Available online at www.sciencedirect.com
ScienceDirect
Physics Procedia 70 (2015) 1057 – 1060
Physics Procedia

2015 International Congress on Ultrasonics, 2015 ICU Metz

Monitoring of Lactic Fermentation Process by Ultrasonic Technique

B. Alouache*, A. Touat, T. Boutkedjirt, A. Bennamane

Faculty of Physics, U.S.T.H.B., BP 32, El-Alia, DZ-16111 Bab Ezzouar, Algiers, Algria

Abstract

The non-destructive control by using ultrasound techniques has become of great importance in food industry. In this work, Ultrasound has been used for quality control and monitoring the fermentation stages of yogurt, which is a highly consumed product. On the contrary to the physico-chemical methods, where the measurement instruments are directly introduced in the sample, ultrasound techniques have the advantage of being non-destructive and contactless, thus reducing the risk of contamination. Results obtained in this study by using ultrasound seem to be in good agreement with those obtained by physico-chemical methods such as acidity measurement by using a PH-meter instrument. This lets us to conclude that ultrasound method may be an alternative for a healthy control of yoghurt fermentation process.

Peer-review under responsibility of the Scientific Committee of ICU 2015

Keywords: Lactic fermentation; Ultrasoud; Ultrasonic velocity, Ultrasonic attenuation; pH.

1. Introduction

Yogurt is a milk product which is obtained by the so called fermentation action of lactic acid bacteria Streptococcus thermophilus and Lactobacillus bulgaricus, which leads to the obtaining of a more or less consistent coagulum. This induces the decomposition of the glucose resulting in the production of a lactic acid with a content of 0.7% and a pH less than or equal to 4.6 (Luquet and Carrieu (2005)). This fermentation results in a change of the phase of milk from the liquid to the gel state, following a precipitation of proteins, which are destabilized by an increased acidity of the solution. Like all food products, yogurt quality should be monitored and evaluated (Navratil et al. (2004)). There are a variety of quality control methods, such as those based on the technical analysis of the physico-chemical and microbiological properties (Tamime and Robinson (2000)).

* Corresponding author. Tel.: +213-559-024-855; fax +213-21-247-344.
E-mail address: basma_alouache@yahoo.fr

1875-3892
Peer-review under responsibility of the Scientific Committee of ICU 2015
doi:10.1016/j.phpro.2015.08.225

The pH meter is the experimental tool used to determine the progress of the milk fermentation by measuring acidity versus time. However, its use requires the introduction of the probe into the sample and, subsequently, regular cleaning. On the contrary, ultrasonic technique provides high advantages compared to other control techniques, as it is a non-invasive, real-time and contactless. The evolution of the ultrasonic parameters, such as the amplitude of the ultrasonic echo reflected from the sample and the ultrasound propagation velocity, can provide information on the state of the milk (Ammann and Galez (2003), Ogasawara et al. (2006)). That is why we have adopted this technique in the context of this work.

2. Materials and methods

The preparation of yogurt was made following standard steps (Wu et al. (2001)). The prepared mixture is poured into sample holders, which are covered by a thin transparent film to be protected and insulated from the external environment (air, water).

2.1. Ultrasonic measurements

The experimental design (Fig. 1) is composed of an ultrasonic planar transducer (Panametrics, 5 MHz nominal frequency, 19 mm diameter). A mechanical holding system ensures a good alignment of the transducer and the sample faces. The assembly is placed in a tank (250 x 250 x 300 mm^3) containing the propagation medium (distilled water). The bath temperature is controlled and maintained at 45° C by using of a temperature controller provided with a heater. Acidity measurements are taken by means of a pH-meter (Crison brand MM40). The transducer is connected to an ultrasonic pulser-receiver (Sofranel 5073PR). The acquisition system is constituted of a digital oscilloscope (Tektronix TDS 2012) connected to a computer via an IEEE-GPIB bus. The propagation velocity of the ultrasonic wave is given by the following expression:

$$V_g = {}^{2\Delta Z}/_{\tau}. \tag{1}$$

ΔZ represents the difference in the distance traveled by the ultrasonic wave in two samples of different thicknesses and τ is the corresponding time of flight of the wave (Fig. 2). This latter has been calculated by estimating the difference between the positions of the first zero crossings of the signals corresponding to the first echoes emanating from the rear faces of the two samples respectively.

