EFFECTS OF ELECTROMAGNETIC WAVES ON THE LEVEL OF FATTY ACIDS IN UHT MILK

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Abstract

The aim of this study was to determine whether long-term storage of UHT milk and its heating in a microwave has an impact on the fatty acid profile. Material consisted of 4 types of UHT milk from different manufacturers with a fat content of 3.2%. Analyses were conducted for 13 days. Milk was stored in the original container in a refrigerator at 4°C. Milk samples after opening the package were heated for 1 and 2 minutes in a microwave. Absolute density, acidity, freezing point, electrolytic conductivity and solids non-fat, crude fat, lactose, total protein and minerals were estimated. Physical and chemical parameters of milk were determined using ultrasonic analyzer Lactoscan MCC. The fatty acid composition was determined using a gas chromatograph. Fatty acid methyl esters were identified by comparison with the standards (Supelco 37 Component FAME). UHT milk storage after opening at 4°C and heating in microwave for 1 or 2 minutes (microwave power 1100 W and power heater 750 W) did not result during the period of 13 days in significant changes in the fatty acid profile. Also were not stated other significant changes in the values of physical and chemical parameters of milk during the experiment. Differences that occurred in the electrolytic conductivity may result from evaporation of water during storage of milk and heating, as indicated by its freezing point. On this basis, it can be concluded that storing milk in the fridge and reheating it in the microwave does not have a significant impact on its physicochemical properties and fatty acid profile.

Keywords: UHT milk quality, microwave, fatty acid composition

Introduction

In countries with the longest average human life such as Denmark, Norway, Finland, Sweden, USA, Canada, UK, Ireland, the Netherlands, Greece, Switzerland, drinking milk is mostly pasteurized and not sterilized UHT. On the Polish dairy market UHT milk has a very strong position and its consumption is as high as 45% of the total amount of milk produced. This is probably due to the fact that this type of milk is suitable for long-term storage (Wroński et al., 2009). During a sterilization process certain physico-chemical changes occur in the milk (Usarek et al., 1997). CO_2 escapes under the influence of heat, which causes a slight reduction in titratable acidity of milk and at the same time increases its active acidity (reducing the level of pH) due to the release of hydrogen ions H^+. Heating also induces changes in the structure of casein micelles, which are enhanced by annealing the denatured whey protein, as well as the movement of calcium phosphate, which passes from the ionic forms to an insoluble colloidal form. In the milk after instant sterilization (UHT 130–160°C, 1 s) lactulose, an epimer of lactose is formed in an amount of 100–500 mg/cm^3, and after a conventional sterilization (UHT 135–150°C, 1–2s) – 900–1380 mg/cm^3. Milk whey protein denatures at 60–70% during instant sterilization and at 70–80% during the conventional sterilization. Preservation of milk by sterilization method causes a higher loss of vitamins than pasteurization (Śmietana et al., 2004). Heat treatment does not cause physical or chemical changes that would reduce the nutritional value of the fat fraction of milk (Rodriguez-Alcala et al., 2009; Molto-Puigmarti et al., 2011). These treatments, however, can lead to the partial denaturation of the whey protein, casein micelle dissociation and disruption of milk fat globules shells (Pereda et al., 2007; Zamora et al., 2007). However, heat treatment changes the physical properties of the fat globules in whole milk and cream. Denaturation of agglutinin that they clump decreases the ability of the accumulation of fat on the surface of the milk. There is also evidence that the milk heated at 60°C for 30 minutes under a pressure of 200 MPa, increases the activity of the native lipase (Datta et al., 2005). Rodriguez-Alcala et al. (2014) observed that the UHT sterilization (135°C, 30 s) and microwave pasteurization (650 W, 1.30 min), decreased in the milk total level of conjugated linoleic acid C18:2 (CLA), but increased the percentage of both isomers (t9t11) of this acid. The changes, however, were not statistically significant.

