ULTRASONIC PROPERTY OF RADISH UNDER COMPRESSION LOAD

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ABSTRACT

The objective of this research was to study the effect of contact force of ultrasonic probe on the ultrasonic attenuation measurement of radish. The relationship between ultrasonic attenuation (y) and contact force (x) for radish can be expressed as equation $y=a+bLn(x)$, where $a=8.7194+2.168\times(\text{porosity})$ and $b=-9.9188+0.0075\times(\text{volume})$.

The relationship between ultrasonic power spectrum (y) and contact force (x) for radish is also represented by equation $y=a+bLn(x)$, where $a=60.1965-1.4714\times(\text{porosity})$. The coefficient b has no significant relation with radish properties.

Key Word : Ultrasound, Radish, Contact force, Attenuation, Power spectrum.

INTRODUCTION

Some studies have been investigating the ultrasonic techniques for quality evaluation of fresh food products, especially for fruits and vegetables. Ultrasonic techniques have been used for determination of fat in beef, in pork, and in fish, but have not been used widely for fruits and vegetables (Kress-Rogers, 1993; Haugh, 1993).

The velocity and attenuation coefficients of ultrasonic wave are the two determinants when applying ultrasonic technique in vegetables and fruits quality testing. By acquiring these two properties, the mutual relationship between the physical properties of vegetables and fruits and ultrasonic wave can be obtained and served as the quality indices.

In food industry, the ultrasonic techniques are good for monitoring processing system by the fact that they are non-invasive, reasonably accurate and relatively cheap. Furthermore sound waves travel easily through many materials that are opaque to light. They are, however, strongly attenuated by gases. Sound attenuation measurements have been used considerably less than velocity measurements with real foods. Unlike liquid or viscoelastic materials, solid materials shaped like vegetables and fruits pose a particularly tricky problem as far as the use of ultrasound is concerned. The wave attenuation of fruits and vegetables is very high due to the porosity nature of plant tissues. The drawback is the high attenuation resulted from the porous nature for fruits and vegetables (Nishizu et al., 1995; Tanaka et al., 1993). This means that it is difficult to apply ultrasonic techniques to media with a large air content (Pinder and Godfrey, 1993).

The potential of ultrasonic non-destructive evaluation has been recognized for some time and studied in line with internal defects, hollow heart, ripeness and maturity of fruits and vegetables such as potatoes, avocado, kiwi fruit, apple and melon (Sarkar and Wolfe, 1983; Ha et al., 1990; Haugh, 1993; Tanaka et al.,1993; Galili et al., 1993; Mizrach et al., 1994a; Mizrach et al., 1994b; Lu and Chung, 1996). Mizrach et al. (1994a, 1998) showed correlation between ultrasonic properties and some ripening parameters of melon, potato and avocado fruit tissues. Mizrach et al. (1999a,1999b, 2000) evaluated ultrasonic wave analysis and the physiological properties of cv. 'Tommy Atkins' mango fruit in time and frequency domains, and to establish relationship between the nondestructive ultrasonic measurements and the major physiological quality indices of mango fruit. Nielsen et al. (1997,1998) studied texture evaluation of carrots by adopting 37 kHz ultrasound transducer.

The ultrasound transducers or probes are pressed against the surface of fruits or vegetables during measuring the ultrasound properties. The objective of this study was to study the effect of contact force of ultrasonic probe on radish surface on the ultrasonic attenuation measurement of radish.

