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Volume measurement of mango using acoustic resonance technique

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Abstract

The objective of this research was to study and develop equipment to measure the volume of mango based on a technical acoustic resonance technique, namely that the resonance frequency that occurs in a Helmholtz resonator varies with the volume of air in the resonator. This method was used to measure nondestructively the volume of mango. The equation for volume prediction was derived from experiments by using different sizes and positions of mangoes. The prediction equation was a linear relationship between the volume of the mango and the resonance frequency. In addition, the experimental results showed that the standard error of prediction was 9.41 and the bias was -11.59 cm^3.

Keywords : Mango, Volume measurement, Helmholtz resonator

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1. Introduction

The volume of non-geometric fruit plays a key role in many applications. For instance this measurement has been utilized to determine the maturity of fruit and to design the parameters of sizing and grading machinery. Due to the variety of sizes and shapes of mangoes, their volume is difficult to measure. Several methods have been tried to date for measuring the volume of fruit. For instance, Forbes used an image processing algorithm to estimate pear volume from two-dimensional digital images [1]. The algorithm is based on the extraction of shape features from two dimensional profile images. Charoenpong proposed a 2D Ellipse Model to estimate the volume of Nam-Dokmai mango, whose cutting surface was assumed to be an ellipse [2]. This method used two CCD cameras to obtain top view and side view photographs for calculating the mango volume. The well-known Helmholtz resonator has found application in a wide variety of technologically significant problems. This technique provides a nondestructive and accurate method of measuring an object's volume. Nishizu used this technique to estimate the volume of food in a continuous system [3].

The technique presented here uses the theory of a Helmholtz resonator to measure the volume of an object in a resonator. A Helmholtz resonator consists of an enclosed cavity with a small opening, which is connected to a straight acoustic tube as shown in Figure 1. The Helmholtz resonance frequency is given by:

$$f = \frac{c}{2\pi}\sqrt{\frac{S}{LV}} \qquad (1)$$

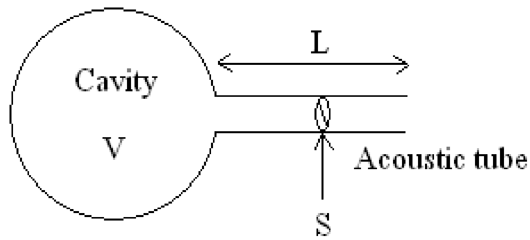

Figure 1 Helmholtz resonator [4]

Where c is the speed of sound, S and L are the cross-sectional area and length of the tube, respectively, and V is the volume of the cavity.

By measuring the resonance frequency with some objects in the resonator, the object's volume can be found by subtracting the cavity volume from the resonator volume, and the cavity volume can be determined using equation (1).

2. Experimental helmholtz resonator

The Helmholtz resonator was constructed using a cylinder pipe of polyvinyl chloride (PVC) with a diameter of 10 cm and a length of 25 cm because this size was appropriate to contain a mango. Different sizes of the Helmholtz resonator affect the magnitude of the resonance frequency according to equation (1). The lower end of the cylinder was covered with a plastic plate. The speaker was installed in the open top end of the cylinder. The microphone was mounted on the cylinder wall at a height of 15 cm from the base. The components of the designed resonator are shown in Figure 2.

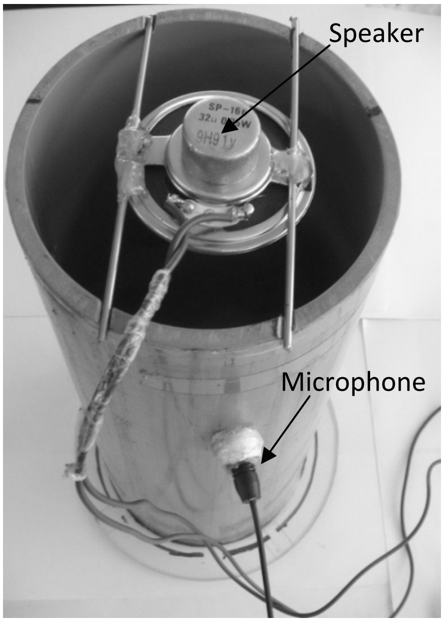

Figure 2 Helmholtz resonator

3. Signal processing of sound

The microphone as a sound sensing element was connected directly to the audio input of a sound card of a personal computer and the speaker was interfaced with the audio output of the sound card. The sound signal in patterns of a chirp wave with a frequency range of 50-150 Hz was generated into the resonator. The response signal corresponding to a chirp wave was sensed by the microphone and was directed into the sound card. The MATLAB program was used as a tool for signal processing. This program converted the received signal in terms of time domain to a frequency domain by using a fast Fourier transform (FFT) algorithm with a rectangular window function. A sampling frequency of 8000 Hz and a sample size of 1600 were used. The highest magnitude of frequency was the resonance frequency occurring in the resonator. The procedure of signal processing is shown in Figure 3.