Microwave heating is a form of dielectric heating which is used industrially for the processing of food and also used domestically for cooking or thawing of food (Song and Kang, 2016). Microwaves (MWs) are electromagnetic waves that are within a frequency band of 300 MHz to 300 GHz (Chandrasekaran et al., 2013); however, MW-heating applications have been limited to a few narrow frequency bands for industrial, scientific, and medical use to avoid interference with the radio frequencies used for telecommunication purposes. The typical bands are 915±25 MHz and 2,450±50 MHz with penetration depths ranging from 8 to 22 cm at 915 MHz and from 3 to 8 cm at 2,450 MHz depending on the moisture content. The domestic MW ovens operate at 2,450 MHz, whereas both frequencies are used for industrial purposes. It is worthwhile to note that outside of the United States, frequencies of 433.92, 896, and 2375 MHz are also used for MW heating (Ahmed and Ramaswamy, 2007; Guo et al., 2017). UHT milk stored in the refrigerator after opening retains the freshness for a relatively long time. The development of microorganisms in the milk after each closing of the carton, from which its sample was collected, occurs after 14 days (Zapletal et al., 2009). Often the milk is consumed after being heated in the microwave. The most important structural and chemical changes that occur during MW heating are protein denaturation and aggregation, Maillard reactions, and lactose isomerization, which are mostly related to thermal effects of MW heating (Iuliana et al., 2015). The Maillard reaction is also one of the most important causes of sensory quality and nutrient loss in heat-treated milk and dairy products, which is mainly caused by a significant loss of the essential amino acid lysine (2% to 3% in pasteurized and 7% to 10% in UHT milk) due to its non-enzymatic reaction with lactose. Furthermore, it promotes the production of off-flavors and brown-colored pigments (melanoidins), as well the polymerization of milk protein (Dumuta et al., 2011; Iuliana et al., 2015; Tessier et al., 2006).

The aim of the study was to demonstrate whether storing UHT milk after opening the package and heating it in a microwave has an impact on the fatty acid profile.

Material and methods

Material

Material consisted of 4 types of UHT milk from different manufacturers with a fat content of 3.2%. Each tested group consisted of 8 samples from different unit packages.

Procedures

The experiment was carried out for 13 days. Milk was stored in the original container in a refrigerator at 4°C. At this time, the milk sample was tested 4 times during the research for 1 (0 – control), 4, 8 and 13 days. Into the vessel resistant to high temperatures was poured 150 ml of milk and then subjected to the action of microwaves emitted by a microwave (Samsung, model GW73B, of microwave power up to 1100 W and 750 W power of the heater). In each of the four cartons of milk two samples were taken (150 ml each) and heated for 1 and 2 minutes. Milk was taken from the package (stored at 4°C) and the milk was preheated in a microwave to attain room temperature.

Methods

Marked physical parameters included density, acidity, freezing point and electrolytic conductivity. Analyzed chemical components were solids non-fat (SNF), fat, lactose, total protein (TP), and mineral matter (MM). The physicochemical parameters of milk were investigated by the ultrasonic analyzer Lactoscan MCC model (Milktronics Ltd).

The fatty acid (FA) profile was determined using a gas chromatograph Trace GC Ultra (Thermo Electron Corp., Waltham, USA) with a flame ionization detector FID temp. 250°C equipped with a column Stabilwax with dimensions of 30 m × 0.25 mm × 0.25 mm. Helium was used as carrier gas and fed at a flow rate of 1 ml/min and division (split flow) of 10 ml/min. Injector and detector temperature were 220°C and 250°C, respectively. The column temperature was maintained at 60°C for 3 min, then raised at a rate of 7°C/min to 200°C and held at this temperature for 20 minutes. To 5 mg fat obtained after extraction of milk with a solvent mixture of chloroform-methanol (2:1) was added 50 ml of toluene and esterified by adding 100 µl of 2N sodium hydroxide in methanol for 20 minutes at room temperature (Christie, 2001). After addition of 0.5 ml of 14% BF_3 in methanol again reacted for 20 minutes at room temperature. The resulting esters extracted hexane. On the chromatograph were injected 1 µl. Fatty acid methyl esters were identified by comparison with standards (Supelco 37 Component FAME Mix, Sigma-Aldrich Co.). The analysis took into account saturated (SFA) and unsaturated (UFA) fatty acids, including monounsaturated (MUFA) and polyunsaturated (PUFA).

