Emir. J. Food Agric. 2013. 25 (2): 89-96
doi: 10.9755/ejfa.v25i2.11553
http://www.ejfa.info/

NUTRITION AND FOOD SCIENCE

The relation between the texture properties of mangosteen (*Garcinia mangostana* Linn.) and the resonance frequency in detection of the translucent and yellow gummy latex

Rittisak Jaritngam*, C. Limsakul and B. Wongkittiserksa

Department of Electrical Engineering, Faculty of Engineering, Prince of Songkla University, Thailand

Abstract

A nondestructive measurement to predict an internal translucent disorder and yellow gummy latex in mangosteen fruit has proposed by using Vibration Frequency based on Strain gage Sensor (VFSS). This measurement was used vibration with frequency 0 – 50 Hz. The VFSS of 100 mangosteen samples were obtained an evaluation of various existed VFSS signal features based on time and frequency domains. From the experimental results, mass is the best comparing with the other property. This measurement can detect the yellow gummy latex in mangosteen at 35 Hz and 40 Hz.

Key words: Vibration fruit based on Strain gage Sensor (VFSS), Feature extraction, Yellow gummy latex

Introduction

The mangosteen is the queen of fruit and one of the high economical fruit in Thailand. Moreover, it is also useful about an antioxidant for health (Migdalia et al., 2011). However, the problem and quality of mangosteen is measured not only by external factors such as color, shape, size, skin blemishes, latex training and insect damage and must not include the translucent and yellow gummy latex. Currently, by opening the flesh up was the high accuracy for checking the mangosteen. So, the non-destructive inspection is needed. In recent years, the quality determination of mangosteen, Voraphat (1996) studied the effect of water to translucent flesh disorder using a chemical technique. The non-destructive methods of mangosteen in Thailand, a floating technique using differences in specific gravity is currently undertaken for non-destructive detection of translucent flesh disorder in mangosteen. Similarly, Tawatchai et al. (2004) had been proposed the microwave technique to classify the translucent flesh disorder in term of magnitude of the reflection microwave signal.

However, it has been shown that the dielectric of material changes accordingly to its moisture. By the time, the short wavelength infrared spectroscopy used to predict the translucent flesh disorder in intact mangosteen (Sontisuk, 2007). Somchai et al. (1999) had proposed the non-destructive 2D cross-sectional visualization of mangosteen. The X-ray and NMR techniques have been found as new potential tools for non-destructive internal quality evaluation of durian and mangosteen fruits (Yantarasri et al., 1996). The resonance frequency used to detect translucent flesh disorder and yellow gummy latex (Rittisak et al., 2001).

The Physiological disorder for mangosteen is reliable with the water and hollow in the fruit as shown in table 1. In resonance frequency to vibration measurement, Garcio-Romus et al. (2005) had proposed the response of fruit to vibration depends on their mass and shape. Moreover, De Belie et al. (2000) used this methodology to measure pear firmness while the fruits were still on the tree. These authors impacted each fruit near the stem and read the frequency at the opposite side using an accelerometer. Moreover, the non-destructive vibration used to determine the maturity levels of durian (Kongrattanaprasert et al., 2001), the acoustic measurement and an intrusive method for determining tissue firmness were compared to assess the textural properties of kiwifruit (Muramatsu et al., 1997), firmness measurement of muskmelons by acoustic impulse transmission (Junichi et al., 2005), the vibration element analysis to determine firmness evaluation of melon (Nourain

Received 20 March 2012; Revised 04 April 2012; Accepted 06 May 2012; Published Online 28 November 2012

*Corresponding Author

Rittisak Jaritngam
Department of Electrical Engineering, Faculty of Engineer, Prince of Songkla University, Thailand

Email: rittisak.ja@gmail.com

et al., 2005). In addition, the Laser Doppler Vibrometer (LDV) technique was monitor ripening behavior temperature (Shoji et al., 2006), the acoustic impulses were detected internal hollow in watermelon (Diezma et al., 2002), the acoustic response evaluation of the storability of Piel de Sapo melons (Lleó et al., 2005).

