Available online at www.sciencedirect.com

ScienceDirect

Physics Procedia 70 (2015) 1260 – 1263

Physics Procedia

2015 International Congress on Ultrasonics, 2015 ICU Metz

Sound Speed Measurement of Chicken Liver from 22°C to 60°C

R. Martínez-Valdez*, V. H. Contreras M., A. Vera, L. Leija

Department of Electrical Engineering, Bioelectronics Section, CINVESTAV-IPN, Av. Instituto Politécnico Nacional 2508, San Pedro Zacatenco, Gustavo A. Madero, Mexico City 07360, Mexico

Abstract

Soft tissue acoustic characterization has been widely explored in order to understand the ultrasonic bio-effects. Speed of sound and attenuation are the most frequently measured parameters. In hyperthermia and ablation applications, tissue temperature increases due to ultrasound exposure. Sound speed temperature dependence of 10 chicken liver samples was measured in order to obtain its behavior at hyperthermia temperature interval. Pulse-echo technique was used for measuring the ultrasound speed of the tissue sample. Sound speed measurement in chicken liver at 21.8°C was 1588.2 m/s, while at 60.5°C was 1609.3 m/s. With these results, we proposed a 5^{th} order polynomial to fit the curve described by the ultrasound velocity temperature dependence in chicken liver of the form $c_{liver}=2.664e^{-6}T^5-0.000536T^4+0.04192T^3-1.615T^2+31.76T+1337$, where c_{liver} is sound speed in chicken liver and T is the temperature. It is clear that more experimentation is needed in order to have final results.

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

Keywords: chicken liver; propagation speed; pulse-echo method; ultrasound

1. Introduction

Ultrasound has been used as a tool to explore the mechanical properties of biological tissues such as heart, liver, kidney, skin, etc. Backscatter echoes, attenuation coefficient, sound speed and other nonlinear parameters are techniques used to study the acoustic characteristics of biological tissues (Pereira et al., 2003). Many researchers have investigated the thermal-dependent changes in tissue sound speed to differentiate water-based tissues, such as

* Corresponding author. Tel.: +52-55-57473800 ext. 6212; fax: +52-55-57473981.
E-mail address: maukato@gmail.com

1875-3892
Peer-review under responsibility of the Scientific Committee of ICU 2015
doi:10.1016/j.phpro.2015.08.280

liver, from fatty tissues (Ghoshal et al., 2011). In a review made by Seo et al. (2011), they report that when the temperature increases the acoustic waves propagate faster in water-based tissues; while the sound speed decreases in fatty tissues. Daoud et al. (2013) reported that the temperature raise from 20°C to 37°C leads to a quasi-linear increase in the sound speed in normal and cancerous human livers. There, the weight composition of both liver types included small fat content of 2% approximately.

In ultrasonic hyperthermia and ablation applications, the sound speed changes due to the heat absorbed by the tissue. As mentioned before, one of the techniques employed to measure the propagation velocity is known as pulse-echo. This technique consists in a transducer used as emitter-receiver and a reflectors arrangement with a known distance among them. The interaction between the ultrasonic pulse and the reflectors produces an echo pair that is stored, in a PC, to be analysed. These signals contain useful data such as time-of-flight in order to estimate the sound speed. It is important to remember that the distance among reflectors must be known and the alignment must be close between both reflectors (Lopez-Haro et al., 2012). The aim of this work is to estimate the speed of sound of chicken liver as function of temperature from 22°C to 60°C by using the pulse-echo technique.

2. Methodology

A 5 MHz transducer (Olympus Panametrics® NTD, V309 5 MHz/0.5", 767258) was driven with a 200 V/ 50 ns pulse delivered by a home-made generator. The biological tissue was fixed parallel at 15 cm from the transducer radiating surface. Two 1.57 mm diameter needles used as reflectors were fixed into a 26.44 mm diameter Nylamid cylinder, similar to that described by Lopez-Haro et al. (2010). The needles tips distance between each other was 6.45 mm. The reflectors were inserted into a chicken liver sample. Chicken liver samples were preserved in a saline solution following the protocol reported by López-Haro et al. (2010) in order to slow down its decomposition process. Afterwards, they were stored at the fridge at an approximate temperature of 4°C for further use.