Statistical analyses

The data were statistically analyzed in the program Statistica 9.1. The differences between the averages of individual parameters were examined using GLM procedure according to the following model: $Yijkl = \mu + Di + Pj + + (D{\times}P)_{ij} + \epsilon ij$,

where:

μ – average overall,

Di – the fixed effect of the i-th day after opening the milk (1, 4, 8, 13),

P_j – the fixed effect of the j-th time heating in the microwave in minutes (1, 2),

$(D{\times}P)_{ij}$ – interaction between day after opening and time of heating in the microwave

ϵij – random error.

The significance of differences was tested by Scheffe test.

Results

During storage and heating UHT milk showed no statistically significant changes in its physical parameters. The density of the milk is the result of the density of its components and is in the range from 1.029 g/cm^3 to 1.033 g/cm^3 (Table 1). The active acidity (pH) in the first day of the experiment, after opening the milk was 6.34–6.37. There was an increase in the acidity of the milk not heated between day 0 and 13, by an average of 0.08 (Table 1). Therefore, in practice, this translates into a change in the degree of freezing point and, consequently, increase in the threshold of tolerance by determining the water of foreign origin. The results showed that the freezing point ranged between –0.480 and –0.500°C. We observed significant differences in the values of electrolytic conductivity between milk heated and analyzed immediately after opening the package or not heated in the subsequent days of storage. Especially the milk after 13 days heated for 1 minute, differed highly significantly (<0.001) from the milk at day 0 heated for 2 min and milk at day 4 heated for 2 min and milk at day 8 heated for 0 and 2 minutes (Table 1).

Table 1. Effect of storage period of UHT milk since the opening of packaging and heating time on the physical parameters (means ± SD)

Factors		Physical parameters			
Day	Heating min	Density g/cm^3	Acidity pH	Freezing point °C	Electrolytic conductivity mS/cm
0	0	1.0278 ± 0.0005	6.37 ± 0.07	-0.48 ± 0.01	3.98^{aA} ± 0.04
	1	1.0281 ± 0.0006	6.37 ± 0.07	-0.49 ± 0.01	4.02 ± 0.04
	2	1.0290 ± 0.0008	6.34 ± 0.07	-0.50 ± 0.01	4.11^{aC} ± 0.05
4	0	1.0287 ± 0.0005	6.34 ± 0.06	-0.48 ± 0.01	4.00^{b} ± 0.03
	1	1.0277 ± 0.0005	6.31 ± 0.04	-0.48 ± 0.01	4.05^{c} ± 0.04
	2	1.0278 ± 0.0005	6.26 ± 0.04	-0.50 ± 0.01	4.40^{AbBdDe} ± 0.04
8	0	1.0280 ± 0.0004	6.28 ± 0.10	-0.49 ± 0.01	4.09^{E} ± 0.04
	1	1.0279 ± 0.0004	6.36 ± 0.07	-0.48 ± 0.01	3.99^{B} ± 0.02
	2	1.0286 ± 0.0007	6.36 ± 0.05	-0.50 ± 0.01	4.10^{F} ± 0.03
13	0	1.0281 ± 0.0006	6.21 ± 0.15	-0.49 ± 0.01	4.00^{d} ± 0.05
	1	1.0281 ± 0.0007	6.30 ± 0.08	-0.49 ± 0.01	3.91^{CcDEF} ± 0.04
	2	1.0284 ± 0.0007	6.34 ± 0.05	-0.49 ± 0.01	4.00^{e} ± 0.03

Means in the rows marked with the same lowercase letters (a, b, c, d, e) vary significantly, p≤0.05.
Means in the rows marked with the same capital letters (A, B) vary significantly, p≤0.01.
Means in the rows marked with the same capital letters (C, D, E, F) vary significantly, p≤0.001.

Table 2. Effect of storage period of UHT milk since the opening of packaging and heating time on the content of chemical components (means ± SD)

