NONDESTRUCTIVE MATURITY DETERMINATION OF DURIAN BY FORCE VIBRATION

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ABSTRACT

This paper proposes a method for determining maturity levels of durian by using nondestructive vibration. The vibration is transferred directly through durian at a region between prickles that located at the middle of durian. The measurement of frequency responds from vibration of durian is done by using laser doppler. The signal is processed for finding voltages, frequency, time interval and velocity of vibration. These data relate to % dry weight and elastic constant. For the experimental results, the maturity of durian can be classified into two groups, immature durian and mature durian, related to threshold value of velocity of vibration at 500 cm/sec. and elastic constant at 300 $(dyne/cm^2)^{1/2}$ and it can be classified with 95% of accuracy.

1. INTRODUCTION

The durian is one of the high economical fruits that Thailand has exported for several years. To guarantee the qualification of them is an important process. There are many methods to determine their qualities, both destructive and non-destructive. The non-destructive approaches are preferred. Unfortunately, the autonomous quality control in non-destructive way is very difficult, since there are varied factors needed to consider, for example, the thickness of its peel, non-uniformity, roughness of its prickle skin, and so on.

In quality determination of fruits, Ketsa and Daengkanit [1] presented the relation between the maturity of durians and the internal chemical organization. This approach is a destructive method. [2] and [3], the authors presented quality measurement of fruits by considering their external characteristics such as color, size, and shape. Slaughter [4] utilized the near infrared to determine the chemical structure inside tomatos and peachs. However, the infrared is not appropriate for the pericarp fruits such as durians. Schatzki et. al [5] and Clark et.al[6] proposed the film x-ray analysis and MRI analysis, respectively. However, both methods need the expert system. For [7]-[10], these researchers used the ultrasonic for the maturity determination of avocado and watermelon. By using ultrasonic , the transducers need to touch the object not less than 96% of its region. Therefore this method is not applied for durian. [11]-[12] presented maturity determination of durian by knocking, and then took its signals to analyze for determination of frequency response. But the results showed low accuracy because of non-linearization of knocking.

Therefore, this paper presents the nondestructive maturity determination of durian by using the linear vibration for study in the relation of voltages, frequency response, and velocity of vibration between input and ouput vibration. Our proposed method uses transfer of vibration directly through durian at a region between prickles located at the middle of durian. Because middle region of durian have the least thickness of skin, and the space between prickles and the internal air cavity are very high. Laser doppler is used to measure output vibration, and then its signal is classified by determination of relation of % dry-weight. Peerapong [12] presented method for determining %dry-weight related to immature durian and mature durian at threshold value 30% dry-weight. By the pulp of durian 50 g. is fumed at 65°C for 48 hours, then % dry-weight can be obtained from:

$$\%dryweight = \frac{W_{behind}}{W_{before}} * 100 \qquad (1)$$

Where w_{behind} is weight behind fuming and W_{before} is weight before fuming

2. SYSTEM

The prototype system architecture for determination maturity of durian is shown in Fig. 1. After durian is carried by clamp and sets on the soft rubber of the prototype. First, the vibration set (1) which can vibrate with frequency 0-300 Hz is adjusted by setting the T-needle in perpendicular location between the prickles

located at the middle of durian. Second, at the opposite side of first setting, the laser doppler set (2) is adjusted by setting the focus in coincident location between the prickles too. The focus is far from target 2.5 cm. The incident angle is equal to the reflect angle. After that the signals from this two sets are sent to amplifier (3) and (4), respectively. We can observe these signals on a monitor of oscilloscope (5) and process them by computer (6) for automatic classification of maturity of durian.

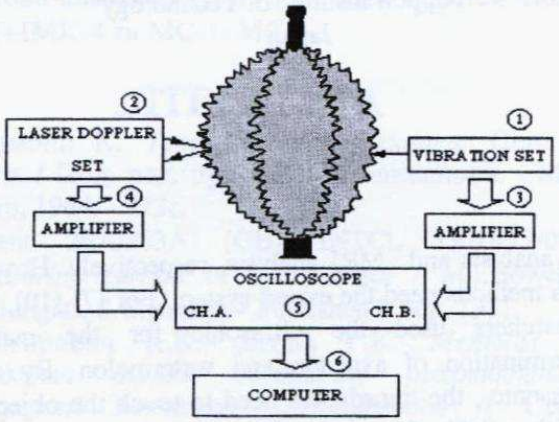

Fig. 1. System Architecture for maturity determination of durian

3. MATURITY DETERMINATION

3.1 Input and Output Vibration

The characteristic of mechanical vibration in medium with mass , elastic and viscostic components, H.L.Oestreicher in [13] show that 1) 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. and 2) the velocity of transversal wave in medium related to characteristic of medium are given by

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

The frequency of input vibration selected at linear output signal and amplitude response is the highest. From the experiments at frequency 30 Hz. is the best. Because can to observed difference of amplitude and frequency of output vibration is the highest. shown in Figure 3. The ripe durian have velocity of vibration less than the young durian where V_t is velocity of vibration , ρ is the density of the medium , ω_b is the angular frequency of vibration ,and 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 (1) if the shear elasticity is dominant compared with the shear viscosity so that $\mu_1 >> \omega_b \mu_2$ is satisfied , the velocity is written as

$$V_t = (\mu_1 / \rho)^{1/2} \quad (3)$$

The amplitude and frequency of vibration determining have many methods such as ultrasonic and accelerometer. But laser doppler method can fix location of target to higher than accuracy and response of vibration. So, the laser doppler method is used in the vibration measuring of durian.

