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# THE EFFECT OF HIGH-PRESSURE HOMOGENIZATION ON CHANGES IN MILK COLLOIDAL AND EMULSIFYING SYSTEMS

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The paper estimates the effect of high-pressure homogenization (20–140 MPa) on selected whole milk properties. High-pressure homogenization did not have a clear effect on the milk acidity. However, a slight increase in viscosity and a clear decrease in milk heat stability were observed along with an increase in the applied pressure. On the basis of a microscopic analysis and the measurement of the absorbance of milk samples, an increase in the fat dispersion degree was observed along with an increase in homogenization pressure up to 100 MPa. Homogenization, especially at the pressure over 80 MPa, resulted in an increase in susceptibility of milk globules to coalescence.

## INTRODUCTION

Pressure homogenization is a technological process aiming at the reduction in size and uniformity of fat globules, thus their even dispersion in milk and an increase in emulsion stability. To prevent fat layer floating during long-term storage of dairy beverages, pressures of around 20 MPa are commonly used.

One of the accompanying effects is an increase in temperature during homogenization, on average by 2–2.5°C with a pressure increase of 10 MPa. The application of high pressures for homogenization allows pasteurization temperatures to be obtained, which combined with mechanical treatment, is an effective method for microbe neutralization [Popper & Knorr, 1990].

The modification of fat dispersion and an increase in the inter-phase area as the result of whole milk homogenization, change the system and the equilibrium of its particular components. It particularly involves the milk colloidal phase because the surface active fractions of plasma proteins, mainly casein, participate in the reconstruction of the homogenized fat globule membranes [Zahar & Smith, 1996]. This causes a change in some of the milk physico-chemical properties. One of them involves an increased susceptibility of homogenized whole milk to coagulating factors [McCrae *et al.*, 1994], which has particular importance during preservation of dairy articles produced with the application of high temperatures.

The aim of this paper was to determine the effect of high-pressure homogenization on some properties of whole milk, particularly on its heat stability, fat dispersion degree and emulsion stability.

## MATERIAL AND METHODS

The material for the experiment was 3.3% fat milk, after homogenization with the application of high pressures in a laboratory homogenizer – Panda produced by Niro Soavi. The applied pressures were selected every 20 MPa from the range from 20 to 140 MPa at a constant temperature of 65°C. Non-homogenized milk was the control sample.

The milk samples were analyzed for: acidity (pH), potential acidity in °SH, viscosity with the use of a capillary viscosimeter (Ubbelhole), and heat stability as the time of heat coagulation of milk at 140°C [Kruk *et al.*, 1973].

The size of fat globules in milk was determined by microscopic methods [Polish Norm PN-A-86059:1975] and the percentage proportion in particular size groups was determined to calculate the mean volume-surface diameter ($d_{vs}$) and the area of 1 mL of fat [Oortwijn & Walstra,1979]. Moreover, the effect of homogenization on the fat dispersion degree was evaluated through the measurement of absorbance of milk samples directly after homogenization ($A_0$).

Emulsion stability was determined by an absorbance measurement of milk samples after shaking (frequency 250 cycles/min, amplitude 5 mm) every hour for 6 h ($A_t$, where t means time of exposure). Milk samples taken immediately after homogenization and during shaking were diluted with a phosphate buffer (pH=7.0) containing 0.5% of sodium dodecylsulphate to achieve dilution of 1:5000 [Britten & Giroux, 1991]. Absorbance was measured at a temperature of 20°C and wavelength of 500 nm with the use of a spectrophotometer type Helios β. The resulting values were presented as $A_t/A_0$. The experiment was repeated 10 times.

## RESULTS AND DISCUSSION

The results of the effect of homogenization pressure on some physico-chemical properties of milk are presented in Table 1.

