Effect of Temperature on Ultrasonic Signal Propagation for Extra Virgin Olive Oil Adulteration

N.A. Alias[1], S.B. Abdul Hamid[2], A.Sophian[3]

Department of Mechatronics Engineering, Kulliyyah of Engineering, International Islamic University Malaysia, 53100 Gombak, Selangor

ain_alias@yahoo.com[1], syamsul_bahrin@iium.edu.my[2]

Abstract. Fraud cases involving adulteration of extra virgin olive oil has become significant nowadays due to increasing in cost of supply and highlight given the benefit of extra virgin olive oil for human consumption. This paper presents the effects of temperature variation on spectral formed utilising pulse-echo technique of ultrasound signal. Several methods had been introduced to characterize the adulteration of extra virgin olive oil with other fluid sample such as mass chromatography, standard method by ASTM (density test, distillation test and evaporation test) and mass spectrometer. Pulse-echo method of ultrasound being a non-destructive method to be used to analyse the sound wave signal captured by oscilloscope. In this paper, a non-destructive technique utilizing ultrasound to characterize extra virgin olive oil adulteration level will be presented. It can be observed that frequency spectrum of sample with different ratio and variation temperature shows significant percentages different from 30% up to 70% according to temperature variation thus possible to be used for sample characterization.

1. Introduction

Olive oil is one of the health beneficial vegetables oil to humans to consume in their daily life with the proper balanced in diet [10]. This oil is commonly used as significant ingredient in cooking, salad dressing or in food products formulation. It is also stated in the Quran that olive tree is considered as a blessed tree in Islam and a source of a good nutrition to life [9]. As of April 2017, current price of virgin olive oil in Ringgit Malaysia is about RM 19,343.41 per metric ton or about RM 19.34 per litre. In this case, olive oil could be considered as one of the edible oils that can be classified as a high value due to its expensive price in the market.

High value products are of the subjected to adulteration involving the replacement of high-cost ingredient with lower grade and cheaper substitutes and this sometimes can be difficult to detect [2]-[7]. Adulteration of olive oil with various seed oils is common problem affecting the quality and commercial value of the products. This practice will cause a major loss in economic value and commercial exploitation of olive oil [3]. Olive oil is a commonly adulterated food product of the world due to its relatively low production and expensive prices compared to other vegetables and seed oils as previously expressed. Adulteration of olive oil is a serious problem for regulatory agencies, oil suppliers and could also be a threat to the health of consumers. Hence, there are several techniques that has been introduced specifically to detect adulteration of olive. Current common methods are using cylindrical capacitive sensor as dielectric-based system, controlled cooling of differential scanning calorimetry (DSC), mass spectrometry, standard method by The American Society for Testing and Materials International (ASTM International) such as Density test, Evaporation test, Distillation test, Chemical Marker test and Gas Chromatography [4]. These methods may be used to determine the adulteration but tend to be fixed with

laboratory apparatus and can cause delay in validation. Ultrasound is one of in-situ approach available to detect adulteration but prone to error due to temperature variance and mass chromatography requires a complicated sample preparation.

Ultrasound technology is an environmentally friendly, externally applied, non-invasive and well proven in medicine, industry and sciences. Common application of ultrasound in industry is non-destructing test (NDT), thickness measurement, flow speed measurement, characterization of dispersions, manipulation of particles, enhancement of flow in microchannel (ultrasonic streaming) and fish detection (ultrasound real-time identification)
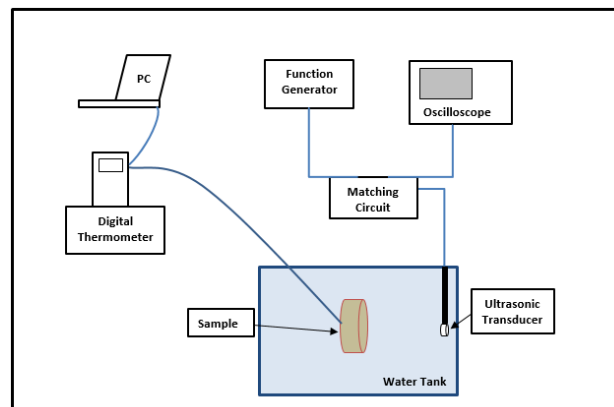
There are two basic ultrasonic testing that is either the reflected waves (pulse-echo) or the transmitted waves (through transmission). Pulse echo system are more useful compared to through transmission in terms of application as they required one-sided access to the object being inspected or tested. Ultrasound wave travel at a speed of sound that is related to compressibility (K) and density of a material combined with the laws of conservation of mass and momentum, directly imply the existence acoustic waves [6]. Other than that, viscosity of fluid that undergoes propagation of ultrasonic wave will change the waveforms due to attenuation and the dispersion of the propagation medium. In the ultrasound system used for experimental purposes, common methods involve are based either on the measurement of reflection coefficients and as well as by the determination of the characteristics of propagation (velocity and attenuation). Measurement of velocity propagation and attenuation when propagate ultrasonic waves allows to determine the physical quantities of the medium. In this case, it shows that is possible to characterize the adulteration of extra virgin olive oil using ultrasound measurements.

