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Proceeding Paper

Acoustic Properties of Chihuahua, Manchego, and Panela Type Cheeses, Applying Ultrasonic Spectroscopy

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Abstract: In this paper, a study to determine the acoustic properties of Chihuahua, manchego, and panela chesses, applying acoustic spectroscopy in the ultrasound spectrum. The products were purchased at a local store in the capital city of Chihuahua. The echoscope block of the GAMPT® acoustic tomograph with acoustic sensor at 2 MHz was used to measure the acoustic phase velocity [m/s] depending on the thickness, with a quasiregular temperature of 16 °C of the environment. The method applied was by transmission with normal incidence. Measurements were performed in triplicate. The volumetric density and acoustic impedance of the cheeses as well as the rheological properties were determined by indirect method. The results show that the acoustic phase velocity of the Chihuahua, Manchego and panela cheeses were $APV_{Chi} \approx 1221.47$ m/s, $APV_{man} \approx 1436.05$ m/s, and $APV_{pan} \approx 1142.28$ m/s, respectively. The volumetric density of the Chihuahua, Manchego and panela cheeses were $\varrho_{Chi} \approx 1.16$ gr/cm^3, $\varrho_{man} \approx 1.11$ gr/cm^3, and $\varrho_{pan} \approx 1.70$ gr/cm^3 to 12.1 °C, respectively.

Keywords: acoustic properties; acoustic phase velocity; acoustic attenuation; cheeses; Chihuahua; manchego; panela; quality; transmittance; ultrasonic spectroscopy

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1. Introduction

In Mexico, cheeses made mainly from bovine, goat, sheep, and buffalo milk are produced. Where a great diversity of types of cheeses stands out according to their geographical location in the country, such as aged, white, cotija, Chihuahua, fresh, Manchego, Oaxaca, panela, to mention a few examples [1]. Each one of them has a specific procedure for its manufacture and maturation [2].

Many investigations have been development on cheeses in general. From nutritional properties to rheological properties (physical) [3]. And where the thermodynamic parameters are a fundamental key for the manufacture, conservation, and maturity of the cheeses.

To know some physical properties of cheeses, different excitation sources or methods have been used, such as low intensity ultrasound. For example, ref. [4] Lee et al. they applied ultrasound to determine the rheological properties of cheeses by analyzing transverse plane acoustic wave. In [5], Benedito et al. they applied ultrasound to determine the maturity of Mahon cheese. In [6], Mulet et al. they determined the effect of temperature on the speed of ultrasonic propagation in cheeses. In [7], Benedito et al. they determined the acoustic properties in the ultrasound spectrum of cheddar cheese. In [8], Wang et al.

they analyzed the functional properties by means of image processing. In [9], Cho et al. they determined the physical properties of cheddar cheese, by ultrasonic techniques, without contact. In [10], Benedito et al. they analyzed the cheese manufacturing process by means of ultrasound. In [11], Benedito et al. they evaluated the texture of Manchego cheese by means of ultrasound. In [12], Leemans et al. they described and determined the internal defects of the cheese structure. In [13], Nassar et al. they studied the internal matrix structure of cheese by applying ultrasound. In [14], Telis-Romero et al. they studied the composition of fresh cheese through ultrasound. In [15], Crespo et al. they studied the quality of cheese with sheep's milk by applying low-frequency ultrasound.

In this investigation we present a study to measure the acoustic phase velocity of different commercial cheeses.

2. Materials and Methods

It was determined to measure the acoustic phase velocity of the cheeses as a function of thickness. A total of 15 products of Chihuahua, manchego, and panela cheeses were purchased in a commercial store in the city of Chihuahua. The products were stored at a temperature of 4 °C for one week, while the measurement experiments were carrier out, in the Biochemistry laboratory of the Faculty of Zootechnics and Ecology of Autonomous University of Chihuahua, (FZyE-UACh).

2.1. Experimental Setup

The measurements of the volumetric densities and acoustic phase velocities were carrier out under the following thermodynamic conditions in the laboratory: open system, atmospheric pressure: 1023.0 hPa; humidity: 37%, laboratory temperature: 24.2 °C ± 1 °C.

The volumetric density of the cheeses was obtained indirectly. Cuts were made each cheese, where samples of parallelepiped geometry shapes of 1, 2, 3, 4, 5, and 6 cm thick were obtained, which were measured with a vernier (MITUTOYO®). Then the mass of each of the samples was determined by means of a balance (Scout Pro, Ohaus®, NJ, USA). This procedure was carried out for each of the fifteen pieces of cheese [16].