In this paper, we propose a non-destructive technique by using VFSS measurement and analysis data by Fast Fourier Transform method (FFT) on frequency domain to detect translucent flesh disorder and yellow gummy latex in mangosteen.

Materials and Methods

Fruit sample and VFSS measurement

Mangosteens were purchased from a local fruit auction in Nakornsri Tummarat, Thailand. The sample was delivered to laboratory to record of signal data on the following by VFSS instrument. About 100 Thai mangosteens were used to study the optimum condition of VFSS measurement and 26 intact mangosteens were used for evaluation the accuracy of translucent flesh disorder detection. Four samples were appeared as translucent flesh disorder with yellow gummy latex while 20 samples were yellow gummy latex. The vibration signal was vibrated in medium sample at frequency of 25 to 40 Hz while amplitude input was 2.5 volt. After, the experiment was completed; the peel of each sample was slit with knife and takes a photograph by digital camera. The samples were cut to record the internal morphology as shown in Figure 1(a), 1(b), 1(c) and 1(d).

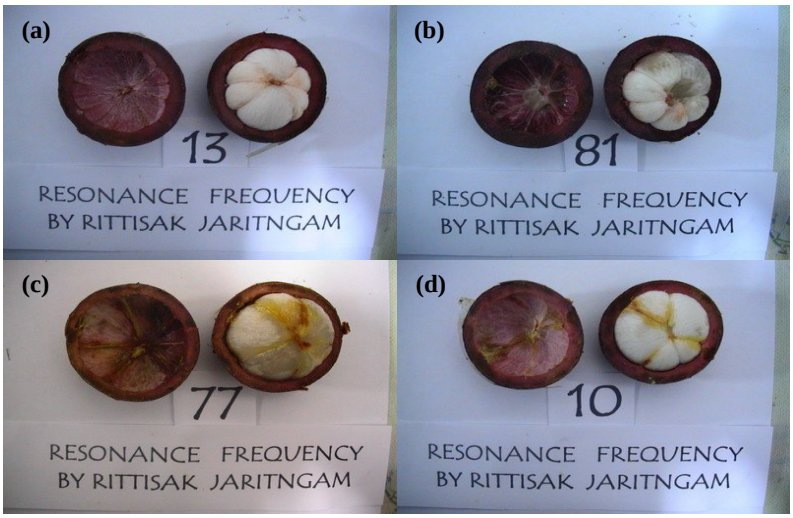
Instruments

The amplitude and frequency of vibration determine have many methods such as ultrasonic and accelerometer and Laser Doppler method can fix sensor with the fruit, there have response of vibration and accuracy. VFSS measurement has used in the vibration measurement of mangosteen.