Figure 1A shows the experimental set up for the ultrasonic echoes acquisition. Transducer-sample-reflectors system was placed inside a thermostatic bath (Techne, TU-20D Tempunit®) which was filled with bi-distilled degassed water to regulate the system temperature. Sound speed was measured in the temperature interval from 22°C to 55°C with successively increments of 2°C or 5°C. A mercury thermometer monitored the water temperature. Two hypodermic thermocouples (Omega® Engineering, Inc.) were used to measure the reference medium temperature and the biological sample temperature. A PC interface (NI® SignalExpress) recorded the temperature increment in both tissue and water by means of a data acquisition system (NI® cDAQ-9172 and NI®9219).

Sound speed was calculated from the time-of-flight (TOF) between the maximum peak echoes difference,

$$c_s = \frac{2 * d}{TOF} \tag{1}$$

where c_s is the speed of sound in the biological tissue sample, d is the distance between the needle reflectors, and $TOF = t_2 - t_1$, see Fig. 1B.

Ten ultrasonic echoes were acquired with a digital oscilloscope (Lecroy®, 6100A waveRunner) at each temperature value. Mean sound speed was calculated for each temperature value in the ten chicken liver samples. The regulation of the temperature presented differences of ±0.7°C according to the mercury thermometer; therefore, temperature was averaged in 5°C intervals and the mean and standard deviation sound speed for each specific interval was calculated.

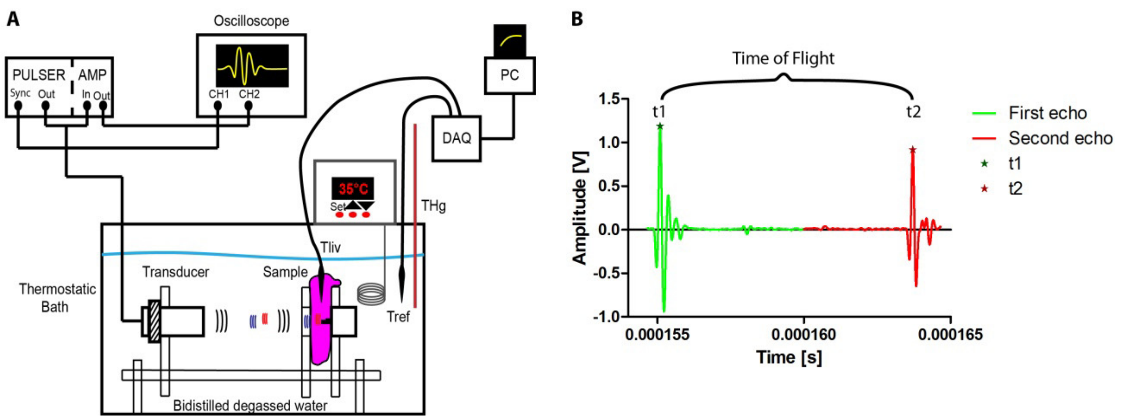

Fig. 1. (A) Experimental set up; (B) Echoes obtained from needle reflectors in reference medium (bi-distilled degassed water).

3. Results and discussion

Figure 2A shows the temperature dependence of the sound speed of ten chicken liver samples. It is clear that all samples presented a similar trend in ultrasonic velocity in the proposed temperature interval. Measurements in samples S2 and S5 were done with 2°C successively increments. Sample S2 showed sound speed variations from 20°C to 44°C. The differences in the sound speed for all samples might be due to internal structure of each chicken liver, sample misalignment with the transducer surface, etc.

Figure 2B shows the mean and standard deviation of sound speed in chicken liver obtained in this work. It also can be seen that the chicken liver propagation speed is in agreement with both human and bovine liver data reported by Bamber and Hill (1979). Sound speed obtained from measurements at 21.8°C was 1588.2 m/s and 1609.8 m/s at 46°C which are close to the values of human liver (Bamber and Hill, 1979), and 1609.3 m/s at 60.5°C.