Factors		Physical parameters				
Day	Heating min	SNF %	Fat %	Lactose %	TP %	MM %
0	0	7.96 ± 0.13	3.55 ± 0.06	3.90 ± 0.07	2.69 ± 0.05	0.68 ± 0.01
	1	8.04 ± 0.16	3.56 ± 0.06	3.94 ± 0.08	2.72 ± 0.06	0.69 ± 0.01
	2	8.30 ± 0.21	3.66 ± 0.05	4.06 ± 0.10	2.81 ± 0.08	0.71 ± 0.02
4	0	7.93 ± 0.13	3.60 ± 0.06	3.88 ± 0.06	2.68 ± 0.05	0.68 ± 0.01
	1	7.96 ± 0.14	3.59 ± 0.06	3.89 ± 0.07	2.69 ± 0.06	0.68 ± 0.01
	2	8.22 ± 0.13	3.68 ± 0.08	4.02 ± 0.07	2.78 ± 0.05	0.70 ± 0.01
8	0	8.01 ± 0.11	3.64 ± 0.09	3.92 ±0.06	2.70 ± 0.05	0.69 ± 0.01
	1	8.00 ± 0.09	3.59 ± 0.06	3.91 ± 0.05	2.70 ± 0.04	0.67 ± 0.04
	2	8.17 ± 0.17	3.68 ± 0.06	3.99 ± 0.09	2.76 ± 0.07	0.70 ± 0.01
13	0	8.05 ± 0.17	3.66 ±0.03	3.94 ± 0.09	2.72 ± 0.06	0.69 ± 0.02
	1	8.06 ± 0.18	3.63 ± 0.09	3.94 ± 0.09	2.72 ± 0.08	0.69 ± 0.02
	2	8.12 ± 0.18	3.62 ± 0.06	3.97 ± 0.09	2.75 ± 0.07	0.70 ± 0.02

During determinations SNF fluctuated in the range of 7.93% to 8.30%. Fat and lactose remained at stable levels throughout the observation period at 3.55–3.68% and 3.88–4.06%, respectively (Table 2). The content of saturated fatty acids (SFA) in the test samples of milk showed no statistically significant differences depending on the storage time and heating (Tables 3a and 3b).

Table 3a. Effect of storage period of UHT milk since the opening of packaging and heating time on the SFA profile (%; means ± SD)

Factors		SFA					
Day	Heating Min	C4:0	C6:0	C8:0	C10:0	C12:0	C14:0
0	0	3.63 ± 0.09	2.54 ± 0.08	1.56 ± 0.05	3.44 ± 0.17	3.85 ± 0.23	12.55 ± 0.45
	1	3.64 ± 0.07	2.56 ± 0.05	1.57 ± 0.05	3.48 ± 0.17	3.86 ± 0.19	12.54 ± 0.44
	2	3.64 ± 0.13	2.56 ± 0.09	1.57 ± 0.05	3.47 ± 0.17	3.87 ± 0.23	12.57 ± 0.43
4	0	3.73 ± 0.08	2.60 ± 0.04	1.61 ± 0.04	3.57 ± 0.19	3.94 ± 0.24	12.75 ± 0.52
	1	3.65 ± 0.08	2.55 ± 0.04	1.58 ± 0.05	3.47 ± 0.21	3.85 ± 0.26	12.57 ± 0.49
	2	3.79 ± 0.12	2.65 ± 0.10	1.66 ± 0.09	3.67 ± 0.27	4.03 ± 0.34	12.89 ± 0.63
8	0	3.64 ± 0.12	2.60 ± 0.08	1.63 ± 0.09	3.59 ± 0.26	3.99 ± 0.30	12.81 ± 0.66
	1	3.50 ± 0.10	2.53 ± 0.03	1.60 ± 0.04	3.56 ± 0.20	3.98 ± 0.25	12.88 ± 0.55
	2	3.51 ± 0.03	2.51 ± 0.07	1.57 ± 0.06	3.52 ± 0.22	3.93 ± 0.24	12.85 ± 0.65
13	0	3.66 ± 0.19	2.59 ± 0.07	1.61 ± 0.06	3.55 ± 0.21	3.96 ± 0.27	12.73 ± 0.61
	1	3.69 ± 0.11	2.64 ± 0.19	1.64 ± 0.13	3.60 ± 0.37	4.01 ± 0.47	12.77 ± 0.92
	2	3.76 ± 0.23	2.68 ± 0.25	1.67 ± 0.16	3.69 ± 0.43	4.06 ± 0.47	12.98 ± 0.85

Table 3b. Effect of storage period of UHT milk since the opening of packaging and heating time on the SFA profile (%; means ± SD)