According to Pascal Laugier and Guillaume Haïat, temperature of the medium also effect the speed of sound (c) as temperature dependence of c. Previous research has proved that speed of sound in the water is 1482 m/s at 20 ^{o}C and varies between 20 ^{o}C and 37 ^{o}C with a temperature coefficient about 2.5m/s/^{o}C [5]. Moreover, when heat is subjected to fluid, the particles will speed up and spread out immediately and vice versa. This will result on fluid to expand as the volume increase as well as causes the density to increases. (D=M/V if V gets smaller M/V gets bigger). This shows that temperature of sample that undergone propagation of ultrasound waves should be taken into consideration during experiment as it will affect viscosity of fluids. This paper is organized as follows, as in next section is materials and methodology used followed by results and discussion in section 3 and section 4 is a conclusion of the paper.
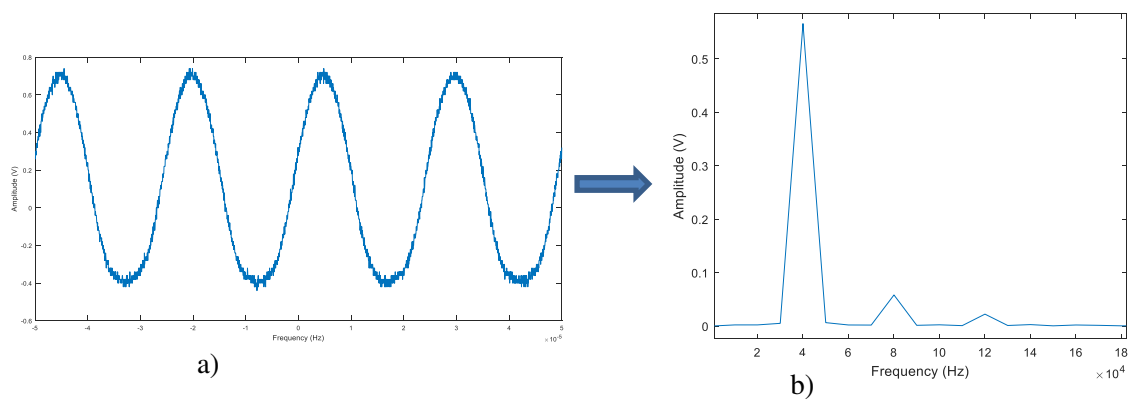
2. Materials and Methodology

Sample used in determination of virgin olive oil being mixed with other filler material of palm oil was poured into glass with a volume of 300 ml. Water is used as reference sample and sample used for the analysis contained mixture of extra virgin olive oil with palm oil bought from local supermarket. Sample used are 100% olive oil and ratio of 50:50 and 30:70 of olive oil and palm oil. Thus, the same concentrations are used which related to adulteration of olive oil with other filler materials. Temperature range are taken based on standard ambient and storage temperature of extra virgin olive oil which are 27 ^{0}C, 30 ^{0}C and 33 ^{0}C. Temperature of the sample is controlled using digital thermometer and heater was used to increase the temperature of the sample.

