Romanian Reports in Physics, Vol. 67, No. 2, P. 423–430, 2015

IMPACT OF MICROWAVES ON THE PHYSICO-CHEMICAL CHARACTERISTICS OF COW MILK

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Received October 28, 2013

Abstract. The purpose of this study was to investigate the influence of the microwave radiations on the physico - chemical characteristics of raw milk and to establish the correlations between the physical parameters in order to appreciate milk quality. The results showed that the values of fat, protein, dry matter and lactose decreased during the microwave exposure while the average density value increased. Between lactose content and electric conductivity there is a negative correlation (r = –0.956) while between protein content and surface tension there is a positive correlation (r = 0.937). We conclude that physical parameters are sensitive indicators of milk quality.

Key words: cow milk, microwave, physico - chemical composition.

1. INTRODUCTION

The appearance of the microwave oven as a source of thermal preparation of food, in general, determined us to enquire what is the impact of microwaves on compositional, physico-chemical and organoleptic characteristics of food as compared to conventional forms of thermal treatment. Microwaves are high frequency electromagnetic radiations, characterized by a frequency band between 300 MHz and 300 GHz. The wavelengths of microwaves pertain to the interval, 1 mm – 1 m, in the electromagnetic spectrum these radiations being situated between the low frequency radio waves and infrared radiations, which means that microwaves are non-ionizing radiations [1, 2].

The thermal effects of microwave treatment are related to the heat generated following the absorption of their energy by water, organic molecules or ions [3]. Food heating by microwave is the results of the conversion of microwave energy into heat by friction of dipole molecules vibrating due to rapid fluctuation in the electromagnetic field. Kowalski *et al.* (2012) [4] studied the microwave impact on honey quality, Kurják *et al.* (2012) [5], and Beke *et al.* (2012) [6] examined the apple, potato and onion sample possibilities of drying by microwave, or Beszédes *et al.* (2011, 2012) [7] suggested the possibility of microwave energy use in sugar beet processing and food industrial sewage sludge treatment. Although the microwave oven is widely used as a source of food preparation, there are still not enough information about the microwave heating consequences regarding the compositional and nutrititional quality of food.

The milk may be considered as an emulsion or suspension of fats in an aqueous solution of substances which are both colloidal (the majority of proteins) and under the form of a valid solution (carbohydrates, minerals, etc.). Milk is an aqueous solution (87.3 % water), containing organic (fats, proteins, lactose, vitamins, enzymes) and inorganic components (Ca, P, Mg, Na, K, Cl, etc.).

Milk can undergo different changes during its preparation (boiling and microwaving) or processing, which may include moderate or severe heat treatment that can lead to undesirable changes [8, 9]. Valero *et al.* (1999) [10] mentioned the studies carried out on the effect of microwave treatment on different characteristics of milk [11–15].

Sieber *et al.* (1996) [16] presented a number of issues related to milk heating with the help of microwaves. The quoted sources show that microwave treatment is very effective in what concerns the presence of various microorganisms and that, at the same time, the microwave heated milk composition is similar to that of classically heated milk. However, there are few studies regarding the impact of microwaves on milk composition. Biophysics, alongside with biochemistry offer us the advantage of investigating this aspect by quick and very efficient methods from an economic point of view, taking into account the fact that there is an interdependence between the two. Raw milk quality is very important for the quality of milk and dairy products made of it. Therefore, quality of raw milk is under strict control.

The purpose of this study was to investigate the influence of the microwaves on the physico-chemical composition characteristics of the raw milk and to establish existent correlations between theses physical parameters in order to be used for milk quality appreciation.

2. MATERIAL AND METHODS

Material. The research material was represented by 5 milk samples of 200 mL each, collected from milk containers offered for sale, by farmers. The milk samples were thermally treated by using a microwave oven, model MWG20H, with 800 W electric power, made by WorldStar Company, according to the following time periods: $t_0 = 0$ s, $t_{10} = 10$ s, $t_{20} = 20$ s, $t_{30} = 30$ s, $t_{60} = 60$ s, and $t_{120} = 120$ s. Evaluation of changes in the chemical composition of the milk samples was determined using the instrument MilkoScan® S54B, which works in infrared spectrometry. The following components were determined: fats, total proteins, lactose, and non-fat solids (SNF). We calculated dry matter (DM) by adding milk fat to not-fat solids. The determined physical parameters were: dynamic viscosity (η), surface tension (σ), specific gravity (SG) and electric conductivity, using instruments and standards methods used in the biophysics laboratory at Faculty of Animal Science of the Banat's University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" from Timisoara [17].

