Non-destructive detection of air traces in the UHT milk packet by using ultrasonic waves

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Abstract

In this present work, our objective is to characterize UHT milk quality inside his package without any destruction. We propose to employ the ultrasonic transmission method which is suitable for characterization of opaque media like UHT milk. For this we follow the evolution of ultrasonic parameters in different temperatures depending on air intrusion inside package. We analyzed the experimental results between both cases: package with air intrusion and package without air intrusion. We proceed by this comparative study in order to investigate the suitability, feasibility and reliability of this emerging technique as a new alternative to the conventional destructive techniques.

Keywords: ultrasonic, non-destructive, quality, UHT milk;

1. Introduction

The quality control is an important aspect in food production. The major purpose of this control is to verify the acceptability of food in terms of nutritional value and safety. The development of new techniques for the quality control continues to increase according to the requirements imposed by the consumers and the authentication of food security. Several non-destructive methods are being developed for food quality control, we mention the following examples: the near-infrared spectroscopy, Raman spectroscopy, biosensors and ultrasound.

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The potential of ultrasound as a tool for non-destructive quality control of food products is currently under investigation. The ultrasonic waves have a valuable feature that consists in its ability to characterize opaque materials such as packed UHT (R.R.B. Singh et al., 2014) and packed fruit juice (Luis Elvira et al., 2014). Recently, ultrasonic techniques were used to monitor lactic fermentation of milk, (Taifi. N et al., 2006), (Mohammadi et al., 2014), measurement of milk compositions (Michele S et al., 2014) and control of milk coagulation (Bakkali F et al., 2001). Ultrasound technology has recently made a very sensitive task that directly affects a critical need of consumers. This major advantage consists in detection of microbial contamination of milk. In this context, we mention the following published works: (Elvira, L et al., 2003) have patented an ultrasonic inspection method for liquid food products; (Nagata, M et al., 1987) was able to detect early infection in modified milk pack submerged in water; (Heaggstrom, E, 1997) have developed a device for detection of microbial growth within the UHT milk pack; (L. Elvira et al., 2005) analyzed the performance of their ultrasonic device to perform non-destructive and rapid detection of microbial contamination of UHT milk packs.

UHT milk quality is determined by the absence of any air-trace in the package. Industrials take, according to a specific sampling, a number of packets of UHT milk per day for destructive testing. However, this procedure creates a problem that keeps pushing especially if we take into account the fact that sometimes we find in reality individual UHT milk packages which are partially or totally damaged and yet it is mentioned above that is still valid for consumers.

Our prime objective in this works is to develop an ultrasonic technique which aims to characterize all UHT milk packets instead to characterize just a few ones. This characterization aims to detect non-destructively the presence of any air-trace in the package since its presence will have a negative influence on UHT milk quality during storage time, and sometimes this happens before the expiration date is exhausted.

2. Material and methods

2.1. The experimental device of ultrasonic measurements

The figure.1 shows the experimental setup of ultrasonic measurements used in this work in order to follow the evolution of the ultrasonic parameters. In this method, we used two identical transducers. These transducers and the samples were immersed in water inside a thermostat. The transducers (0.5 MHz as a central frequency) are mounted face to face on the opposite sides of the UHT package.

![Ultrasonic device](image)

Fig. 1. Illustration of ultrasonic device used in experiments.

2.2. Ultrasonic measurements

2.2.1. Measurement of the peak to peak amplitude

The figure below shows an example of the ultrasonic signal transmitted through the package of the UHT milk. It is clear that this transmitted signal consists of several been astride echo, what complicates the calculation of this parameter because we do not know how these echo are going to evolve during all the experience.
To avoid this problem, we follow the envelope of the signal apply to this one in every acquisition the transform of Hilbert. To facilitate us the spot to measure the amplitude crest with crest by calculating in every acquisition the superior envelope and the envelope inferior of the ultrasonic signal. Finally we go back to the value of the amplitude crest with crest by making the subtraction of the upper maximum of the envelope with regard to the lower minimum of the envelope.

Fig.2. Example of the ultrasound signal transmitted through the package of the UHT milk.

Fig.3. The envelope of the ultrasound signal transmitted through the package of the UHT milk.

2.2.2. Measurement of flight-time

In our case we measure flight-time by exploiting the cross correlation method. The principle of this technique is to take the first signal transmitted as a reference. Then we calculate the correlation function between this reference signal and the acquired signal in each acquisition until the end of experiment.

\[ R(t) \] is the cross-correlation function between the reference signal and the signal transmitted at a given acquisition, \( \text{H}(t) \) the Hilbert transform of the function \( R(t) \), the envelope of the correlation \( R(t) \) is given by the following formula (Idris Aboudaoud et al. 2013):

\[
E(R(t)) = \left( R^2(t) + H^2(t) \right)^{\frac{1}{2}}
\]

(1)

The figure below shows the result of the application of this method in a given acquisition. The flight-time corresponds at the most of the envelope. In the platform developed in this work, we apply this technique for every acquisition of which the purpose to follow the evolution of the flight-time.

Fig.4. The envelope of the cross correlation between the reference and transmits ultrasonic signals.

3. Results

The table below shows an illustration of the evolution of ultrasonic parameters in different temperatures for the both cases studied in this work: sterilized UHT milk package (without air intrusion) and unsterilized UHT milk package (with air intrusion). Each package of the milk is examined in both cases for each temperature. The intrusion of air is achieved thanks to an infinitesimal hole on the package using a syringe.
Table 1. Evolution of ultrasonic parameters in different temperatures for both cases.

| Temperatures | Peak to peak amplitude | Flight-time |
|--------------|------------------------|-------------|
| 27°C         | ![Graph](image1.png)   | ![Graph](image2.png) |
| 30°C         | ![Graph](image3.png)   | ![Graph](image4.png) |
| 35°C         | ![Graph](image5.png)   | ![Graph](image6.png) |
| 37°C         | ![Graph](image7.png)   | ![Graph](image8.png) |
| 40°C         | ![Graph](image9.png)   | ![Graph](image10.png) |

The above figures show the evolution of the peak to peak amplitude and flight-time in different temperatures for the following two cases: sterilized package (absence of air intrusion) and unsterilized package (presence of air intrusion).
intrusion). We note that the flight-time is the parameter that gives us a quickly information about the studied medium in comparison with the peak to peak amplitude. That is being said because the flight-time shows a difference between the sterilized-trace and unsterilized-trace in an early way. This study shows that the temperature 35°C presents an exception because in this temperature we note that the peak to peak amplitude also shows a difference between the both studied cases in an early way. In addition, this ultrasonic technique allowed us to confirm that the temperature 35°C is the ideal temperature for bacterial growth (L. Elvira et al., 2005) because in this temperature where we found early bacterial activity compared to others temperatures. Indeed after 4 hours the bacterial growth has begun in this temperature.

4. Conclusions

This study has demonstrated the reliability of the ultrasonic transmission technique to characterize the presence of any air-trace in UHT milk package. We have demonstrated this by following the evolution of ultrasonic parameters: the peak to peak amplitude and the flight-time. We noticed that the flight-time is the most informative parameter because it shows the difference between sterilized package and unsterilized one at an early stage. In the temperature 35°C, we noticed that both parameters show simultaneously the difference between the both studied cases. This important result shows that 35°C is suitable for the characterization of UHT milk package because it is the ideal one for bacterial growth in comparison with the others temperatures.

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