ORIGINAL SCIENTIFIC PAPER

Influence of High Intensity Ultrasound Treatments on Physical Properties of Sheep Milk

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Summary

In this study, research was based on influence of high intensity ultrasound on inhomogeneous sheep milk. Ultrasonic processor (maximal nominal power – 100W) with the constant frequency of 30 kHz was used for milk homogenization. Changes on temperature, pH – value, density, viscosity and absorbance (500nm) are followed by given process parameters: amplitude (A = 20, 60 and 100 %); time of treatment (t = 2, 6, 10 and 15 minutes), full cycle (c = 1), probe diameters (d = 7, 10 and 14 mm). Statistical analysis was conducted and influence of process parameters and temperature was expressed over p – value (p<0.05; ANOVA; ANCOVA). Applications of different probe diameter have significant influence on all observed physical properties. Longer time of treatment and amplitude showed significant influence on temperature, absorbance and changes on viscosity of sheep milk, while on pH – value and density has no influence. Analyses of covariance (ANCOVA) showed significant influence of the temperature on increasing of absorbance and viscosity, while temperature has no influence on pH – value and density of ultrasonically treated milk.

Keywords: ultrasound, sheep milk, temperature, physical properties

Introduction

Ultrasound process parameters had influence on the temperature increase as result of wave propagation throughout medium. Cavitation as the most accepted mechanism is based on the implosion of bubbles in surrounding media (Bosiljkov et al., 2011; Brnčić et al., 2010; Price et al., 2010; Thiemann et al., 2011). Efficiency of cavitation mechanism depends on applied frequency, intensity and physical properties of observed sample. When applied frequency increase, the number of formed bubbles gets higher, while diameter of bubbles is smaller with minimal quantity of released energy during implosion. At the frequency of 132 kHz the bubble has twice smaller than at 68 kHz (Figure 1) (Price et al., 2010; Feng and Barbosa – Cánovas, 2011; Ashokkumar, 2011).

Fat content is the most important component in raw milk. Propagation of ultrasonic waves in milk with a lower proportion of fatty phase is faster which helping to create a large number of smaller cavitation bubbles whose implosion released a large amount of heat energy which causes an immediate rise in temperature (Cucheval and Chow, 2008). Increasing of temperature as a consequence of high intensity ultrasound may cause alternation on physical properties of milk as changes in temperature, pH – value, density and absorbance. Bryant and McClements (1999) were studied influence of various whey protein solutions at different pH – values on attenuation coefficient. At the pH over attenuation coefficient increased as the temperature increased. Maximum attenuation was realized at 80 °C. Water has the lowest attenuation factor of any liquid measured at low frequencies (Suslick, 1988; Povey, 2006).

Ultrasonic wave during the propagation through the liquid medium become absorbed (P) and dissipated which is expressed with attenuation coefficient (α) represented over equation (1):

$$P = P_0 e^{-2\alpha x} \tag{1}$$

where:

P_0 – preliminary power of ultrasonic wave (starting amplitude of ultrasonic wave)

x – wavelength of the expanded wave [m]

α – attenuation coefficient [Neper/m]

Dissipation and absorbing caused by liquid medium, affect on conversion of mechanic energy into heat which results by increasing of temperature in observed system. Absorption of ultrasonic wave increase as a consequence of internal friction initiated by variation in viscosity, thermal conductivity and lower surface tension. Ultrasonic wave propagation through medium of unequal composition influence on attenuation increases, while mechanic energy of the wave remains constant. Changing in direction of the wave causes a problem in their detection (Hæggström and Luukkala, 2001; Ay and Gunasekaran, 2003; Dukhin et al., 2005; Cho, 2010; Bosiljkov et al., 2010).