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TABLE 1. The effect of homogenization pressure on some physico-chemical properties of milk.

| Treatment | | Acidity pH | Potential acidity (°SH) | Viscosity (mPa·s) | Heat stability (min) |
|---|---|---|---|---|---|
| Control sample | | 6.69 | 6.3 | 1.80 | 4.26 |
| Homogenized | 20 MPa | 6.69 | 6.2 | 1.86 | 3.67 |
| | 40 MPa | 6.69 | 6.3 | 1.92 | 3.12 |
| | 60 MPa | 6.69 | 6.3 | 1.92 | 3.21 |
| | 80 MPa | 6.69 | 6.3 | 1.93 | 2.98 |
| | 100 MPa | 6.69 | 6.3 | 1.93 | 2.71 |
| | 120 MPa | 6.68 | 6.4 | 1.95 | 2.37 |
| | 140 MPa | 6.70 | 6.4 | 1.96 | 2.23 |

The results indicated that homogenization analyzed in this range of pressures practically did not change milk acidity. On the other hand, the homogenized milk viscosity was always slightly higher than that of the control milk sample. As a result of milk homogenization, heat stability of milk decreased and became lower with greater pressures applied (Table 1).

The effect of homogenization on the change of the milk colloidal stability and viscosity results from an increase in milk fat dispersion degree and the subsequent adsorption of milk proteins on the inter-phase surface.

The level of proteins adsorbed on the surface of fat globules and their interactions with plasma proteins play an important role in the stabilization of homogenized milk proteins [McCrae *et al.*, 1994]. Cano-Ruiz and Richter [1997] showed that the amount of protein compounds adsorbed on fat globules increases along with the increase in the fat dispersion degree. Similar results were obtained by Sharma and Singh [1999] during research on the correlations between the amount and composition of proteins adsorbed on the fat surface and the fat dispersion degree. They found that along with a decrease in the size of fat globules, the amount of casein concentrated on their surface increased. At the same time, the proportion of its casein κ decreased. The low level of casein κ corresponded with adsorption of large casein micelle on the fat globules. The casein location on the surface of the homogenized fat with a small proportion of casein κ, which is the protective fraction for native micelle, indicates that fat globules with newly adsorbed protein material behave in a similar way as large casein micelles [Singh *et al.*, 1996; Sharma & Singh, 1999]. As a result, it contributes to a decrease in homogenized milk heat stability. Moreover, milk coagulation occurs as the result of interactions between proteins of milk plasma and those on the surface of fat globules [Sharma & Singh, 1999].

The effect of high-pressure homogenization on the fat dispersion degree in milk expressed as fat globule diameter and the quantity of different diameters are given in Figure 1.

On the basis of the results, an increase in the emulsion phase dispersion after homogenization was observed. The fat dispersion degree increased along with the increase in homogenization pressure up to 100 MPa, whereas the application of higher pressures, such as 120 MPa and 140 MPa, caused a slight decrease in the homogenization effectiveness, most likely due to insufficient amount of surface active material originating from milk plasma (Figure 1A). A similar tendency of changes of fat globule size along with an increase in homogenization pressure in the range of 30 MPa to 90 MPa was observed by Cano-Ruiz and Richter [1997].