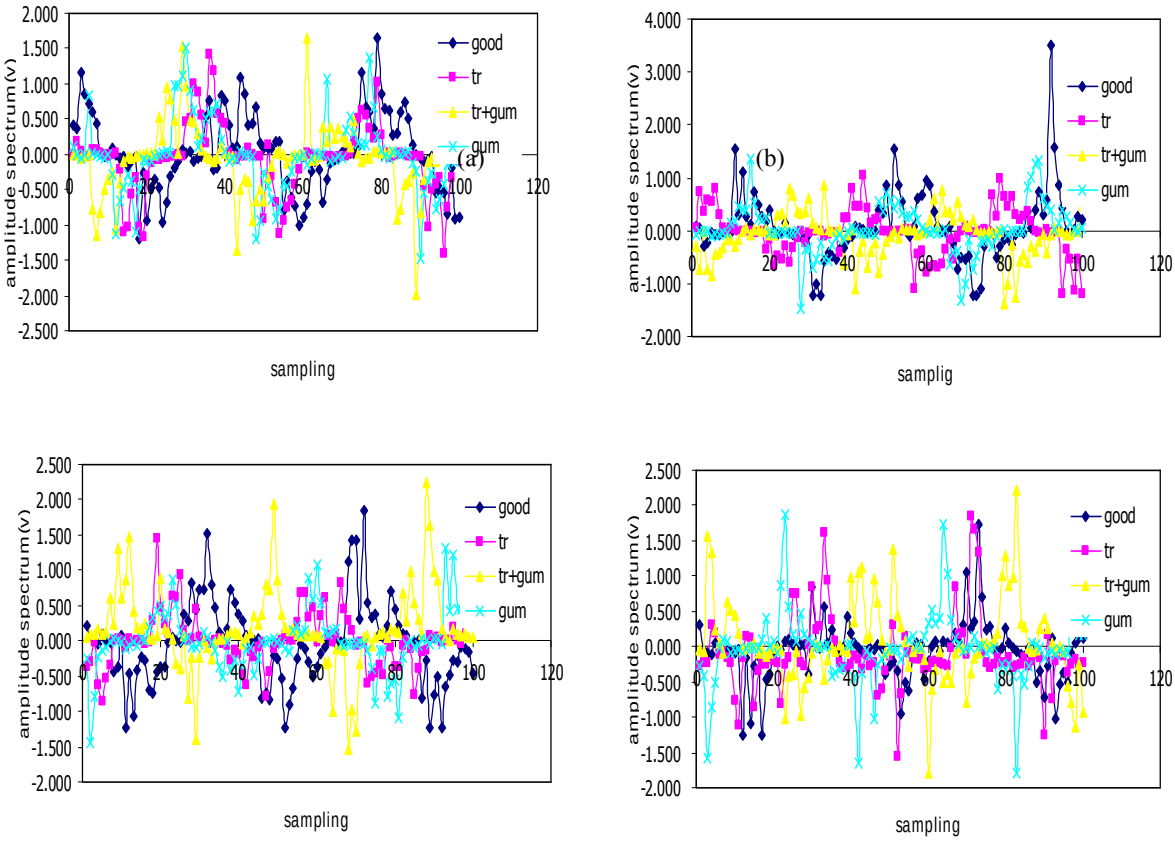
The experimental device consists of the following steps. The first, we put the mangosteen on the base of the prototype, based on vibration set which can vibrate with frequency 0 - 50 Hz. Second, the strain gauge sensor is adjusted by fix on the mangosteen. After that signals from this one sent to amplifier by instrument amplifier circuit (IC = INA 114) to A/D converter. Respectively, we can observe these signals on computer by labview programming and process them by matlab programming for classification of translucent flesh disorder and yellow gummy latex of mangosteen.

Table 1. The different properties of mangosteen (Voraphat, 1996).

No.	Property	Translucent	Yellow Gummy latex	Normal
1	Specific Gravity	Higher than 1	-	Lower than 1
2	Water Volume	Higher than normal	1.21%	
3	Air Volume	Lower than normal	15 time	
4	Density	Higher than normal	3 time	



(a) good sample (b) translucent sample
(c) Translucent and yellow gummy latex (d) yellow gummy latex
Figure. 1 The texture property of mangosteen photograph by digital camera.



(2a) time domain at 25 Hz vibration base, (2b) time domain at 30 Hz vibration base
(2c) time domain at 35 Hz vibration base, (2d) time domain at 40 Hz vibration base
Figure. 2 The differential real time signal of texture property of mangosteen.

Results and Discussion

Data analysis

The resonance frequency in this case, the characteristic of mechanical vibration most parts of the energy radiated from the surface propagates as a transversal wave in the medium when the frequency of low frequency vibration is less than about 1 kHz, the velocity of transversal wave can be expressed as equation (1-4) in medium related to characteristic of medium are given by

$$V_i = \left(\frac{2\left(\mu_1^2 + \omega_b^2 \mu_2^2\right)}{\rho\left(\mu_1 + \sqrt{\mu_1^2 + \omega_b^2 \mu_2^2}\right)} \right)^{1/2} \qquad (1)$$