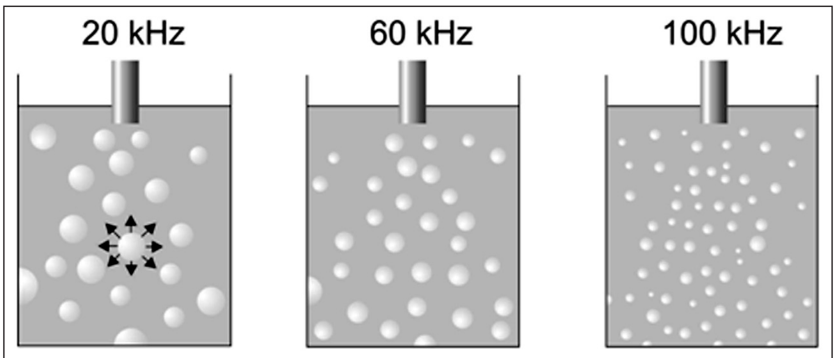

Figure 1. *Influence of frequency on intensity and diameter of cavitation bubbles (Bosiljkov, 2011).*

Materials and Methods

Inhomogeneous sheep milk with following chemical structure: protein content: 4.6 % (N×6.25); total sugars: 4.2 %; fat content: 6.25 %; minerals: Ca – 1730 mgkg^{-1}, P – 790 mgkg^{-1}. Physical properties of inhomogeneous sheep milk: Temperature: 20 °C; pH – value: 6.763; Density (ρ): 1.0341 gcm^{-3}, Absorbance (500 nm): 2.292.

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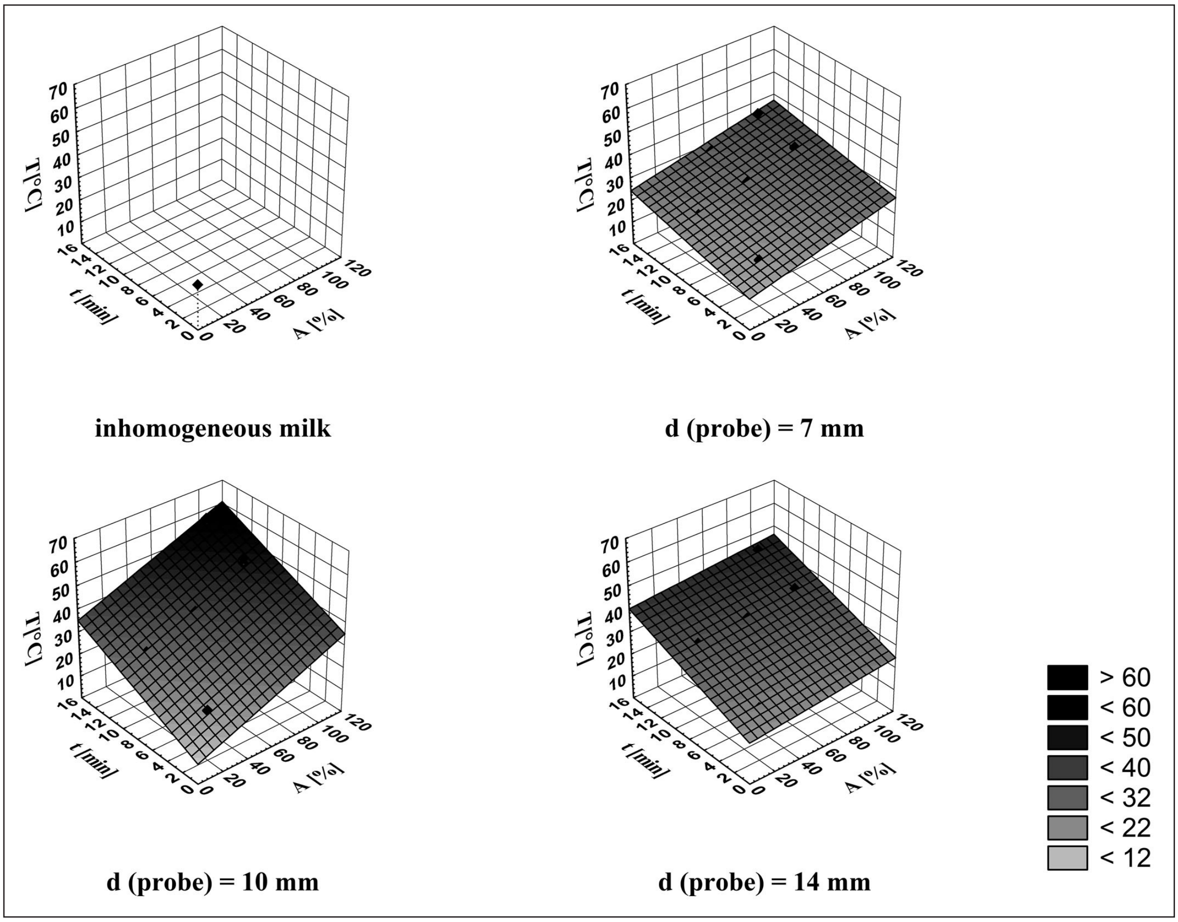