Factors		SFA				
Day	Heating min	C15:0	C16:0	C17:0	C18:0	C20:0
0	0	1.22 ± 0.06	31.72 ± 1.69	0.48 ± 0.02	9.41 ± 0.53	0.13 ± 0.01
	1	1.22 ± 0.06	31.48 ± 1.95	0.48 ± 0.01	9.49 ± 0.58	0.13 ± 0.01
	2	1.22 ± 0.07	31.49 ± 1.73	0.48 ± 0.02	9.34 ± 0.57	0.13 ± 0.02
4	0	1.23 ± 0.07	31.25 ± 1.82	0.48 ± 0.01	9.47 ± 0.59	0.13 ± 0.01
	1	1.22 ± 0.06	31.35 ± 1.67	0.48 ± 0.02	9.57 ± 0.53	0.13 ± 0.01
	2	1.24 ± 0.06	31.15 ± 1.87	0.47 ± 0.02	9.30 ± 0.72	0.12 ± 0.01
8	0	1.25 ± 0.07	31.40 ± 1.59	0.49 ± 0.01	9.40 ± 0.60	0.11 ± 0.03
	1	1.25 ± 0.06	31.54 ± 1.72	0.48 ±0.02	9.39 ± 0.55	0.12 ± 0.01
	2	1.26 ± 0.05	31.54 ± 1.75	0.49 ± 0.03	9.45 ± 0.64	0.13 ± 0.01
13	0	1.24 ± 0.06	31.14 ± 1.92	0.49 ± 0.02	9.57 ± 0.64	0.13 ± 0.01
	1	1.24 ± 0.04	31.07 ± 1.60	0.48 ± 0.02	9.46 ± 0.91	0.12 ± 0.01
	2	1.25 ± 0.05	31.15 ± 1.46	0.48 ± 0.03	9.27 ± 0.89	0.13 ± 0.02

Milk fat contains up to 65% of saturated fatty acids. Monounsaturated fatty acids (MUFA) are found in milk fat at 35%. They have a dominant oleic acid (Table 4).

Table 4. Effect of storage period of UHT milk since the opening of packaging and heating time on the MUFA profile (%; means ± SD)

Factors		MUFA							
Day	Heating min	C10:1	C14:1	C16:1n-9	C16:1n-7	C17:1	C18:1n-7	C18:1n-9	C20:1
0	0	0.38 ± 0.04	1.14 ± 0.05	0.35 ± 0.02	1.47 ± 0.54	0.27 ± 0.01	2.28 ± 0.61	20.50 ± 1.01	0.10 ± 0.02
	1	0.38 ± 0.02	1.15 ± 0.05	0.33 ± 0.06	1.77 ± 0.04	0.27 ± 0.01	2.33 ± 0.66	20.61 ± 1.06	0.10 ± 0.02
	2	0.38 ± 0.02	1.15 ± 0.06	0.35 ± 0.02	1.73 ± 0.05	0.26 ± 0.02	2.32 ± 0.63	20.58 ± 0.94	0.11 ± 0.02
4	0	0.39 ± 0.01	1.16 ± 0.06	0.34 ± 0.03	1.70 ± 0.03	0.26 ± 0.01	2.34 ± 0.64	20.41 ± 1.14	0.10 ± 0.02
	1	0.38 ± 0.01	1.14 ± 0.05	0.33 ± 0.04	1.71 ± 0.01	0.26 ± 0.01	2.39 ± 0.64	20.65 ± 1.01	0.10 ± 0.01
	2	0.40 ±	1.19 ±	0.32 ±	1.70 ±	0.25 ±	2.30 ±	20.12 ±	0.10 ±

		0.02	0.07	0.03	0.04	0.02	0.65	1.40	0.02
8	0	0.39 ± 0.02	1.17 ± 0.07	0.34 ± 0.02	1.73 ± 0.04	0.26 ± 0.02	2.32 ± 0.63	20.23 ± 1.13	0.11 ± 0.02
	1	0.38 ± 0.02	1.18 ± 0.07	0.33 ± 0.04	1.73 ± 0.04	0.26 ± 0.02	2.31 ± 0.65	20.31 ± 1.05	0.10 ± 0.02
	2	0.37 ± 0.02	1.17 ± 0.07	0.34 ± 0.06	1.73 ± 0.06	0.26 ± 0.02	2.27 ± 0.65	20.40 ± 1.11	0.10 ± 0.02
13	0	0.38 ± 0.03	1.17 ± 0.09	0.30 ± 0.03	1.70 ± 0.06	0.26 ± 0.02	2.31 ± 0.68	20.55 ± 1.13	0.11 ± 0.02
	1	0.39 ± 0.03	1.17 ± 0.11	0.34 ± 0.03	1.71 ± 0.05	0.27 ± 0.03	2.31 ± 0.71	20.41 ± 1.75	0.11 ± 0.02
	2	0.39 ± 0.04	1.19 ± 0.11	0.33 ± 0.07	1.70 ± 0.03	0.27 ± 0.02	2.26 ± 0.69	20.09 ± 1.62	0.10 ± 0.02