In order to generate a time domain signal of the transducer, a 5Vp-p continuous sine wave with a frequency of 40 kHz was excited using function generator model INSTEK GFG-8217A (1MHz). Received signal was digitized by oscilloscope model Tektronix TDS 1002B (60MHz). Signal data are taken manually using USB drive features of oscilloscope. Single ultrasonic transducer model JSN SR04 with acoustic emission frequency of 40 kHz is used for transmitting and receiving ultrasonic signal. Figure 1 will illustrate the measurements of ultrasonic system setup and figure 2 shows the example of transmitting signal of continuous wave.
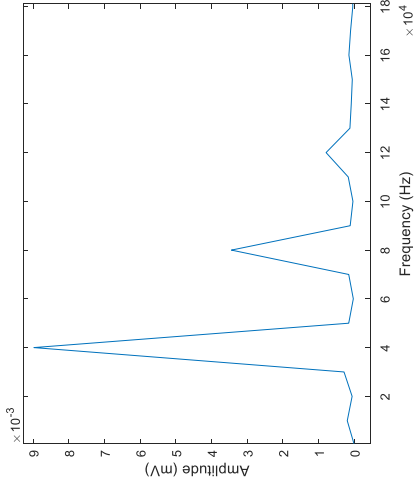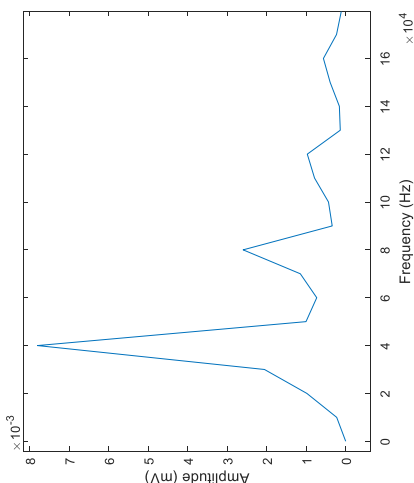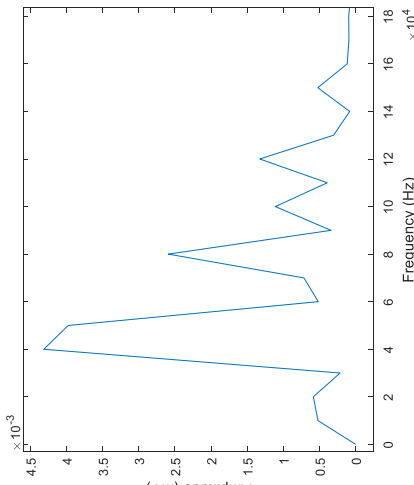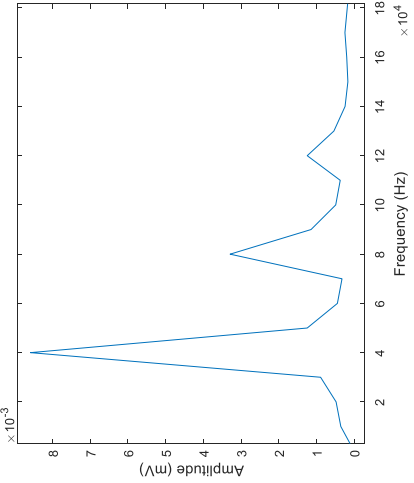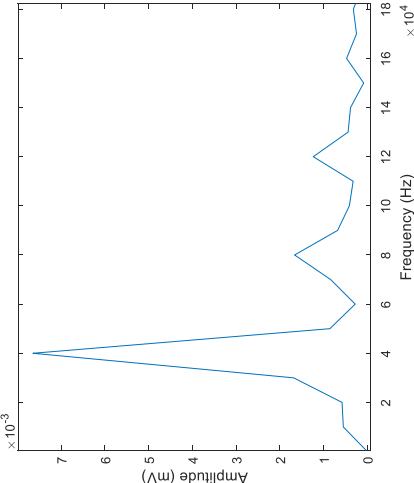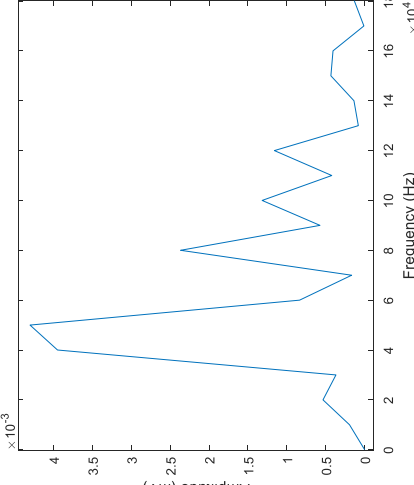
Ultrasound signal generation

Figure 1: Experimental setup of sound wave propagation and signal acquisition

Figure 2: a) Continuous sine wave transmitted signal b)Frequency spectrum of this wave

Results

Table 1 : Different sample ratio and variation temperature spectra

3. Results and Discussion

Results in figure 3 shows that 100% olive oil sample possessed different frequency spectrum of receiving signal and it is possible to characterize adulteration of olive oil. Temperature also plays important role in the formation of frequency spectrum. Variation of temperature effect the received signal as speed of sound, viscosity and density change, thus effect the frequency spectrum as well. Figure 3 shows received signal of olive oil with different sample temperature. First peak of the spectrum shows that higher temperature resulted in lower amplitude of the spectrum and vice versa. This has proved that temperature of sample does affect the received signal of ultrasound and first peak of the signal can be used for further analysis of the sample used.
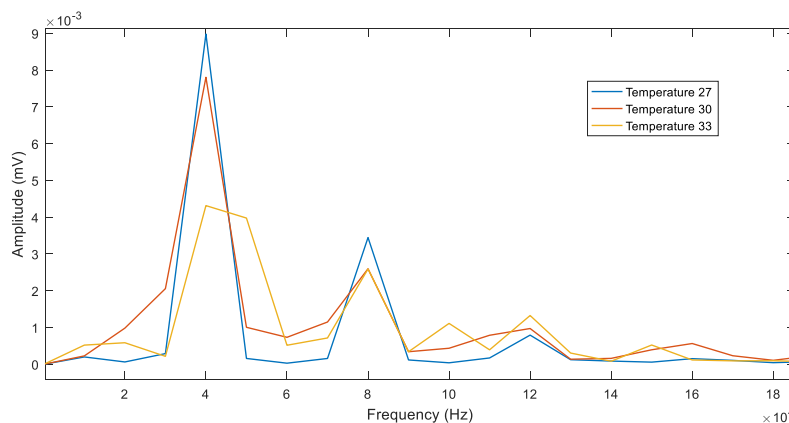