Where V_i is velocity of vibration. ρ is the density of the medium. ω^b is the angular frequency of vibration. μ_1 and μ_2 are the coefficients of shear elasticity and shear viscosity. Respectively, Velocity of vibration related to frequency and wave propagation of vibration. So, property of shear elasticity can be found by velocity measurement of vibration and wave propagation at low frequency. In equation(1), if the shear elasticity is dominant compared with the shear viscosity so that $\mu_1 >> \omega^b$ then μ_2 is satisfied. The velocity is written as

$$V_i = \left(\mu_1 / \rho\right)^{1/2} \qquad (2)$$

The signal of output vibration fruits, when reference voltage output vibration fruits from the prototype for determine velocity of vibration which can be obtained from

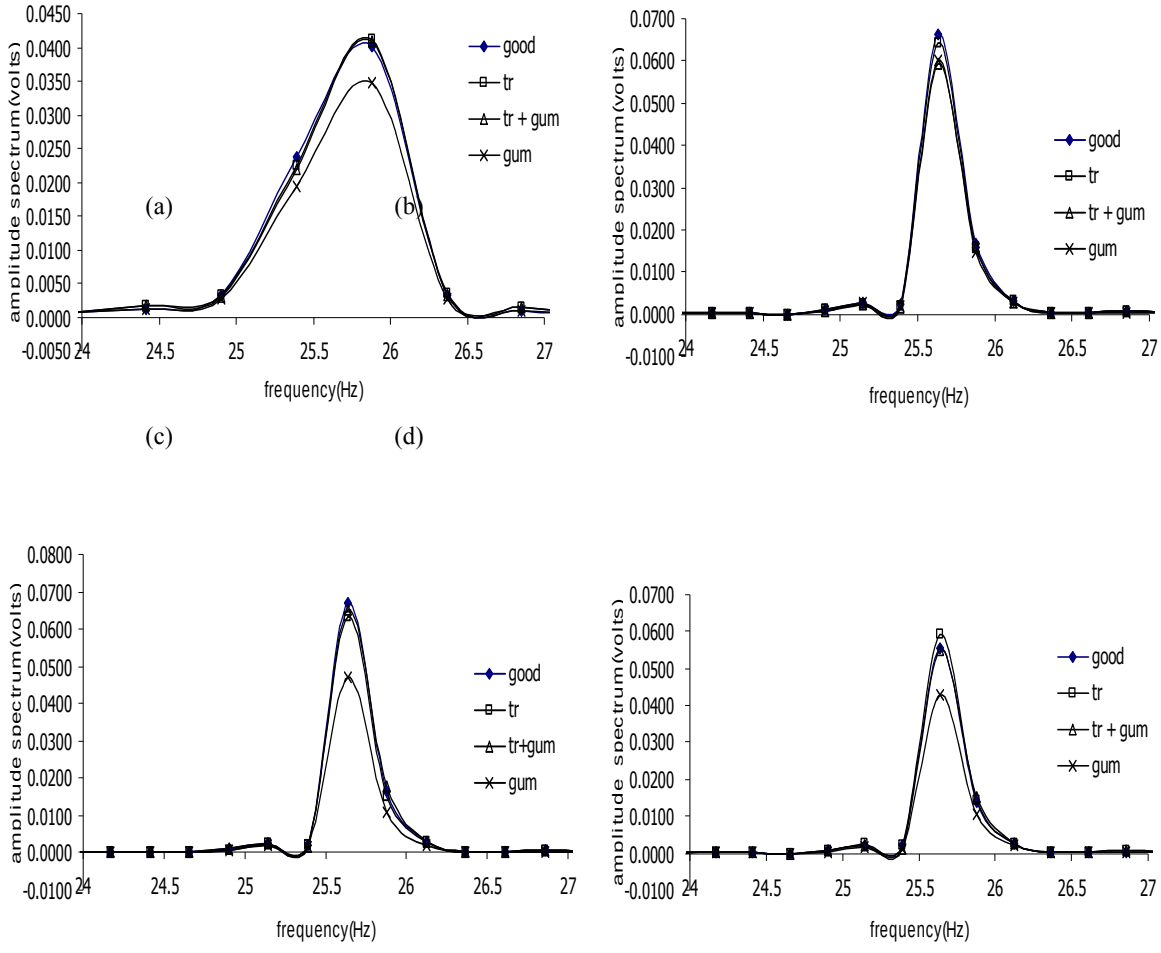
$$V_i = \frac{A}{\alpha T} \qquad (3)$$

$$A = \frac{\alpha V_i}{F} \qquad (4)$$

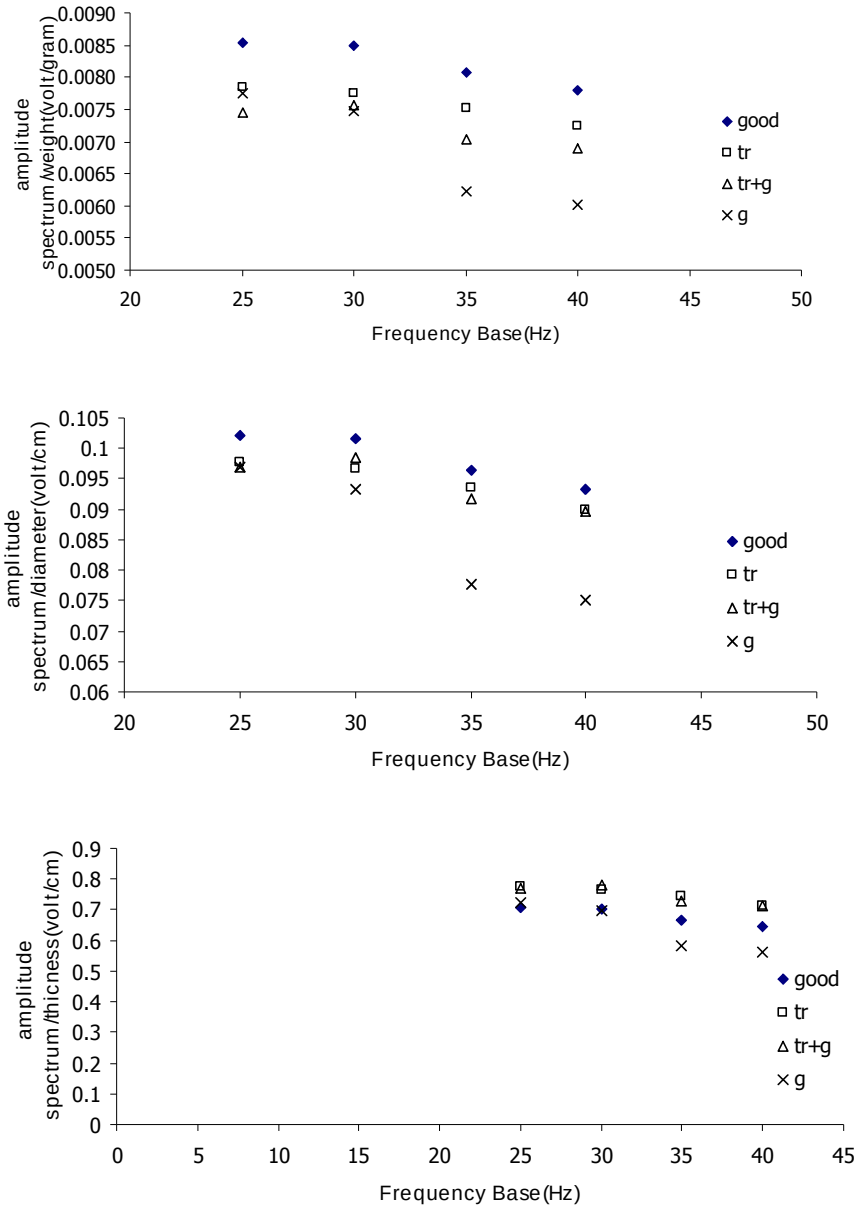
Where A is the voltage of output vibration. T is the time of output vibration. α is voltage of output vibration from the prototype. F is the resonance frequency vibration