Statistical analysis. All determinations were performed at least in triplicate. The values of the parameters are expressed as the average ± standard error (SE) at confidence interval of 95 %. All data were analysed with the XLSTAT, Version 2013 5.01. To verify the relation between variables, the following method of interpreting the Pearson correlation coefficients was used [18]: very strong association for a correlation of 0.7 or higher; substantial association for a correlation of 0.5 or higher; moderate association for a correlation of 0.3 or higher; low association for a correlation of 0.1 or higher.

3. RESULTS AND DISCUSSIONS

DM in cow milk samples ranged between 11 % and 16 %, varying according to the breed, lactating, feeding conditions, season, etc. This index characterizes the nutritional value of milk and directly affects the specific consumption of raw milk for concentrated milk products, cheese, etc. Table 1 shows the percentage (average ±SE) of the chemical composition of cow milk. Table 2 shows the correlations between physico - chemical characteristics of milk.

Table 1

The physico - chemical parameters averages (±SE) depending on the exposure time

Microwaves exposure time of the sample, [s]	DM [g %]	SNF [g %]	Fats [g %]	SG	Proteins [g %]	Lactose [g %]
0	13.97±1.10	9.24±0.21	4.73±1.29	1.031±0.0018	3.40±0.09	5.28±0.06
10	13.76±0.97	9.34±0.17	4.42±1.12	1.031±0.0019	3.48±0.06	5.17±0.08
20	13.18±0.65	9.48±0.08	3.7±0.72	1.032±0.0014	3.47±0.05	5.14±0.08
30	13.02±0.56	9.54±0.05	3.36±0.56	1.033±0.0010	3.47±0.05	5.11±0.09
40	12.69±0.46	9.57±0.04	3.12±0.48	1.033±0.0010	3.45±0.05	5.07±0.1
60	12.63±0.47	9.6±0.04	3.04±0.48	1.033±0.0008	3.39±0.07	4.99±0.15
120	12.74±0.5	9.73±0.06	3±0.49	1.033±0.0007	3.34±0.06	4.91±0.18

Table 2

Pearson correlation matrix between physico - chemical characteristics of milk

Variables	Conductivity [mS/cm]	Fats [g %]	DM [g %]	SNF [g %]	Lactose [g %]	Proteins [g %]	Specific gravity (SG)	Surface tension 10^{-3} [N/m]	Viscosity [cP]
Conductivity [mS/cm]	**1**	**-0.891**	**-0.877**	**0.912**	**-0.956**	-0.376	**0.934**	-0.199	**-0.855**
Fats [g %]	**-0.891**	**1**	**0.994**	**-0.962**	**0.895**	0.301	**-0.984**	0.229	**0.981**
DM [g %]	**-0.877**	**0.994**	**1**	**-0.935**	**0.873**	0.285	**-0.970**	0.217	**0.980**
SNF [g %]	**0.912**	**-0.962**	**-0.935**	**1**	**-0.963**	-0.434	**0.963**	-0.328	**-0.946**
Lactose [g %]	**-0.956**	**0.895**	**0.873**	**-0.963**	**1**	0.546	**-0.928**	0.379	**0.882**
Proteins [g %]	-0.376	0.301	0.285	-0.434	0.546	**1**	-0.373	**0.937**	0.411
SG	**0.934**	**-0.984**	**-0.970**	**0.963**	**-0.928**	-0.373	**1**	-0.259	**-0.957**
Surface tension 10^{-3} [N/m]	-0.199	0.229	0.217	-0.328	0.379	**0.937**	-0.259	**1**	0.382
Viscosity [cP]	**-0.855**	**0.981**	**0.980**	**-0.946**	**0.882**	0.411	**-0.957**	0.382	**1**

Values in bold are different from 0 with a significance alpha level =0.05

Lower values of DM in microwave treated milk may be explained by: quantitative decrease of the proteins, of lactose and of fat samples and also by a possible decrease in the amount of some vitamins, for example, A, B9, C and E, according to some results obtained from other studies [19]. A fats content decrease has been noticed from the experimental data with increasing the exposure time to microwaves, from 4.73 g % at 0 s to 4.42 g % at 10 s microwaves and up to 3 % at 120 s treated milk with microwave (Table 1) which means a decrease of 36.58 % as compared to untreated milk. This decrease was also confirmed by data found in other studies [19]. Some studies revealed that microwave heating affected fat oxidation and fatty acid isomer formation [19, 20].