Figure 3: Frequency spectrum of 100% olive oil sample with different temperature

Table 2: Data obtained from frequency spectrum of different temperature and sample used

Sample	Temperature (^{0}C)	Amplitude (V)		
		First peak	Second peak	Third peak
100% Olive Oil	27	0.00906	0.00342	0.00133
	30	0.00793	0.00261	0.00094
	33	0.00451	0.00259	0.000809
50:50 ratio	27	0.00806	0.00331	0.00125
	30	0.00772	0.00241	0.00124
	33	0.00398	0.00168	0.00117
30:70 ratio	27	0.00735	0.00327	0.00176
	30	0.00695	0.00331	0.00101
	33	0.00571	0.00249	0.000806

Table 3: Percentage different of frequency spectrum amplitude

Sample	Temperature (^{0}C)	Percentage different	
		First peak to second peak	Second peak to third peak
100% Olive Oil	27	62%	61%
	30	67%	64%
	33	42%	68%
50:50 ratio	27	58%	62%
	30	68%	48%
	33	57%	30%
30:70 ratio	27	55%	46%
	30	52%	69%
	33	62%	61%

Table 1 shows the frequency spectral of received signal that goes with different initial condition. All sample that undergoes propagation of sound wave showed different frequency spectrum under the same condition of temperature and pressure and possessed different spectral with the variation of temperature. Percentage different of one peak to another peak is calculated using values obtained from the graph as shown in table 2. Calculations shows that percentage are varies from 30% to 70%. This shows that changes of the amplitude are quite significant. Hence, further analysis on frequency spectrum which is in frequency domain can be done to characterize the analysed materials from different aspects as of density and viscosity compare to time domain analysis. Thus, this present work shows that characterization of the materials can be done using ultrasound signal based on the different values of amplitude obtained from the spectrum.

4. Conclusion

Based on the observation of the frequency spectrum of the sample undergoes continuous sine wave of 40kHz frequency digitized by the oscilloscope, it is possible to use frequency spectrum for further analysis of sample characteristics based on results that shows shift of peak to peak values of the spectrum amplitude which is quite significant. Temperature of sample should be taken into considerations as the spectra of propagation of ultrasound signal also changed.

5. Acknowledgement

6. References

[1] Baroni, D. B., & Bittencourt, M. S. Q. (2011). Ultrasonic Spectral Analysis For Nuclear Fuel Characterization.

[2] Calorimetry, D. S. (n.d.). Detecting the Adulteration of Extra Virgin Olive Oil by Controlled Cooling DSC, 3–5.

[3] Dourtoglou, V. G., Dourtoglou, T., Antonopoulos, A., Stefanou, E., Lalas, S., & Poulos, C. (2003). Detection of olive oil adulteration using principal component analysis applied on total and regio FA content. Journal of the American Oil Chemists' Society, 80(3), 203–208. https://doi.org/10.1007/s11746-003-0677-1

[4] Gupta A. K. and SharmaR.K. (2002). A new method for estimation of automobile fuel adulteration, 357–371.

[5] Oliveira, P. A., Silva, R. M. B., Morais, G. C., Alvarenga, A. V, & Félix, R. P. B. C.-. (2016). Speed of sound as a function of temperature for ultrasonic propagation in soybean oil. Journal of Physics: Conference Series, 733, 12040. https://doi.org/10.1088/1742-6596/733/1/012040

[6] Sudhan, M., & Gudur, R. (2013). Spectral Ultrasound Characterization of Tissues and Tissue Engineered Constructs.

[7] Tay, a, Singh, R. K., Krishnan, S. S., & Gore, J. P. (2002). Authentication of Olive Oil Adulterated with Vegetable Oils Using Fourier Transform Infrared Spectroscopy. LWT - Food Science and Technology, 35(1), 99–103. https://doi.org/10.1006/fstl.2001.0864

[8] Azadmard-Damirchi, S., & Torbati, M. (2015). Adulterations in Some Edible Oils and Fats and Their Detection Methods. Journal of Food Quality and Hazrds Control, 2, 38–44.

[9] Qur'an, (24:35)(23:20)

[10]   Maria L.Palmetti, 2011,Palm Oil : Nutrition, uses and impact, Nova Science Publishers, Inc. New York