The amplitude and frequency of vibration determining have many methods such as ultrasonic and accelerometer and LDV methods which can fix sensor on sample; there have response of vibration accuracy. In this paper, we used VFSS measurement that has been used in the vibration measuring of mangosteen. We choose the frequency vibration between 25 to 40 Hz and input signal is 2.5 Volt, for the mangosteen with different texture property when transfer input signal. Output signal has different amplitudes and frequency has related to internal air cavity, weight and diameter follow to texture property of mangosteen. In Figure 2(a-d), the good mangosteen has patterned signal difference with unusual mangosteen, translucent flesh order and yellow gummy latex.

A Fast Fourier Transform (FFT) is converted from the time signal into a frequency spectrum with frequency 0 to 500 Hz. The resonance frequency, there is usually a high peak, while the spectrum with good mangosteen shown usually one high peak at 26 Hz as we can observe from Figure 3(a-d). From the experiment result, weight and diameter have related with amplitude spectrum. Ratio of amplitude spectrum per weight in every frequency base is the best compared with the other as we can observe from Figure 4(a), there are obtains the ratio is higher than 0.008530 volt/g. There are higher than secondary base vibration about 0.000050 volt/g, the ratio of amplitude spectrum with diameter are the secondary. The lastly, amplitude spectrum per thickness peel are the poor shown in the Figures 4(b) and 4(c). However, this measurement can detect the yellow gummy latex in mangosteen at the 35 and 40 Hz, the amplitude is lowest compared with the other frequency.



(3a) frequency at 25 Hz vibration base, (3b) frequency at 30 Hz vibration base
(3c) frequency at 35 Hz vibration base, (3d) frequency at 40 Hz vibration base
Figure. 3 The typical spectrums for texture property.



(4a) ratio of amplitude spectrum/weight, (4b) ratio of amplitude spectrum/diameter
(4c) ratio of amplitude spectrum/thickness peel.
Figure. 4 The frequency are the best by VFSS measurement comparison
with the other vibration.

Table 2. Mean amplitude spectrum of the texture property in mangosteen.

	Mean amplitude spectrum(Volt)			
Frequency(Hz)	Good	Translucent	Translucent + Yellow gummy latex	Yellow gummy latex
Amplitude				
25	0.519877	0.502694	0.511703	0.494359
30	0.517261	0.496899	0.519601	0.476186
35	0.491520	0.481140	0.483758	0.396590
40	0.475493	0.463501	0.473570	0.382587

Table 3. Mean amplitude spectrum/weight of the texture property in mangosteen.

	Mean amplitude spectrum/weight (Volt/g)			
Frequency(Hz)	Good	Translucent	Translucent + Yellow gummy latex	Yellow gummy latex
Amplitude/weight				
25	0.008530	0.007853	0.007448	0.007761
30	0.008487	0.007762	0.007563	0.007475
35	0.008065	0.007516	0.007042	0.006226
40	0.007802	0.007240	0.006893	0.006006

Table 4. Mean amplitude spectrum/diameter of the texture property in mangosteen.

	Mean amplitude spectrum/diameter (Volt/cm)			
Frequency(Hz)	Good	Translucent	Translucent + Yellow gummy latex	Yellow gummy latex
Amplitude/diameter				
25	0.102097	0.097686	0.097005	0.096933
30	0.101583	0.096557	0.098503	0.093370
35	0.096528	0.093495	0.091708	0.077763
40	0.093380	0.090000	0.089776	0.075017

Table 5. Mean amplitude spectrum/thickness of the texture property in mangosteen.