The specific gravity (SG) of milk is influenced by the proportion of its constituents. Generally, in cow milk, it ranges from 1.028 to 1.033 [17, 21]. Fat, being the most variable ingredient of milk, has a maximum influence on the SG of milk. An increase in the fat content of milk results in lowering of SG, and the decrease in the fat content of milk increases the SG. A SG variation from 1.031 for raw milk to 1.033 for milk treated 120 s with microwave is observed. The increasing of the milk density with increasing of the microwave exposure time shows that there has been an evaporation of water from the milk samples.

Milk proteins are part of the complex protein group that contains all the essential amino acids not only in sufficient quantities, but also in an optimal correlation for rational nutrition; consumption of 0.5 kg of milk fully meets the needs of the body in the essential amino acids for 24 hours. Milk proteins, due to the phosphocalcic complex, are transformed more effective, in muscle proteins, as compared to other proteins.

The reducing concentration of milk proteins with the increasing of microwave period exposure has also been confirmed by data from other studies [19]. Microwave treatment conditions are accompanied by a transfer of free sulfhydryl groups from the soluble to the insoluble protein fraction. Inaccessible sulfhydryl groups become exposed by protein unfolding during microwave treatment. This allows the formation of new covalent inter- and intramolecular disulfide cross-links via sulfhydryl-disulfide exchange and oxidation reactions. Decreasing the overall free sulfhydryl content it might be possible to lessen internal disulfide bond formation and protein aggregation. As free amino acids are significantly more reactive than those bound in the peptide chain, it is possible that they react with milk lactose during the microwave treatment resulting in Maillard reaction products. The most important structural and chemical changes that occur during the microwave treatment are the denaturation and aggregation of proteins, the Maillard reaction, and the lactose isomerization.

From the all organic milk components, the proteins influence mostly the surface tension and the dynamic viscosity. The viscosity of a heterogeneous substance such as milk, at a given temperature, depends on its composition and the physical state of its colloidally dispersed substances, including milk fats. At normal temperature, viscosity of milk varies from 1.5 to 2 centipoises [cP]. The results showed a decrease of the viscosity as the microwave time exposure is increased.

The protein content ranged, under the influence of microwaves, from 3.34 g % to 3.48 g %. Milk with high protein content (> 3 g %) has a viscosity around 2 cP [22]. The viscosity is a physical parameter that can be used in appreciation the protein content of milk, the two parameters being positive correlated ($r = 0.407$). Viscosity is a quality factor of many foods. Its value is not only considered as a quality factor, but also as a parameter of product control [23]. We observed also a positive correlation between the protein content and the surface tension ($r = 0.937$) by microwave treatment of milk samples. It has been also noticed a decrease in the lactose concentration with increasing the time of microwave exposure from 5.28 g % for t_0 to 5.17 g % for t_{10} and up to 4.91 g % for t_{120}.

Electrical conductivity is the property of a substance to transport electrical charges. In a pure solution, the conductivity is a function of the ionic concentration. In a heterogeneous system, such as milk, the fats and the colloidally dispersed substances obstruct the ions in their migration and decrease the conductivity. The electrical conductivity is due to the presence of sodium, potassium and chloride ions in milk. The electrical conductivity increases with increase in temperature. The conductivity average value, at 30 ºC, is 4.67 [mS/cm] for cow milk. From the correlation matrix (Table 2) and Fig. 1 we can observe that between the concentration of lactose and electrical conductivity of milk there is a negative correlation ($r = -0.956$), as it was concluded also by other studies [24].