MATERIALS AND METHODS

The volume, density, width of radish were measured for 43 samples before placing the whole radish between two ultrasound transducers mounted on the universal testing machine Instron 4465. The Young's modules of radish was measured from cut sample of 12 mm in diameter and 20 mm in depth. The porosity of radish was also measured from cut sample of 12 mm in diameter and 30 mm in depth. The sample was immersed in a small pressurized container filled with water in it and porosity was calculated by Eq.(1).

$$\phi_o = \frac{\Delta V}{V_s\left(1 - \frac{P_o}{P_1}\right)} \times 100 \tag{1}$$

ϕ_o : porosity (%) ; $\triangle V$: water volume change (mm^3) ; V_s : sample volume (mm^3) ; P_o : 14.7 psi ; P_1 : absolute pressure (psi)

The transmitter-receiver system with pulser-receiver (Parametric 5058PR) and low-frequency probes (Parametric X1021, 50-KHz, Φ 4.5 cm) and oscilloscope (LeCroy 9304A) was adopted to measure the attenuation of whole radish. The instrumentation of the system is as shown in fig.1. The transmitting signals were recorded at different contact force of the ultrasound probes on the radish. The load intervals ranged from 2 to 20 kg with a 2 kg interval. The attenuation coefficient was calculated by Eq.(2).

$$\alpha = \frac{1}{x}\ln\left(\frac{(V_{pp})_o}{(V_{pp})_x}\right) \tag{2}$$

α : attenuation coefficient (neper/m; $(V_{pp})_o$: original signal (volt) ; $(V_{pp})_x$: transmi tted signal (volt) ; x : signal transmitting length (m)

The regression of attenuation coefficients on contact force was performed and the effect of radish properties on attenuation was also added to the regression equation.

RESULTS AND DISCUSSION

The negative relationship between attenuation coefficient and contact force for different porosity is shown in fig. 2. The higher the contact force is the lower the attenuation coefficient. Due to the large air volume in radish high attenuation was observed in high porosity radish. The correlation between attenuation coefficient and porosity is around 0.7 for contact force ranging from 2 to 20 kg. The correlation between attenuation coefficient and Young's modules is between 0.3 and 0.4. The relationship between correlation coefficient and measured radish properties is shown in fig. 3.

The regression equation between ultrasonic attenuation (y) and contact force (x) for radish is represented by equation y=a+bLn(x) with R^2 ranging from 0.73 to 0.99. The regression coefficient a and b were regressed respectively with radish properties such as density, volume, width, Young's modules, and porosity. The standard regression coefficient is listed in table 1. For constant a, the standard regression coefficient for porosity is 0.671 and statistically significant at α=0.01. This means that porosity has greatest influence on coefficient a than other factors. For constant b, the standard regression coefficients for porosity and volume are –0.347 and 0.311 respectively and also statistically significant at α=0.05. In stepwise regression analysis only porosity and volume factors were included in the regression equations, therefore the regression equations for coefficients a and b are a=8.719+2.168 × (porosity) with R^2=0.3698 and b=-9.9188+0.0075× (volume) with R^2= 0.1126.

In power spectrum analysis, the positive relationship between power spectrum and contact force for different porosity is also shown in fig.4. The higher the contact force is the higher the attenuation coefficient. The correlation between power spectrum and porosity is around -0.7 for contact force ranging from 2 to 20 kg. The correlation between attenuation coefficient and Young's modules is between 0.2 and 0.3. The other relationship between correlation coefficient and measured radish properties is also shown in fig. 5.

The regression equation between ultrasonic power spectrum (y) and contact force(x) for radish is also represented by equation y=a+bLn(x) with R^2 ranging from 0.78 to 0.99. The regression coefficients a and b were also regressed respectively with radish density, volume, width, Young's modules, and porosity.

The standard regression coefficient is listed in table 2. For constant a, the standard regression coefficient for porosity and density are respectively -0.631 and 0.221 and statistically significant at α=0.01. This means that porosity and density have significant influence on coefficient a. For constant b, all of the standard regression coefficients are statistically significant at α=0.01 and their absolute values are between 0.204 to 0.274. This means that volume, density, width, Young's modules, and porosity have approximately equal influence on coefficient b. In stepwise regression analysis only porosity is included and the regression equation is simplified to a = 60.1965-1.4714 × (porosity). For constant b no factor is included in the stepwise regression analysis.