	Mean amplitude spectrum/thickness (Volt/cm)			
Frequency(Hz)	Good	Translucent	Translucent + Yellow gummy latex	Yellow gummy latex
Amplitude/thickness				
25	0.705875	0.775671	0.769479	0.725665
30	0.702323	0.766728	0.781356	0.698989
35	0.667372	0.742412	0.727456	0.582151
40	0.645612	0.715195	0.712137	0.561596

From the experiment, the Table 2 presents the frequency based vibration within 25 and 30 Hz comparison with the amplitude spectrum. There are the best values about 0.476186 – 0.519877 volt and are higher than the frequency vibration based at 35 and 40 Hz which are valuable about 0.382587 – 0.491520 volt. Moreover, the amplitude spectrums of the good sample are higher than the other sample fruits. Hence, the yellow gummy latex sample can be detected at the frequency based vibration which has the value lowest than the other sample.

In Table 3, it is the value of amplitude spectrum per weight. From the experimental results, there are the same trend with the experiment from Table 2, the ratio of amplitude spectrum per weight in normal sample are higher than the other fruits are about 0.007802 – 0.00853 volt/g on the frequency based vibration. In addition, the frequency based vibration at the 25 Hz has the highest ratio in the 40 Hz frequency based vibration, the ratio has the poor. Moreover, the translucent flesh disorder and translucent flesh disorder combine with the yellow gummy latex are similar to 0.007240 – 0.007853 volt/g and 0.006893 – 0.007448 volt/g. In the part, the mangosteen has yellow gummy latex symptoms only will be the ratio valuable was poor in the same vibration. From the experiment result, the trend of mangosteen can detect in the all frequency based vibration and sorts out mangosteen have yellow gummy latex in 35 and 40 Hz frequency based vibration.

Table 4, represents the value of amplitude spectrum per diameter. From the experimental results, there are the same trend with the experiment from Table 2 and 3, the ratio of amplitude spectrum per diameter in normal sample are higher than the other (about 0.093380 – 0.102097 volt/cm) on the frequency based vibration. In addition, the frequency based vibration at the 25 Hz has the highest and in the 40 Hz frequency based vibration, the ratio has the poor. Moreover, in the value of mangosteen are the translucent flesh disorder and translucent flesh disorder combine with yellow gummy latex are similar to 0.090000 – 0.097686 volt/cm and 0.089776 – 0.097005 volt/cm. Respectively, in the part, the ratio valuable of mangosteen having yellow gummy latex symptoms only was poor in the same vibration. From the experimental results, the trend of mangosteen can detect in the all frequency based vibration and sorts out mangosteen

group have yellow gummy latex in 35 and 40 Hz frequency based vibration.

Table 5 shows the value of amplitude spectrum per thickness peel. From the experiment result, the good mangosteen has ratio value of translucent flesh disorder and translucent flesh disorder combination with the yellow gummy latex between 0.645612 – 0.705875 volt/cm at the frequency based on 25, 30, 35 and 40 Hz. Moreover, the frequency based vibration is 25 Hz has highest and has lowest at the frequency base vibration about 40 Hz. However, the translucent flesh disorder and translucent flesh disorder combination with the yellow gummy will be the ratio valuable lowest which about 0.561596 – 0.725665 volt/cm in the same frequency based vibration.

Conclusion

The VFSS of mangosteen fruit was sufficient to use for translucent flesh disorder and yellow gummy latex detection in mangosteen. The texture property can be classified into 4 groups (good, translucent flesh disorder, translucent flesh disorder combination with yellow gummy latex and yellow gummy latex) vibration based on 25 Hz, where the best amplitude and ratio of amplitude with diameter are the same. Frequency based vibration at 35 and 40 Hz can be classify as yellow gummy latex, the amplitude is lowest than the other frequency based on vibration. However, the accuracy can be increased by rejection of other effects such as hardening pericap, fruit size and skin color before evaluation.

Acknowledgement

The authors acknowledge the support by the graduation scholarship, Prince of Songkla University (PSU) and would like to thank Dr. Kittinan Maliwan, Lecturer in Mechanical Engineering, PSU for help technical in providing vibration set as well as Electrical Engineering (EE) department for their Kind technical help and use of laboratory.

References

De Belie, N., S. Schotte Lammertyn, J. Nicolai, B. J. De Baerdemaeker. 2000. Firmness changes of pear fruit before and after harvest with acoustic impulse response technique. J. Agric. Eng. Res. 77(2):183-91.