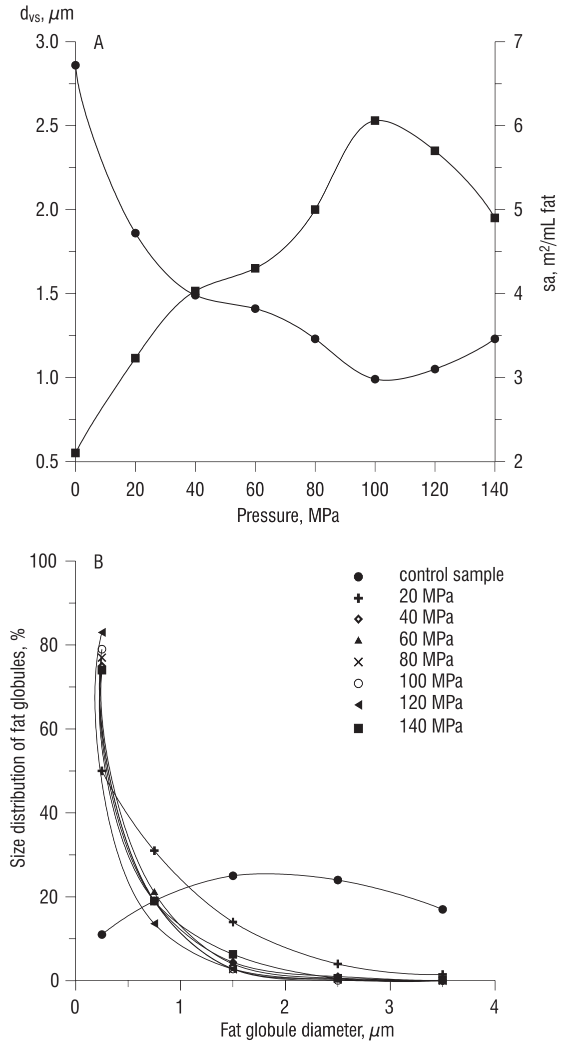


FIGURE 1. Effect of homogenization pressure on the fat dispersion degree in milk. A – volume surface diameter ($d_{vs}$) – ● – and area of fat (sa) – ■ –; B – size distribution of fat globules.

The changes in the fat globules dispersion degree contributed to the expanded fat surface as the result of homogenization at pressures below 100 MPa. The application of higher pressures, however, caused a decrease in fat surface (Figure 1A).

The application of high-pressure homogenization (≥40 MPa) also contributed to a clear unification of fat globule size, whose diameter did not exceed 2 μm and was mainly (about 80%) below 1 μm (Figure 1B). The percentage of fat globules in the analyzed size groups was similar in all milk samples.

In the investigation on the effect of homogenization on the fat globule dispersion degree in milk, fat capability to absorb electromagnetic radiation was used. The changes in the fat dispersion degree were determined through the measurement of milk absorbance immediately after homogenization and the results are given in Figure 2.

An increase in absorbance of homogenized milk samples at the pressure up to to 80 MPa was demonstrated (Figure 2).

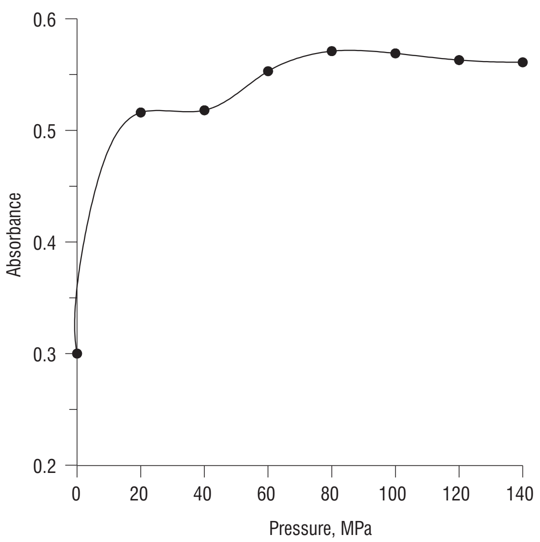


FIGURE 2. Effect of homogenization pressure on milk absorbance.

Further increase in homogenization pressure did not result in significant changes in absorbance. The obtained results confirm the findings of Pearce and Kinsella [1978] who demonstrated an increase in milk absorbance along with an increase in fat dispersion degree.

High homogenization effect does not guarantee emulsion stability during product storage.

The indicator of emulsion stability could be the change of fat dispersion degree in milk during mechanically--induced destabilization. It is expressed as the change in milk absorbance in comparison to the initial value, *i.e.* $A_t/A_0$ value. The decrease in the value of this ratio during milk exposure to mechanical treatment indicates a decrease in the emulsion stability.