Therefore it is better to adopt the regression equation of attenuation coefficient against contact force. By combining regression equation of attenuation y=a+bLn(x), a=8.719+2.168× (porosity) and b= -9.9188+0.0075×(volume) the radish porosity can be evaluated with statistically significant at α=0.01 and R^2= 0.434-0.508 under different contact force. This means that radish porosity could be evaluated from ultrasound measurement. Further report on this issue will be discussed in the future.

CONCLUSIONS

The ultrasound transducers or probes are pressed against the surface of fruits or vegetables during measuring the ultrasound properties. The objective of this study was to study the effect of contact force of ultrasonic probe on the ultrasonic attenuation measurement of radish. The relationship between ultrasonic attenuation (y) and contact force (x) for radish can be represented by equation y=a+bLn(x), where a=8.7194+2.168×(porosity) with R^2=0.3698 and b= -9.9188+0.0075×(volume) with R^2=0.1126. The radish porosity can be statistically evaluated at significant level of α =0.01 with determinant coefficient R^2= 0.434-0.508 under different contact force.

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Table 1. Standard regression coefficient for ultrasonic attenuation

	a	b
Volume (cm^3)	-0.033	0.311*
Density (g/cm^3)	-0.067	-0.276
Width (mm)	0.017	-0.057
Young's Modules (MPa)	0.186	-0.117
Porosity	0.671*	-0.347*

* : significient at α=0.01

Table 2. Standard regression coefficient for ultrasonic power spectrum

	a	b
Volume (cm^3)	-0.122	-0.214*
Density (g/cm^3)	0.221*	-0.206*
Width (mm)	-0.019	0.271*
Young's Modules (MPa)	-0.171	0.274*
Porosity	-0.631*	0.204*