Figure 2. *Influence of process parameters on temperature of sheep milk*

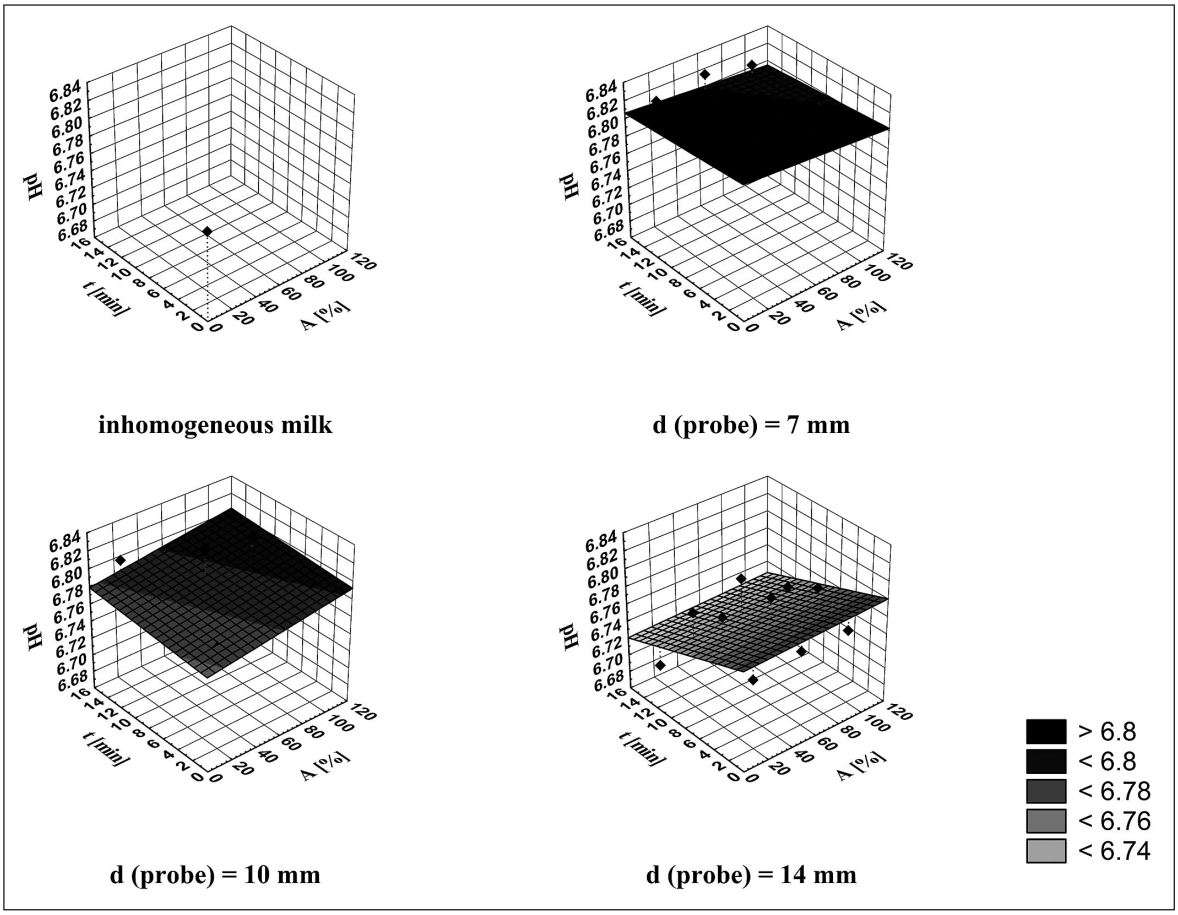

Figure 3. *Influence of process parameters on pH – value of sheep milk*

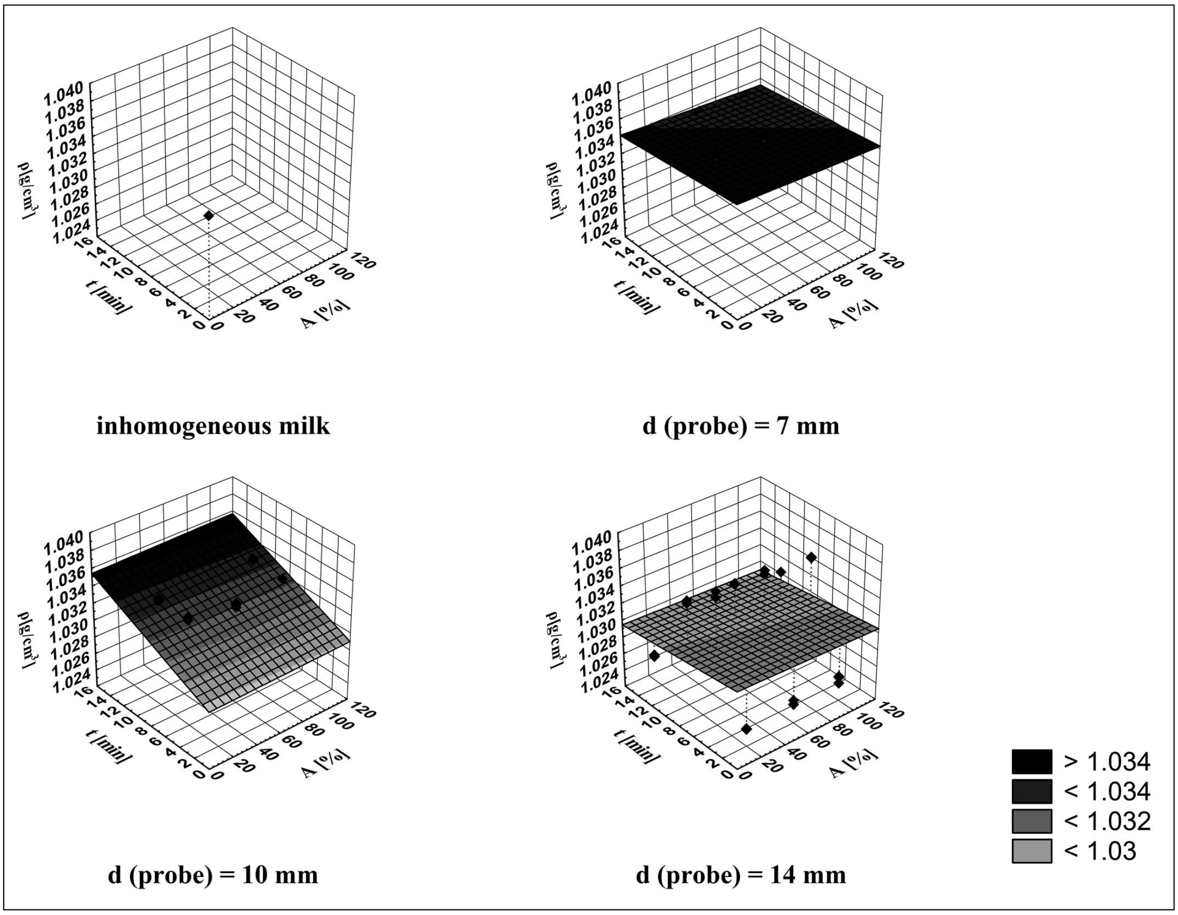

Figure 4. Influence of process parameters on density of sheep milk