Table 5. Effect of storage period of UHT milk since the opening of packaging and heating time on the PUFA profile (%; means ± SD)

Factors		PUFA			
Day	Heating min	C18:2n-6	C18:3n-3	C18:3n-6	CLA
0	0	1.47 ± 0.04	0.40 ± 0.09	0.08 ± 0.01	0.67 ± 0.23
	1	1.46 ± 0.03	0.41 ± 0.10	0.08 ± 0.01	0.68 ± 0.24
	2	1.46 ± 0.01	0.42 ± 0.11	0.08 ± 0.01	0.68 ± 0.25
4	0	1.43 ± 0.03	0.39 ± 0.10	0.08 ± 0.01	0.62 ± 0.23
	1	1.46 ± 0.03	0.41 ± 0.11	0.08 ± 0.01	0.65 ± 0.24
	2	1.41 ± 0.04	0.39 ± 0.10	0.17 ± 0.02	0.63 ± 0.23
8	0	1.42 ± 0.07	0.40 ± 0.10	0.08 ± 0.01	0.66 ± 0.22
	1	1.40 ± 0.09	0.40 ± 0.10	0.08 ± 0.01	0.65 ± 0.24
	2	1.46 ± 0.05	0.40 ± 0.12	0.08 ± 0.01	0.66 ± 0.26
13	0	1.45 ± 0.05	0.40 ± 0.11	0.08 ± 0.01	0.63 ± 0.23
	1	1.45 ± 0.05	0.40 ± 0.11	0.08 ± 0.01	0.64 ± 0.26
	2	1.43 ± 0.07	0.40 ± 0.12	0.08 ± 0.01	0.63 ± 0.26

The percentage of short and medium chain SFA (C4:0–C14:0) in UHT milk was stabilized on the following days of the experiment (Tables 3a and 3b). The average level of these fatty acids was 70% and no significant differences were observed between the content of individual acids on the first and last day of the experiment.

Storing UHT milk and heating it in a microwave in the individual stages of the study did not affect the changes in the proportions of the analyzed UFA acids (Tables 4 and 5). In the group of PUFA acids, four bioactive fatty acids were identified: linolenic acid C18:2n-6, α-linolenic acid ALA C18:3n-3, γ-linolenic acid GLA C18:3n-6 and conjugated linoleic acid CLA. The average MUFA level was 26% and PUFA 3%, with small differences between the values of the same fatty acids being statistically insignificant.

