty acids recorded in whey cream was related primarily to an increase in the concentration of oleic acid ($C_{18:1}$), accompanied by a slight decrease in the levels of the acids $C_{10:1}$, $C_{12:1}$, $C_{14:1}$, $C_{16:1}$ and $C_{17:1}$.

Processing milk fat had normal composition, with proper proportions between particular acids. Small differences were observed only in the content of minor fatty acids. Processing milk fat contained no isotetradecanoid acid ($C_{14\ ISO}$) in free form, which was found in whey cream fat.

Whey cream fat contained smaller quantities of volatile free fatty acids than milk fat. These differences concerned, among others, the acids $C_{10:1}$, $C_{14:1}$, C_{16ISO}, $C_{16:1}$ and C_{17} in whey cream fat obtained during Gouda cheese production, and the acids $C_{10:1}$, C_{12}, $C_{12:1}$, $C_{14:1}$ and $C_{17:1}$ in whey cream fat obtained during Mazurski cheese production.

Significant differences in the levels of FFAs and VFAs are a consequence of whey centrifugation. Readily soluble VFFAs remain in the centrifuged whey in the major part, whereas higher free fatty acids, both saturated and unsaturated, pass into the lipid fraction of whey cream. The levels of FFAs are also affected by fat concentration in whey cream. This concerns both saturated and unsaturated free fatty acids. A comparison of changes in the content of particular groups of fatty acids in processing milk and whey cream, taking into account the differences in milk fat concentration in milk and whey cream, shows that the amount of VFAs decreased and the quantity of saturated and unsaturated fatty acids increased in both types of cream. The concentrations of higher saturated fatty acids in whey cream fat obtained during the production of Mazurski cheese and Gouda cheese was by respectively 43.0% and 21.34% higher than in milk fat. Much greater differences were observed

TABLE 4. Concentrations of free fatty acid by groups (mg/100 g fat) in processing milk fat and whey cream fat during the production of Gouda cheese and Mazurski cheese.

Concentations of free fatty acids by groups (mg/100 g fat)	Gouda cheese		Mazurski cheese	
	processing milk	whey cream	processing milk	whey cream
Volatile	29.21	14.86	25.98	8.31
Higher saturated	112.13	136.06	58.28	83.35
Monounsaturated	78.21	97.02	38.75	47.18
Polyunsaturated	3.57	8.09	2.29	4.87

in the levels of polyunsaturated fatty acids. In whey cream fat obtained during Mazurski cheese production their content increased by as much 212.6%, *i.e.* from 2.29 mg/100 g of milk fat to 4.87 mg/100 g of whey cream fat, and in whey cream fat obtained during Gouda cheese production – by 226.6%, *i.e.* from 3.57 mg/100 g of milk fat to 8.09 mg/100 g of whey cream fat. Mono- and polyunsaturated fatty acids contributed to these changes to the lowest degree (Table 4). An over twofold increase, compared with the raw material, in the content of polyunsaturated fatty acids in whey cream obtained during the production of Gouda cheese and Mazurski cheese could be partly related to whey cream storage under unfavorable conditions, conducive to the proliferation of psychrotrophic microflora. Lipases of this group of microorganisms show a decided preference for long-chain unsaturated fatty acids. Hydrolysis of milk fat with liberation of polyunsaturated fatty acids may occur already at the stage of milk collection and storage. Further changes in milk fat take place in the process of cheese production. Therefore, it should be stressed that undesirable changes in milk fat initiated during raw material storage and developing during cheese production may intensify and lead to numerous cheese defects [Björck & Farkye, 1992; Fox & Stepaniak, 1993].

CONCLUSIONS

1. No significant correlations were observed between cheese production technology and the quality of whey cream and whey cream fat obtained in the process. Whey cream showed differentiated quality. The range of changes in milk fat was related primarily to raw material quality.

2. The proportions of fatty acids and their groups in the fat of particular types of whey cream and respective cheese milk samples were similar. The concentrations of free fatty acids and their groups in particular types of whey cream were relatively high and differentiated.

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JAKOŚĆ TŁUSZCZU SERWATKOWEGO UZYSKANEGO W PROCESIE PRODUKCJI WYBRANYCH RODZAJÓW SERÓW DOJRZEWAJĄCYCH

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Dokonano analizy porównawczej tłuszczu mleka serowarskiego (traktowanego jako tłuszcz w stanie natywnym) z tłuszczem śmietanki serwatkowej uzyskanej przy produkcji serów Gouda i Mazurski. Surowiec użyty do wyrobu serów charakteryzował się zróżnicowanymi cechami fizykochemicznymi (tab. 1) oraz różnym udziałem poszczególnych kwasów tłuszczowych jak i ich grup (tab. 2). Nie wykazano istotnych zależności pomiędzy stosowaną technologią wyrobu danego rodzaju sera a jakością otrzymanej śmietanki serwatkowej i jej tłuszczu. Udział kwasów tłuszczowych, jak i ich grup w tłuszczu poszczególnych rodzajów śmietanki serwatkowej i odpowiadających im prób mleka kształtował się na zbliżonym poziomie (tab. 2). Stwierdzono stosunkowo wysoką i zróżnicowaną zawartość wolnych kwasów tłuszczowych oraz ich grup w poszczególnych rodzajach śmietanki (tab. 3 i 4).