The thickness-dependent acoustic phase velocity was obtained by means of an experimental configuration of the transmission mode and applying the theory described by [17]. Signal processing and filtering were performed using the echoscope's internal program.

2.1.1. Transmission Mode

In this configuration system, a laptop was connected via a USB-type connection to the echoscope of an ultrasonic tomograph (GAMPT®, Germany 2016). From this, two 2 cm diameter ultrasonic sensors at 2 MHz were connected, transmitter-receiver configuration, as shown in Figure 1. The excitation pulse was by normal incidence. The sampling rate was 100 MHz. Each of the cheese samples were placed on a support. Ultrasonic gel was used to match the impedance between the ultrasonic sensor and each of the cheese samples.

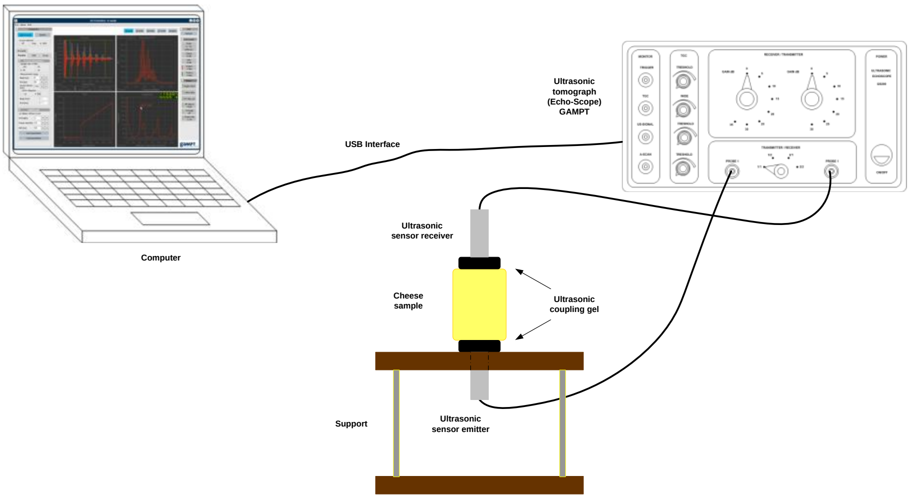

Figure 1. Experimental setup in transmission mode.

Acoustic phase velocity measurement depending on the thickness of each cheese, Chihuahua, manchego, and panela type, were performed per day. Each measurement was performed in triplicate.

3. Results

The property of the cheeses was measured, such as the bulk density and is described in Table 1.

Table 1. Bulk density of the different cheeses 20.1 °C ± 1 °C.

Cheese	Bulk Density [gr/cm³]
Chihuahua	$\rho_{Chi} = 1.16 \pm 0.05$
Manchego	$\rho_{man} = 1.11 \pm 0.05$
panela	$\rho_{pan} = 1.70 \pm 0.05$

In Table 1, shows that panela cheese has the highest bulk density than Chihuahua cheese and later manchego cheese.

In Figures 2–4, show the graphs of the acoustic phase velocity in the different types of cheeses. A linear fit was performed using the Origin 8.0 program (OriginLab®, MA, USA), with a confidence level of 0.95.

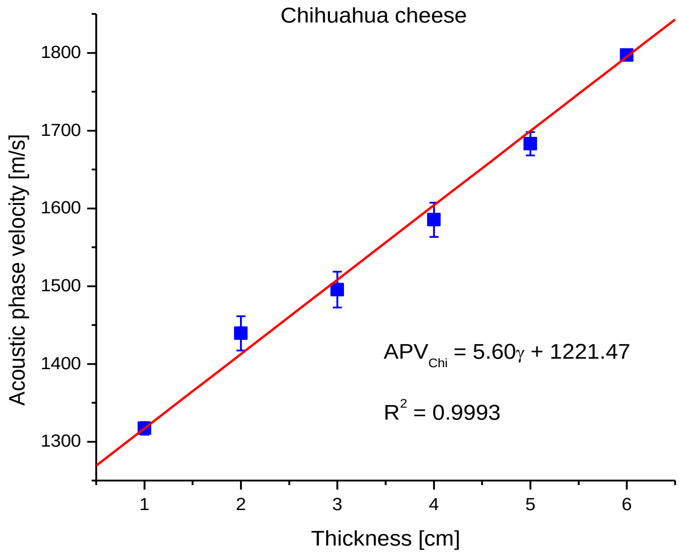

Figure 2. Acoustic phase velocity dependent on the thickness of the Chihuahua-type cheese.