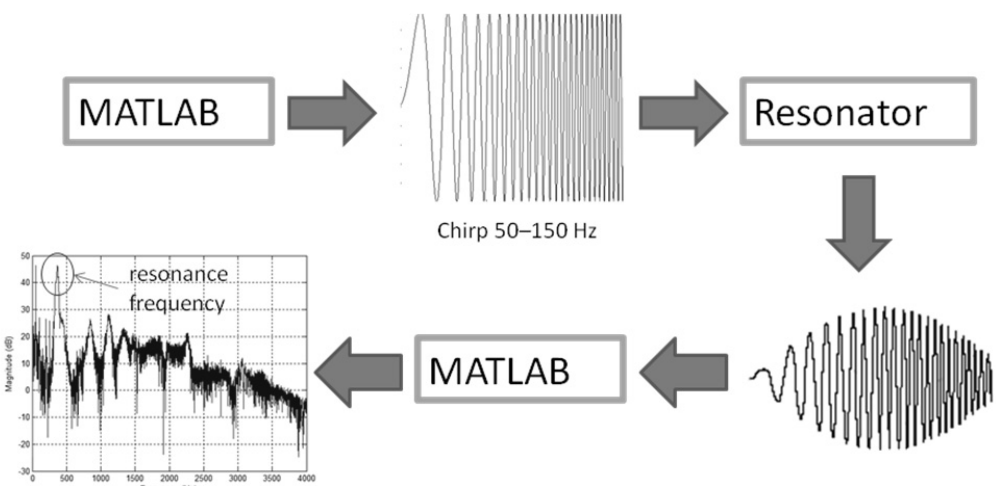

Figure 3 Procedure of signal processing

4. Results and discussion

The experiment was conducted to measure the volume of mango and comprised two main steps. First, the equation of prediction for mango volume was obtained. In this step, mangoes with different sizes (Figure 4) were individually placed into the resonator and then the resonance frequency was measured. Each mango was located at a new position to measure the resonance frequency at different locations as shown in Figure 5. The averaged resonance frequency of 10 measurements of each mango at different locations was recorded (Table 1). Figure 6 shows one of the experimental results from measuring the resonance frequency occurring in the resonator.