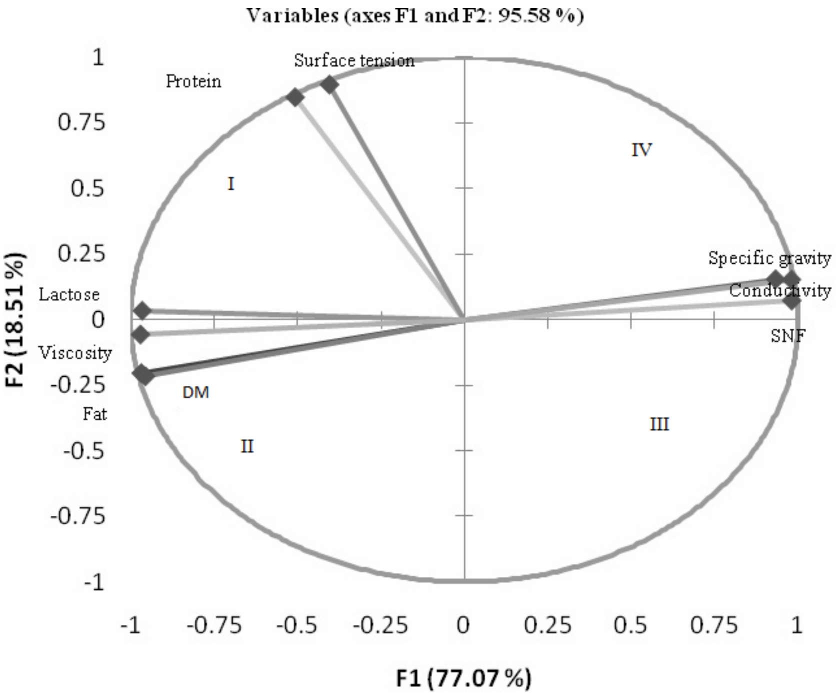

Fig. 1 – Principal Component Analysis (PCA) of variables.

Our experimental data reveal also that the electric conductivity may be used for the appreciation of milk quality. It was noticed a correlative relationship between electrical conductivity and the fat concentration ($r = -0.891$). Principal component analysis (PCA), presented in Fig. 1, grouped the studied variables according to the physico-chemical characteristics. In the first quadrant, there are grouped surface tension, proteins content and the lactose content. In the second quadrant, there are grouped viscosity, DM content and the fats content. DM showed a significant strong positive correlation with fats. The electric conductivity and specific gravity are grouped in the fourth quadrant by highly significant correlations. An inverse correlation was found between viscosity and the electric conductivity. DM and SNF were also negative correlated.

4. CONCLUSIONS

The fats, proteins, dry substance and lactose concentrations decreased as the microwave time exposure increased. Between lactose concentration and the milk electrical conductivity of milk there is a negative correlation ($r = -0.956$) while between surface tension and proteins content there is a positive correlative relationship ($r = 0.937$). Our study demonstrates that the above described physical indices are reliable indicators of the milk quality.

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This chapter on the chemistry of milk therefore begins with a brief review of some basic chemical concepts. Chemical symbols of some common elements in organic matter: C Carbon Cl Chlorine H Hydrogen I Iodine K Potassium N Nitrogen Na Sodium O Oxygen P Phosphorus S Sulphur.Â Basic physical chemical properties of cowsâ€™ milk. Cowsâ€™ milk consists of about 87 % water and 13 % dry substance, table 2.1. The dry substance is suspended or dissolved in the water. Depending on the type of solids and size of particle (table 2.2), there are different distribution systems of them in the water phase. Table 2.1. Physical-chemical status of cowsâ€™ milk. Average composition %.Â The typical characteristics of a colloid are: Small particle size. Electrical charge and. Research on Physico-Chemical Properties of Milk and Milk Derived Productsâ€¦ 583.Â On the same days of milk yields, we estimated levels of fat, protein, lactose, ash, density, and acidity following conventional guidelines. To study effects of piloted preparations on cheese-making properties of milk from experimental cows we made samples of Ossetian brined cheese.Â Table 3: Physico-chemical properties of cowâ€™s milk. n = 10. Index.Â The co-fed adsorbent and antioxidant also had a positive impact on denitrification in experimental animals. Therefore, in milk of cows in Experimental Group III compared to the controls, there were significantly ($P<0.05$) reduced nitrate and nitrite levels, by 2.63 times and 3.33 times accordingly. Physico-chemical characteristics of milk are related to its composition for a particular animal species. Sheep milk contains higher levels of total solids and major nutrient than goat and cow milk. Lipids in sheep and goat milk have higher physical characteristics than in cow milk, but physico-chemical indices (i.e., saponication, Reichert Meissl and Polenske values) vary between different reports. Micelle structures in goat and sheep milk differ in average diameter, hydration, and mineralization from those of cow milk.