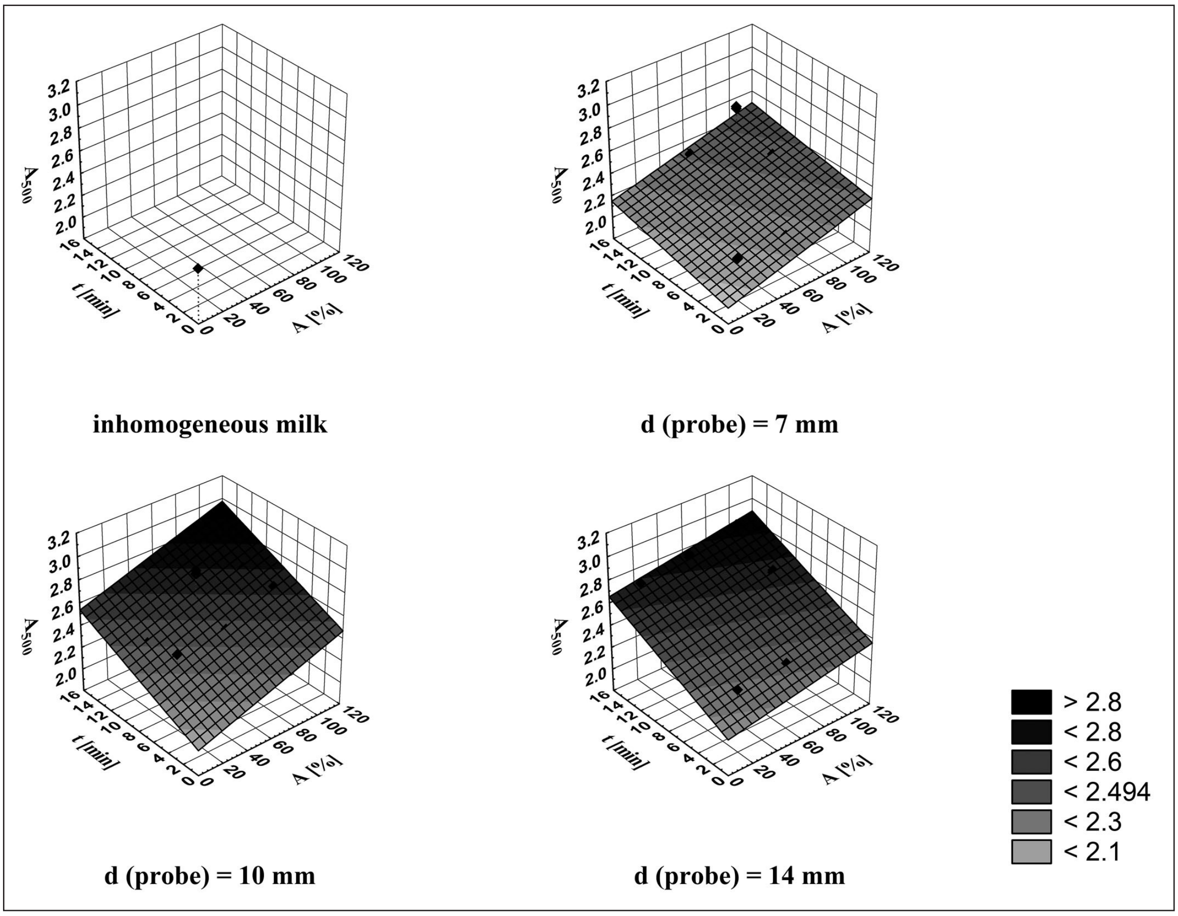

Figure 5. Influence of process parameters on absorbance (500 nm) of sheep milk

Ultrasonic treatment

Inhomogeneous sheep milk was homogenized with 30 kHz ultrasonic processor "UP 100 H" produced by "Dr Hielscher" company (Teltow, Germany) with constant frequency of 30 kHz, using cylindrical probes with different diameter: (d = 7, 10, 14 mm). Ultrasonic treatments was performed by amplitude (A = 20, 60, 100 %); time of treatment (t = 2, 6, 10 and 15 minutes) and full cycle (c = 1). Volume of the sample was 150 ml with immersion depth of the probe 3 cm.