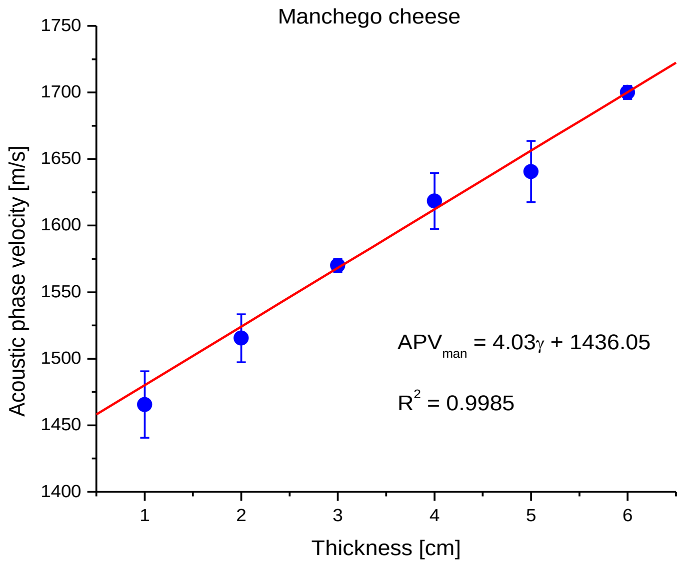

Figure 3. Acoustic phase velocity dependent on the thickness of the manchego-type cheese.

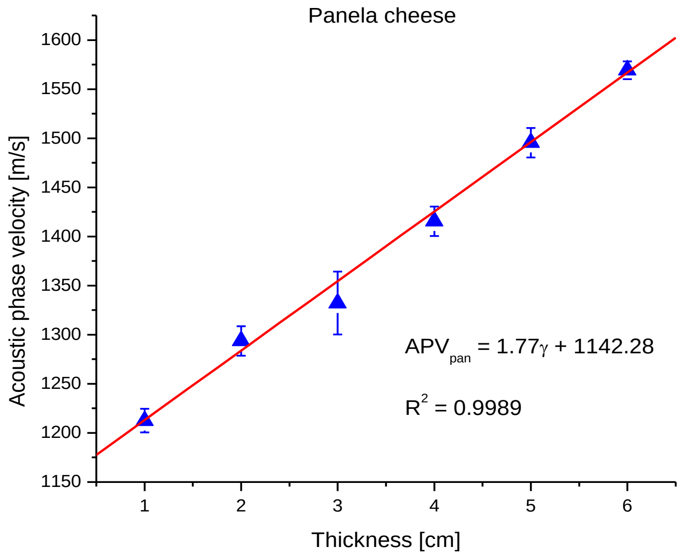

Figure 4. Acoustic phase velocity dependent on the thickness of the panela-type cheese.

In Figures 5–7, show the graphs of the acoustic transmittance as a function of frequency, for thicknesses 1, 2, and 3 cm.

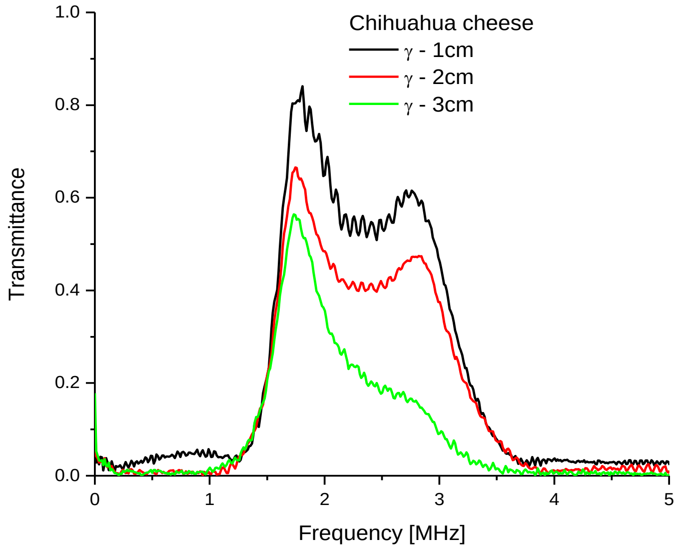

Figure 5. Acoustic transmittance as a function of the frequency of Chihuahua cheese.