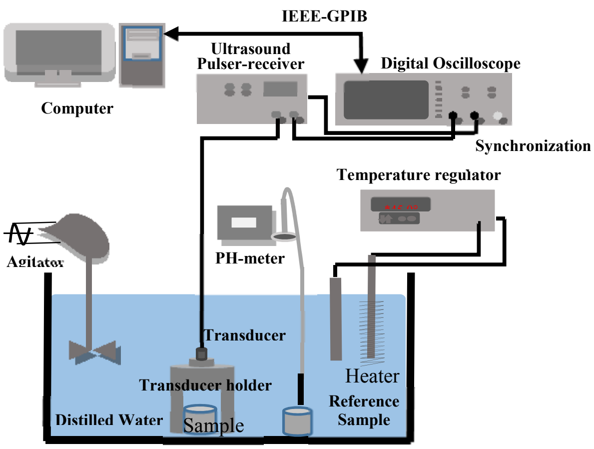

Fig. 1. Schematic diagram of the experimental setup.

The attenuation coefficient was determined, considering reflection and transmission coefficients, by expressions:

$$\alpha(f) = -\frac{1}{2z}\log\left|{}^{P_2}/_{P_1}\right| + {}^{\log\gamma}/_{2z} \quad (2)$$

P_1 and P_2 are the ultrasonic pressures associated to the echoes emanating from the sample front and rear faces respectively and z is the distance separating these faces. In the corrective term of the attenuation coefficient:

$$\gamma = T_1.R_2.T_2'.R_1^{-1} \quad (3)$$

T_1 and T_2' are the Water/Milk and Milk/Water transmission coefficients respectively and R_2 is the Milk/Aluminium reflection coefficient (Rear face of the sample). R_1 is the Water/Milk reflection coefficient.

2.2. pH measurements

The pH of the sample has been measured during fermentation by using a pH electrode (Crison MM40). Measurements were made every 5 minutes with an estimated accuracy of ± 0.2.

3. Results and discussion

During the fermentation, the milk state changes. In the case of lactic acid fermentation, sugars are most converted into lactic acid. Therefore, the acidity of the medium increases and, consequently, induces a change of the pH. This has been verified by using the pH-meter which showed a pH decrease from 6.4 to 4.6.

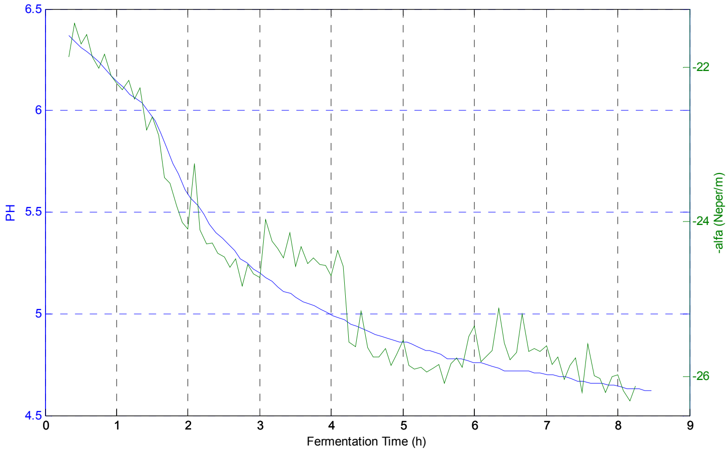

Fig. 2. Evolution of the ultrasonic attenuation coefficient and of the acidity of the milk during fermentation.