The experiments included the determination of the changes in the absorbance of mechanically-treated homogenized milk and the results are given in Figure 3.

During a 6-h shaking of milk samples an increase in the value of $A_t/A_0$ occurred (Figure 3) and indicated the emulsion destabilization. Similar results were obtained by Britten and Giroux [1991] who studied the changes in

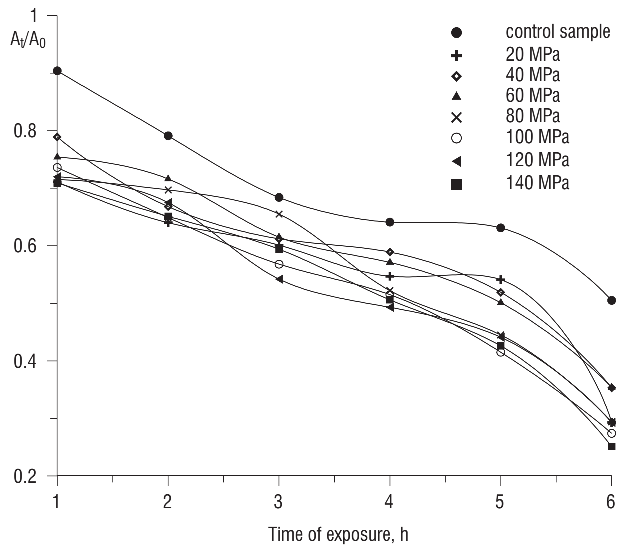


FIGURE 3. Effect of homogenization pressure on changes of milk absorbance during shaking.

turbidity of model emulsions under mechanical treatment. The effect of mechanical treatment on the changes in the milk absorbance points to an increase in the size of fat globules in milk. The changes in absorbance were stronger after five-hour exposure, especially in the case of milk samples homogenized at the pressure over 80 MPa.

The applied method used for the determination of the stability of emulsifying phase, as an indicator of milk coalescence, does not include the evaluation of the range of all the forms of emulsion non-stability. On the one hand, shaking milk samples during their analysis may induce permanent aggregation of fat globules, including their coalescence, on the other hand, it may eliminate creaming. The results of the measurements of the sample absorbance during milk exposure are limited to the information on the resistance of capsules of homogenized fat globules to mechanical treatment.

## CONCLUSIONS

1. High-pressure homogenization does not cause changes in the milk acidity, however, it induces a slight increase in its viscosity and a decrease in heat stability of milk resulting from increased procedure pressure, on average, amounting to 0.14 min/10 MPa.
2. Along with an increase in homogenization pressure from 20 to 100 MPa, a decrease in the average diameter of fat globules follows as well as its increase at the pressure over 100 MPa.
3. On the basis of the results of absorbance, the clear effect of high-pressure homogenization on the milk susceptibility to factors decreasing emulsion stability was observed.

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## WPŁYW WYSOKOCIŚNIENIOWEJ HOMOGENIZACJI NA ZMIANY UKŁADU KOLOIDALNEGO I EMULSYJNEGO MLEKA

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W pracy przebadano wpływ homogenizacji wysokociśnieniowej (20 MPa–140 MPa) na zmiany wybranych właściwości mleka pełnego. Homogenizacja wysokociśnieniowa nie powodowała widocznych zmian kwasowości mleka, stwierdzono natomiast nieznaczny wzrost lepkości oraz wyraźne obniżanie się jego stabilności cieplnej wraz ze wzrostem ciśnienia procesu (tab. 1). Na podstawie analizy mikroskopowej i pomiaru absorbancji próbek mleka stwierdzono wzrost stopnia dyspersji tłuszczu w miarę zwiększania ciśnienia homogenizacji do 100 MPa (rys. 1, 2). Homogenizacja, szczególnie przeprowadzona przy ciśnieniach powyżej 80 MPa, przyczyniała się do zwiększenia podatności kuleczek tłuszczowych mleka na koalescencję (rys. 3).