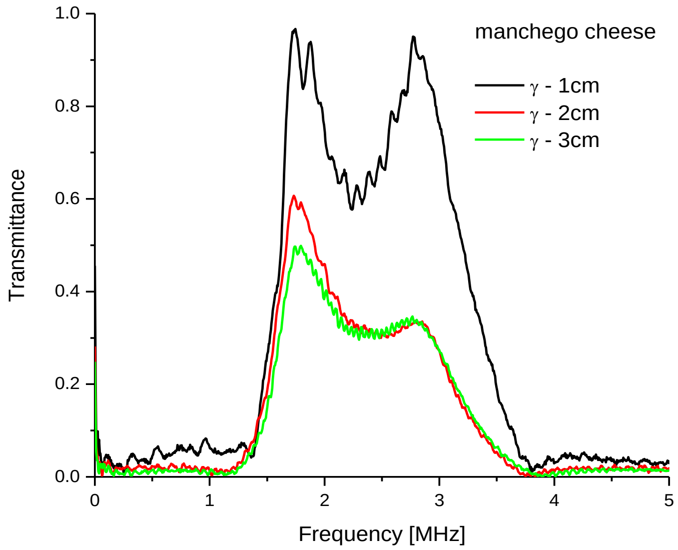

Figure 6. Acoustic transmittance as a function of the frequency of manchego cheese.

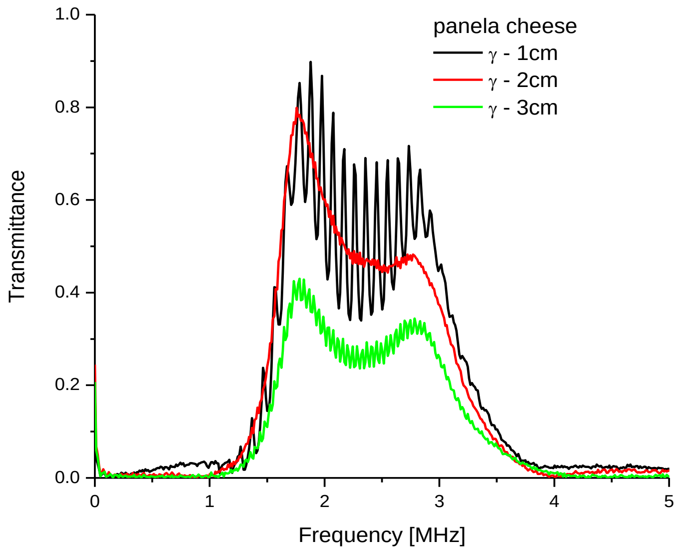

Figure 7. Acoustic transmittance as a function of the frequency of panela cheese.

In Table 2, shows the parameters obtained from direct and indirect measurements of the cheese samples.

Table 2. Cheeses parameters.

Paramater	Chihuahua	Manchego	Panela
Acoustic phase velocity transmission method [m/s]	1221.47 ± 1.53	1436.05 ± 0.66	1142.28 ± 0.66
Bulk density, ϱ [gr/cm^3]	1.16	1.11	1.70
Acoustic impedance, Z [MRayls]	5.706	2.337	7.893
Elastic modulus, G′ [Pa]	5.706	2.337	7.893

Loss modulus by viscoelasticity, G″ [Pa]	367,261.55	273,908.9	1,242,795.77
Acoustic attenuation, α [dB/cm]	0.2728	0.3570	0.7582

The results obtained with respect to the acoustic phase velocity of the cheeses have a linear behavior, where the Manchego cheese has a higher phase velocity than that of the Chihuahua and panela cheeses. However, the bulk density describes that panela cheese has the highest density with respect to Chihuahua and manchego cheeses. And this contradicts phenomenologically from the point of view of physics. A material with a higher bulk density may have a higher acoustic phase velocity than one that does not. This means that, if the panela cheese has higher density, consequently, it would have a higher acoustic phase velocity. However, it should be noted that in the was different in each of them. This influenced these measurements. Likewise, it is necessary to understand that the cheeses were of a commercial type, so the manufacturing, maturation, conservation, and distribution process is ignored, until their use or consumption and this is demonstrated by the results of the acoustic transmittance, where the spectra in function of frequency, describes a non-homogeneity within the structure of cheeses. In Table 2, summarizes the results obtained in the measurements.

4. Conclusions

The acoustic properties of commercial cheeses such as Chihuahua, Manchego, and panela were characterized. Until now, the acoustic properties of the cheeses studied were not found in the reported literature. There are results of the other types of cheeses. Using acoustic pulses as excitation sources generates a greater scattering in the intrinsic properties of cheeses. It is possible to increase the sensitivity capacity of the experiments, if it is done means of adiabatic system. It is proposed to produce Chihuahua, Manchego, panela and other cheeses, to characterize their acoustic and mechanical properties, and compare their results with the properties of commercial cheeses.

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Conflicts of Interest: The authors declare no conflict of interest.

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