Figure 4 Different-sized mango

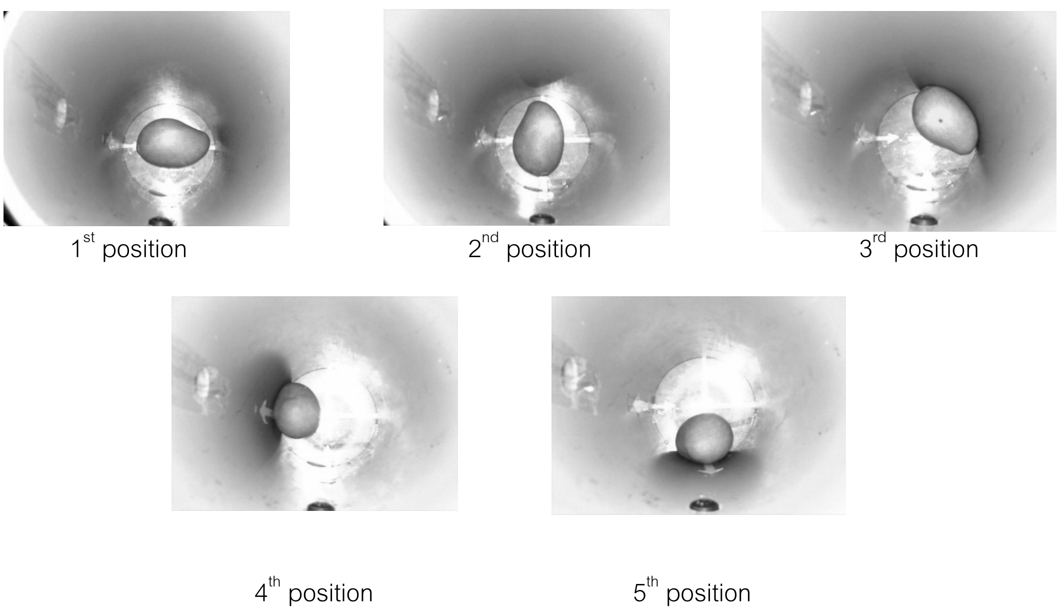

Figure 5 Positions of mango in resonator

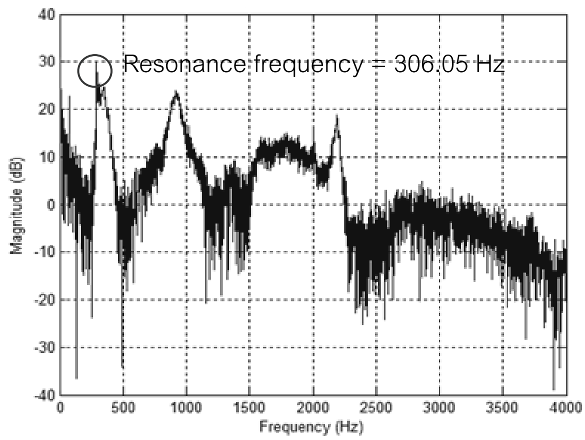

Figure 6 Example of resonance frequency measurement

Table 1 Averaged resonance frequency (Hz) of each mango at different location in resonator

Mango size	1^{st} position	2^{nd} position	3^{rd} position	4^{th} position	5^{th} position
1	306.54	306.84	306.44	306.05	306.15
2	310.45	311.33	311.72	311.72	310.94
3	320.70	320.70	320.49	319.24	319.34
4	324.02	323.93	323.83	323.15	322.56
5	326.87	326.07	326.47	325.98	326.27

From Table 1, at the same position but with different mango sizes, the resonance frequency varied with the size of the mango. For a larger mango, the volume of air in the resonator is less, which causes the resonance frequency to increase. In the case of the same mango in a different position, the resonance frequency was not different significantly. Therefore, the location of the mango in the resonator did not impact on the measuring frequency.

Figure 7 shows the relationship between the actual volumes of mangoes derived from the water replacement method and the resonance frequency of all mangoes which were measured at different location with 10 repeats. The relationship between the actual volume and the resonance frequency was linear as shown in equation 2:

$$V = 7.7718 * f - 2324.6 \quad (2)$$

Where V and f are the predicted volume (cm^3) and the resonance frequency (Hz), respectively.

The second part of experiment tested the accuracy of the prediction equation by using 30 new mangoes with different sizes and shapes. The resonance frequency of each experiment was converted to a volume using the equation of prediction. The predicted volume was compared to the actual volume (Figure 8). The results showed that the volume derived from the equation of prediction was close to the actual volume of the mango, with the standard error of prediction and the bias being 9.43 and -11.61 cm^3, respectively.

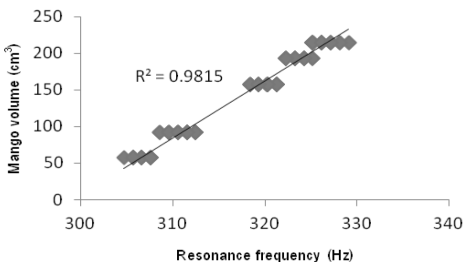

Figure 7 Relation between actual volume and resonance frequency

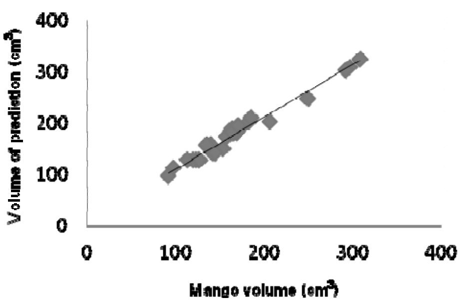

Figure 8 Comparison between the volume of water replacement method and the predicted volume

5. Conclusion

This paper presents a volume measurement system for mango using an acoustic resonance technique. The results indicated that this technique could be applied to measure the volume of mango accurately with a standard error of prediction of 9.43 and a bias of -11.61 cm^3. In addition, the position of the mango placed in the resonator did not degrade significantly the accuracy of measurement. This technique has a lower cost and less system complexity than a digital imaging technique.

6. References

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