Discussion

According to Pluta and Berthold (2010), the advantages of heating foods using a microwave include a quick and direct heating of the product throughout the mass. In addition, the food does not come into contact with the surface heating which prevents overheating of the product and blocking the flow. In the authors' research, during storage and heating UHT milk showed no statistically significant changes in its physical parameters. According to Albert et al. (2009) the density of the milk after heating in the microwave was 1.028 g/cm^3. Similarly, in our own studies this value ranged from 1.0277 g/cm^3 to 1.0290 g/cm^3. An increase in acidity of unheated milk was also observed. These results are consistent with the findings of Panfil-Kuncewicz and Kuncewicz (1997). They showed no effect of fat on the acidity of the milk. According to Kruk and Czerniewicz (1996) milk with high acidity below pH 6.4–6.7 is very sensitive to heating. Constantin and Csatlos (2010) suppose that during the production and processing of milk small amounts of water can dilute milk. This is probably due to the washing and sterilizing equipment or negligent to do so. In our own research, we observed significant differences in the values of electrolytic conductivity between milk heated and analyzed immediately after opening the package. MW heating of milk occurs at a faster rate than in water for the same MW heating system due to the presence of ionic components in the milk (Kudra et al., 1991). Ahmed and Luciano (2009) have shown that the dielectric properties of the β-lactoglobulin dispersions were significantly influenced by concentration and temperature and that the relative electrical permittivity and the loss factor increased at denaturation temperature of 80°C. Muñoz et al. (2018) identified that relative electrical permittivity of raw milk was slightly higher than for skimmed milk. This difference was explained by the different compositions (water, fat, and ash content) of both types of milk. Differences in the electrolytic conductivity of the examined samples of milk may have resulted from evaporation of the water during the heating and storage, as indicated somewhat by freezing point (Martins et al., 2019). In our own research, there were no significant differences in the content of chemical components. During determinations SNF fluctuated in the range of 7.93% to 8.30%. Albert et al. (2009) believe that the average fat-free dry matter content of milk should be about 8.77%. The milk samples investigated in the present study contained comparable values of lactose, minerals and proteins at the beginning and end of the experiment. It can therefore be concluded that both microwave heating and storage times and conditions do not significantly affect the content of the listed ingredients in the milk. The experiment of Constantin and Csatlos (2010) showed a slight change in the physicochemical parameters of cow's milk treated with the operation of the microwave. These changes were visible only in the values of the three decimal places for the freezing point of milk and the second decimal place regarding protein and lactose. It can therefore be concluded that heating the milk in the microwave does not have a significant impact on its chemical composition. According to Meiβner and Erbersdobler (1996), the heating time and temperature are more significant factors causing negative changes in the food than the heat source. In our research the storage time and the heating of milk did not significantly change the MUFA profile. The results obtained in this experiment carried out on UHT milk confirm the findings of Rodriguez-Alcala et al. (2014). Four polyunsaturated fatty acids (PUFA) were present in UHT milk: linolenic acid C18:2n-6, α-linolenic acid ALA C18:3n-3, γ-linolenic acid GLA C18:3n-6 and conjugated linoleic acid CLA. These acids, although present in milk in small amounts, are very important for the biological functions of the human body. Among others, they determine the structure of cell membranes, regulate the secretion of insulin, and they are also a source of tissue hormones, eicosanoids (Tassoni et al., 2008). Herzallah et al. (2005) conducted a study focused on pasteurized, UHT, boiled, and microwaved milk, reporting no changes in the concentrations of total SFA, MUFA, and PUFA. Those authors concluded that the continuous aqueous phase of milk acts as an oxygen barrier that hinders the oxidation reactions, and therefore triglycerides are not altered during processing. In further studies from other authors, cow milk naturally enriched in RA was assayed in the elaboration of UHT milk (Jones et al., 2005). The provided FA composition also showed absence of variations after processing. According to Rodríguez-Alcalá (2009) research, the total concentration of SFA, MUFA, and PUFA remained stable when milk batches were processed to obtain pasteurized, HTST, UHT, STR, HP, and microwave pasteurized milks. Studies by Staniewski et al. (2015) also indicate that HP treatment does not significantly affect the triacylglycerol composition of milk fat, and in the fatty acid profile, the exception is an increase in branched-chain fatty acids. However, samples treated with HP show small but significant changes in the crystallization curves of milk fat compared to samples not treated with HP. Furthermore, when the detailed FA profile was examined, stability was found for most of the compounds in all samples. Analyzing the results of Rodriguez-Alcala et al. (2009) as well as our own results, it can be concluded that if the process of pasteurization, sterilization and heating of raw milk in the microwave does not significantly affect the fatty acid profile, the heating of UHT milk in the microwave will not change this state. According to research of Wroński et al. (2009) long-term storage of UHT milk has little effect on the fatty acid content. The results of the experiment also proved that the UHT milk stored in the refrigerator for 2 weeks after opening the package did not significantly affect the physical and chemical influencing the fatty acid profile.

Conclusion

UHT milk storage after opening at 4°C and heating in microwave for 1 or 2 minutes (microwaves to 1100 W and 750 W heater power) did not result during the period of 13 days in significant changes in the fatty acid profile. There were no further significant changes in the values of physical and chemical parameters of milk during the experiment. The differences that occurred in the electrolytic conductivity may result from evaporation of water during storage of milk and heating, as indicated by its freezing point. On this basis, it can be concluded that the storage of milk in the fridge and reheating it in the microwave does not have a significant effect on its physicochemical properties and fatty acid profile.

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