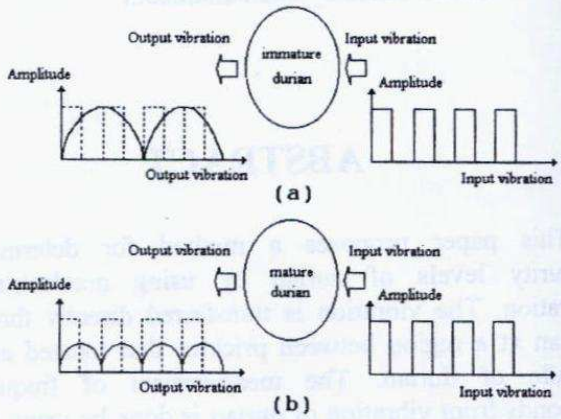

Fig. 2 Relationship between signal of input and output vibration in (a) immature durian (b) mature durian

For the durian with difference maturity , when transfer input vibration at linear amplitude and frequency. The signal of output vibration will have difference amplitude and frequency related to internal air cavity , mass and firmness follow to maturity level of durian. In Fig.2(a) the immature durian have amplitude and frequency of the signal output vibration higher than the mature durian, shown in Figure 2(b). Because the mature durian have more internal air cavity and elasticity than the immature durian , but have less density and firmness. So, the signal of output vibration have less amplitude and frequency than the immature durian.

3.2 Signal

The frequency of input vibration selected at linear output signal and highest amplitude response of the signal of the output vibration. From the result in Fig. 3. the error bar shows the deviation of the values measured at ten different points. We can see at the frequency 30 Hz. is the best. Because it can observe difference of highest velocity of vibration. The mature durian have less the velocity of vibration than the immature durian. And we can not observe the difference of the velocity of vibration when frequency have more than 45 Hz.

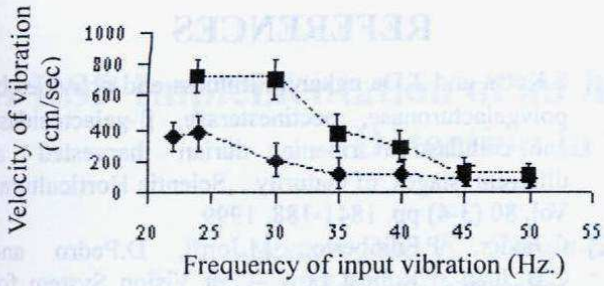

Fig. 3 Relationship between frequency of vibration and velocity of output vibration in
◆ mature durian , ■ immature durian

4. EXPERIMENTAL RESULTS

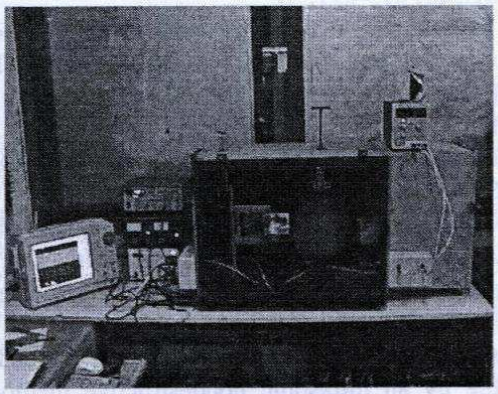

Fig. 4 The prototype system for determination maturity of durian by vibration

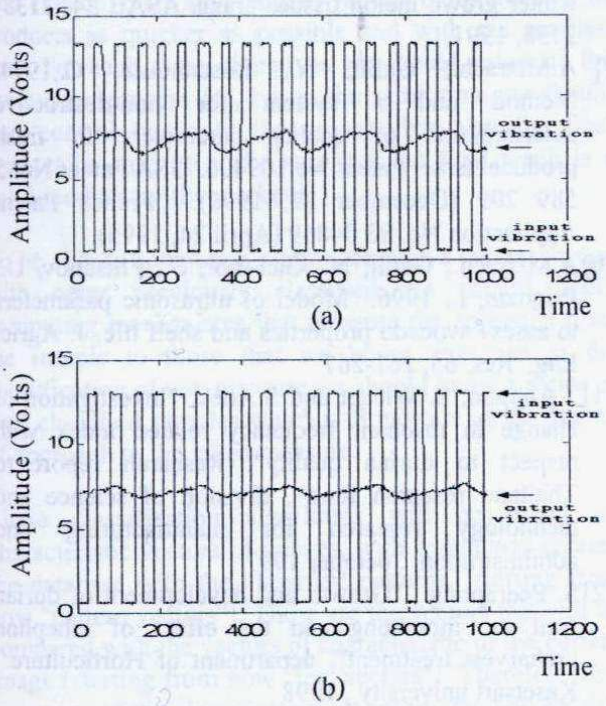

Fig. 5 Relationship between input and output vibration in (a) mature durian
(b) immature durian