Diezma, B., M. Ruiz-Altisent and B. Orihuel. 2002. Acoustic impulse response for detecting hollow heart in seedless watermelon. Acta Hort. 599:249-256.

Garcia-Ramos, F. J. C. Valero, I. Homer, J. Ortiz-Cañavate and M. Ruiz-Altisent. 2005. Non-destructive fruit firmness sensors: a review. Spanish J. Agric. Res. 3(1):61-73.

Junichi, S., M. I. Al-Haq and M. Tsuta. 2005. Application of Portable Acoustic Firmness Tester for Fruits. The fifth International Conference on Information and Technology for Sustainable Fruit and Vegetable Production, Montpellier, France. p.439-443.

Kongrattanaprasert, S., S. Arunrungrusmi, B. Pungsiri, K. Chamnongthai and M. Okuda. 2001. Nondestructive Maturity Determination of Durian by Force Vibration. The IEEE International Symposium on Circuits and System (ISCAS), Sydney, Australia. p.441-444.

Lleó, L., P. Barreiro, A. Fernández, M. Bringas ,B. Diezma and M. Ruiz-Altisent. 2005. Evaluation of the storability of *Piel de Sapo* melons with sensor fusion. The fifth International Conference on Information and Technology for Sustainable Fruit and Vegetable Production, Montpellier, France. p.523-531.

Migdalia, A., A. Bello, L. Rastrelli, M. Montelier, L. Delgado and C. Panfet. 2011. Antioxidant properties of pulp and peel of yellow mangosteen fruits. Emir. J. Food Agric. 23(6):517-524.

Muramatsu, N., N. Sakura, R. Yamamoto, D. J. Nevins, T. Takahara and T. Ogata. 1997. Comparison of non-destructive acoustic method with an intrusive method for firmness measurement of kiwifruit. Postharvest Biol. Technol. 12:221-228.

Nourain, J., Y. Yi-Bin, W. Jian-Ping, R. Xiu-Qin and Y. Chao-Gang. 2005. Firmness evaluation of melon using its vibration characteristic and finite element analysis. J. Zhejiang Univ. B. (6):483-490.

Rittisak, J., C. Limsakul, S. Sdoodee, S. Jaritngam and M. Mani. 2001. To detect gumming fruit of Mangosteen (*Garcinia mangostana* Linn.) by the autoregressive model analysis method. J. Agric. Sci. 32:1-4.

Shoji, T., N. Sakurai, J. Zebrowski, H. Murayamad, R. Yamamotoe and D. J. Nevins. 2006. Laser Doppler vibrometer analysis of changes in elastic properties of ripening 'La France' pears after postharvest storage. Postharvest Biol. Technol. 42:198–207.

Somchai, A., D. Khawaparisuth and K. Chamnongthai. 1999. Nondestructive 2D Cross-Sectional Visualization of A Mangosteen. The fifth International Symposium on Signal Processing and its Applications, Brisbane, Australia. p.443-445.

Sontisuk, T. 2007. Non-destructive prediction of translucent flesh disorder in intact mangosteen by short wavelength near infrared spectroscopy. Postharvest Biol. Technol. 43:202–206.

Tawatchai, T., N. Jittiwaranghl, P. Kumhoml and K. Chamnongthai. 2004. Non-Destructive Grading of Mangosteen by Using Microwave Moisture Sensing. International Symposium on Communications and Information Technologies, Sapporo, Japan. p.650-653.

Voraphat L. 1996. Effect of Water on Physiological Disorders of Mangosteen Fruit (*Garcinia Mangostana Linn*). Developmental Physiology, Master of Science (Agriculture) Department of Horticulture, Kasetsart University, Thailand.

Yantarasri, T., C. Sivasomboon, J. Uthaibutra and J. Sornsrivichai. 1996. X- ray and NMR for nondestructive internal quality evaluation of durian and mangosteen fruits. Acta Hort. 464:97-101.