* : significient at α=0.01

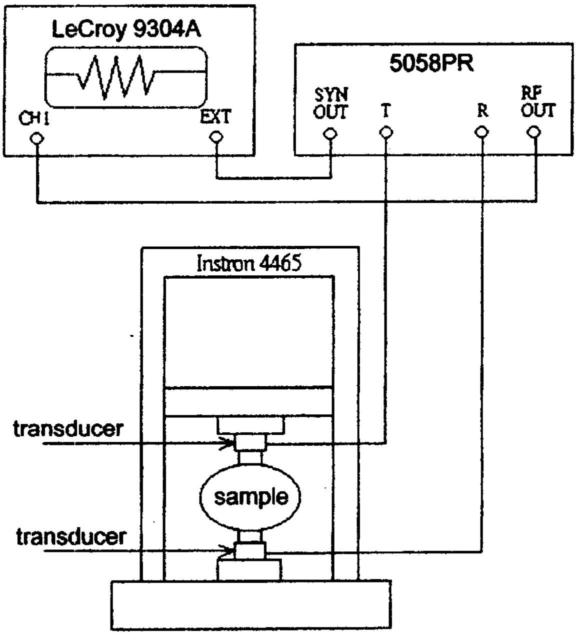

Fig 1. Instrumentation system

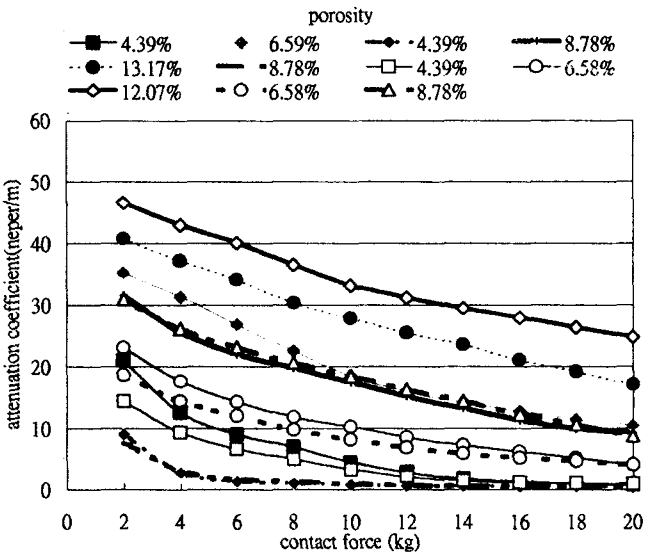

Fig 2. Effect of contact force on ultrasonic attenuation of radish

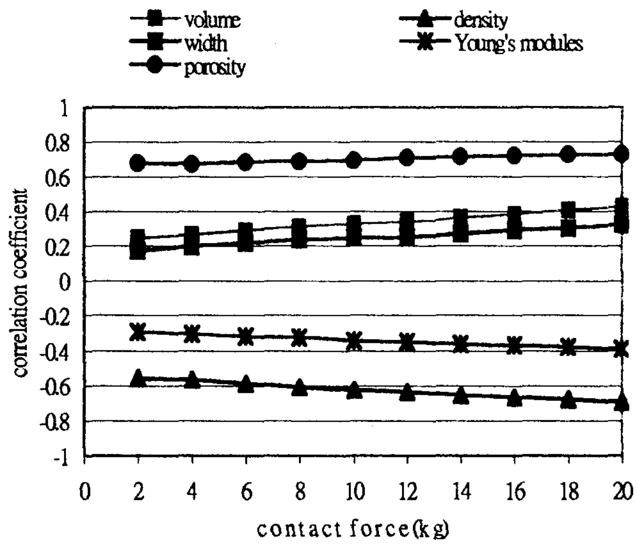

Fig 3. Correlation coefficient between ultrasonic attenuation coefficient and physical properties of radish under different contact force

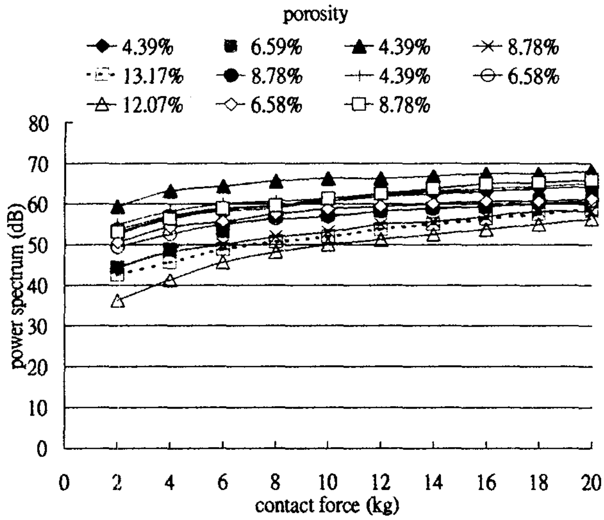

Fig 4. Effect of contact force on ultrasonic power spectrum of radish

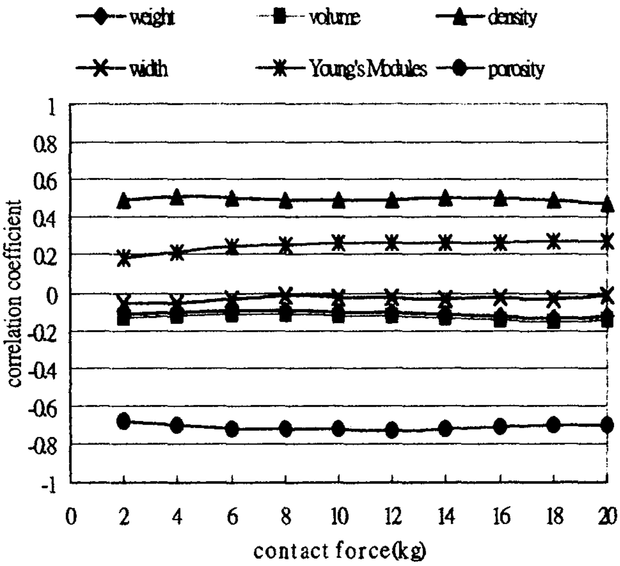

Fig 5. Correlation coefficient between ultrasonic power spectrum and physical properties of radish under different contact force