Measuring of temperature

Starting temperature was 20 °C. During the ultrasonic treatments temperature was measured every 30 seconds using IR – measurer "Rytek" (MiniTemp FS).

Measuring of pH – value

Measurements of pH – value were performed at 20 °C using a calomel electrode of pH – meter „WTW 330i / SET".

Measuring of density

Temperature of density meter "Mettler Toledo DE 40" was setting on 20 °C. After the correction of the sample temperature density of sample was displayed.

Table 1. *ANOVA Influence of process parameters on physical properties of sheep milk ($p<0.05$)*

Physical properties	Parameters	*p* – value	*β*-coefficient
Temperature [°C]	d [mm]	**0.001079**	3.360528
	A[%]	**0.000000**	7.12006
	t[min]	**0.000000**	10.5983
pH-value	d [mm]	**0.000000**	-7.1277
	A[%]	**0.041420**	2.064168
	t[min]	0.434271	-0.784859
Density [gcm^{-3}]	d [mm]	**0.000004**	-4.83556
	A[%]	0.942664	0.0720905
	t[min]	0.127702	1.535138
Viscosity [mPas]	d [mm]	**0.000367**	3.807091
	A[%]	**0.000025**	4.617619
	t[min]	**0.000680**	3.609852
Absorbance (A_{500})	d [mm]	**0.000001**	5.114579
	A[%]	**0.000009**	4.657709
	t[min]	**0.000000**	6.849882

Statistically significant when ($p<0.05$)

Measuring of absorbance

Absorbance was measured by spectrophotometer CONICA-MINOLTA CM – 3500 – d. The values of absorbance are read off using software "Spectra Magic^{TM} NX Ver.1.7.", "Color Data Software CM – S100w". The measuring of absorbance was performed at 500 nm.

Results and discussion

Influence of process parameters on temperature, pH – value, density and absorbance are showed with 3D diagrams categorized by probe diameter (Figures 2 – 5).

In accordance with represented 3D diagrams analyses of variance (ANOVA) showed influence of process parameters on all observed physical properties (Table 1).

Amplitude and time of treatment (higher *β*) have slightly higher impact than probe diameter on temperature increase. Changes in pH – value can be observed in two ways. Increasing of probe diameter influence on decreasing of pH – value which is indicated with negative value of *β*-coefficient. As the probe diameter increasing, interaction between amplitude and probe diameter leads to increasing of pH – value. Probe diameters have influence on decreasing of density while amplitude and time of treatment have no influence. Interval of *β* – coefficient between 3.6 – 6.8 indicates a similar influence of all process parameters on increasing of absorbance and viscosity of sheep milk.

Covariance is a value that tells us how two of the observed size working together. Propagation of ultrasonic waves with constant frequencies, amplitude and cycle through the selected period of time change the temperature during ultrasonic treatment in the surrounding medium.

Table 2. *ANCOVA Influence of temperature on physical properties of sheep milk ($p<0.05$)*

Physical properties	*p*-value
pH-value	0.754744
Density [gcm^{-3}]	0.093134
Viscosity [mPas]	**0.000004**
Absorbance (A_{500})	**0.000000**

Statistically significant when ($p<0.05$)

Mechanical wave motion includes the features of output values, which significantly changes the physical properties of milk samples in the reference system. In accordance with influences of process parameters on physical properties, analyses of covariance (ANCOVA) showed significant influence of the temperature on increasing of absorbance and viscosity, while temperature has no influence on pH – value and density of ultrasonically treated milk (Table 2).

Conclusions

Influence of highest values of process parameters was expressed on increasing of absorbance and viscosity. The highest influence on increasing of temperature has the highest values of amplitude and time of treatment. Consequence of these significant changes is increasing of temperature during ultrasonic treatment. As well as influence of all input levels on physical properties, influence of output level (temperature) has the same influence on wave motion in observed system.

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