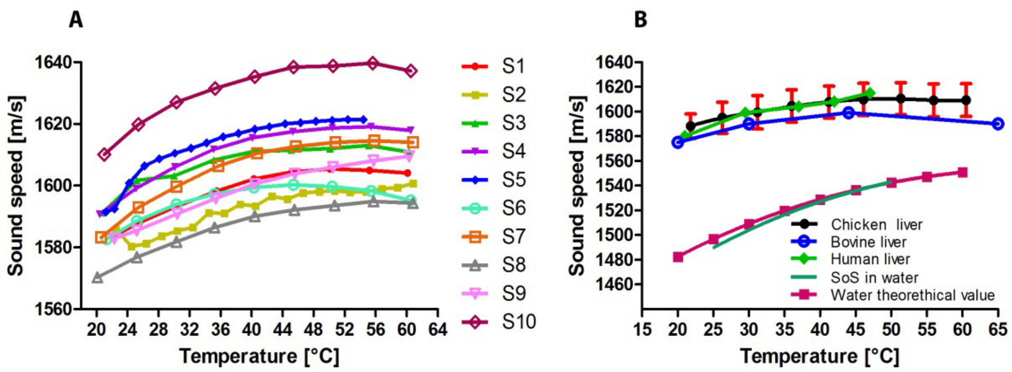

Fig. 2. (A) Sound speed measured for the 10 chicken liver samples; (B) Mean sound speed and standard deviation obtained from the 10 samples, comparison with liver from other species. Temperature dependence of sound speed in water; data obtained from literature.

The maximum standard deviation of speed of sound in chicken liver was ±13.49 m/s at 31.22°C. Figure 2B also shows the theoretical propagation speed in water proposed by Bilaniuk (1993) and the experimental data obtained by Lopez-Haro et al. (2010). From mean sound speed calculated, a 5[th] order polynomial could be fitted to the chicken liver response from 22°C to 60°C with a R^2=0.9987,

$$c_{liver}(T) = 2.664e^{-6}T^5 - 0.000536T^4 + 0.04192T^3 - 1.615T^2 + 31.76T + 1337 \quad (2)$$

where c_{liver} is the sound speed in chicken liver and T is the temperature in degree Celsius.

4. Conclusions

Speed of sound measurement in chicken liver was done in the temperature interval from 20°C to 60°C. The ultrasonic echoes presented signal deformation at higher temperatures; therefore sound speed was measured at 60°C maximum. Data obtained in this work showed good agreement with previous data reported for other mammalian tissues which suggest that chicken liver can be used in ultrasonic hyperthermia experimentations. In fact, we believe that this kind of tissue would be useful for experimenting in ablation therapies. Furthermore, it would be convenient to explore the sound speed of chicken liver behavior for ablation temperatures.

Acknowledgements

Authors thank the CINVESTAV-IPN for all the facilities given to develop this work and the funding given by the ECOS-ANUIES-CONACYT M10-S02 program, CONACYT-F-SALUD 201590 project, CONACYT-F-SALUD 201256 and Joint Cooperation Fund Mexico-Uruguay (SRE-AUCI) 2012-2013.

References

Bamber, J.C., Hill, C.R., 1979. Ultrasonic attenuation and propagation speed in mammalian tissues as a function of temperature. Ultrasound Med. Biol. 5, 149–157.

Bilaniuk, N., 1993. Speed of sound in pure water as a function of temperature. J. Acoust. Soc. Am. 93, 1609.

Daoud, M.I., Mousavi, P., Imani, F., Rohling, R., Abolmaesumi, P., 2013. Tissue classification using ultrasound-induced variations in acoustic backscattering features. IEEE Trans. Biomed. Eng. 60, 310–320.

Ghoshal, G., Luchies, A.C., Blue, J.P., Oelze, M.L., 2011. Temperature dependent ultrasonic characterization of biological media. J. Acoust. Soc. Am.

Lopez-Haro, S. a., Vera, A., Leija, L., 2010. Evaluation of an ultrasonic propagation speed measurement system in the temperature range from 20°C to 45°C. In: Health Care Exchange (PAHCE), 2010 Pan American. pp. 85–89.

López-Haro, S.A., Leija, L., Favari, L., Vera, A., 2010. Measurement of Ultrasonic Properties into Biological Tissues in the Hyperthermia Temperature Range. Phys. Procedia 3, 551–558.

Lopez-Haro, S.A., Reyes, J.L., Vera, A., Leija, L., 2012. Ultrasonic characterization of cell culture medium in the temperature range from 25°C to 50°C. In: 2012 Pan American Health Care Exchanges. IEEE, pp. 71–75.

Pereira, F.R., Machado, J.C., Foster, F.S., 2003. Ultrasound characterization of coronary artery wall in vitro using temperature-dependent wave speed. IEEE Trans. Ultrason. Ferroelectr. Freq. Control 50, 1474–1485.

Seo, C.H., Shi, Y., Huang, S.-W., Kim, K., O'Donnell, M., 2011. Thermal strain imaging: a review. Interface Focus 1, 649–64.