Fig. 2. denotes an increase of the ultrasonic attenuation coefficient. The curve obtained, according to equation (3), exhibits a good similarity with the pH evolution. Fig. 3. illustrates the variation of the ultrasonic velocity during the lactic acid fermentation of milk. We notice a slight increase in this parameter. At the end of the process, there was an increase of about 8 m/s.

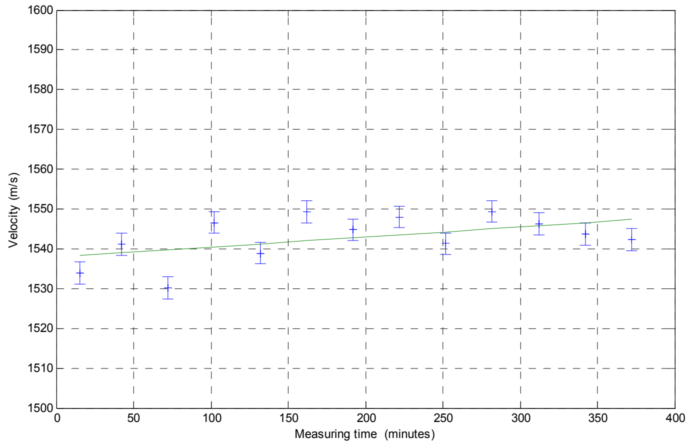

Fig. 3. Evolution of the ultrasound propagation velocity in the milk sample during fermentation.

In general, during the milk fermentation process, the material undergoes physico-chemical changes related to a development of the bacterial cells and an increase in their concentration (Resa et al. (2007)). This change in the nature of the medium induces a change in its mechanical properties, which is characterized by an increase of its density, a slight increase of the ultrasound wave propagation and a non linear increase of its attenuation coefficient. The latter leads to a decrease of the amplitude of the ultrasonic echo emanating from the rear face of the sample.

4. Conclusion

This work demonstrates the ability of ultrasound measurements in following the fermentation process of milk. The ultrasonic echo amplitude diminishes and therefore the attenuation coefficient increases during the fermentation process. This evolution shows a good agreement with the measurements of acidity verified by means of a pH-meter. The low increase of the propagation velocity of ultrasonic waves during the fermentation of milk, which is in the order of uncertainty, suggests that this latter acoustic parameter is not very indicative of the stage of fermentation. Fermentation is a very complex process. However, the results obtained show that the ultrasonic method is a promising non-invasive, real-time and contactless alternative control method of monitoring this phenomenon.

References

Ammann, J. J., Galaz, B., 2003. Sound velocity determination in gel-based emulsions. Ultrasonics 41, 569-579.

Luquet, F. M, Carrieu, G., 2005. Bactéries lactiques et probiotiques. Collection Sciences et Techniques Agroalimentaires, Ed Lavoisier Tec and Doc, Paris, 306.

Navratil, M., Cimander, C., Mandenius, C., 2004. On-line multi-sensor monitoring of yogurt and filmjölk fermentations on production scale. Journal of Agricultural and Food Chemistry 52 (3), 415.

Ogasawara, H., Mizutani, K., Ohbuchi, T., Nakamura, T., 2006. Acoustical experiment of yogurt fermentation process. Ultrasonics 44, 727-730.

Resa, P., Bolumar, T., Elvira, L., Pérez, G., Espinosa, F. M., 2007. Monitoring of lactic acid fermentation in culture broth using ultrasonic velocity. Journal of Food Engineering, 78(3), 1083-1091.

Tamime A. Y., Robinson R. K., 2000. Yoghurt Science and Technology . Wood head Publishing Ltd, Cambridge England, CRC Press.

Wu, H., Hulbert, G. J., Mount, J. R., 2001. Effects of ultrasound on milk homogenization and fermentation with yogurt starter. Innovation Food Science and Emerging Technologies 1, 211-218.