The prototype system architecture for determination *maturity of durian by vibration is shown in Fig. 4. The* experimental results, 30 Hz input square wave and output sine wave, are shown in Fig. 5. We can observe that signals of output vibration in the different maturity of durian have different amplitudes, frequency, and velocity of vibration. Fig. 5(a) is signal of mature durian which has less amplitude and frequency than signal of immature durian in Fig. 5(b).

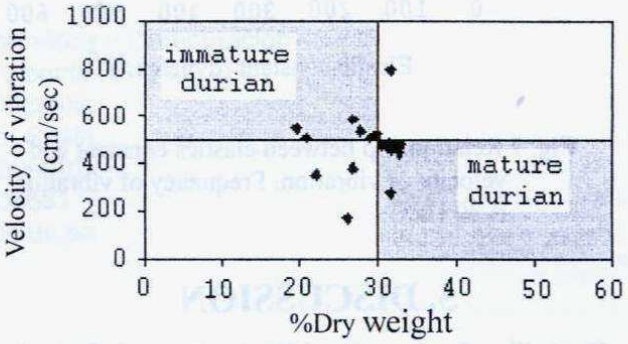

Fig. 6 Relationship between velocity of vibration and %dry weight in immature durian and mature durian

In experiment uses monthong durian 20 fruits, 3/2 shape, special class, weight 4-4.5 kg. The signal of output vibration is processed by computer program, when reference amplitude of signal of output vibration from the prototype is 4.6 V/cm. for determine amplitude, frequency, time interval , distance of vibration and velocity of vibration. Results of velocity of vibration are compared to %dry-weight for relation determination between velocity of vibration and % dry-weight shown in Fig. 6. This relation is compared to the maturity determination by using an Effegi firmness tester with a 5 mm. plunger tip which was inserted to a depth of 0.5 cm. and the force neccesary to do this recorded in newtons for threshold value determination of velocity of vibration. We can set threshold lines at velocity of vibration is 500 cm/sec and 30% dry-weight for results classification of the experiment is best three groups , immature durian and mature durian and error. And it can be classified with 80% of accuracy

Durian having different maturity will also have different characteristics of structure, hard or soft. Due to incresing of quantity of water depends on maturity of durian, so in (3) density and elastic constant of durian will be important signs to classify the maturity. From Fig. 7. the threshold line for classification of three results groups, as immature durian, mature durian, and two error groups, is obtained. The threshold line of elastic constant and velocity of vibration are 300 $(dyne/cm)^{1/2}$ and 500 cm/sec. Respectively. The efficiency of proposed classification method is 95%.

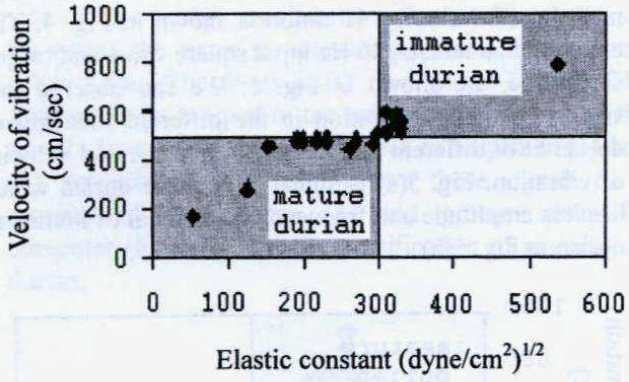

Fig. 7 Relationship between elastics constant and velocity of vibration. Frequency of vibration is 30 Hz.

5. DISCUSSION

From Fig. 6., the error 20% is occurred from the reason that the tip of durian has broken. This makes the experimental results are in a region of high %dry-weight and high velocity of vibration. Not only that, some durian having narrow region between prickles and uncomplete petals makes the results are in the region of high %dry-weight and low velocity of vibration.

To reduce this error, therefore, the experiment of durian having narrow region between prickles is done by cutting their prickles to make sufficient region for measurement process with laser doppler. And uncomplete petal durian will be vibrated at a region as near the middle of petal as we can. For the case of durian with broken tips, we must hold the below of tip of durian with the prototype strongly. The end of T-needle must touch tightly to a region between prickles located at the middle of petal, which has the largest region. The below of durian must touch to the rubber base at least but it must touch enough to control rotating of durian.

From Fig. 7., the error comes from external light sources which make the signals are error. The cover of the prototype is used to solve this problem. The receiver set must be set in the line of the vibration set.

6. CONCLUSIONS

Durian is one of the high economical fruits which requires nondestructive guarantee of their quality. This paper presented nondestructive maturity determination of durian by vibration at low frequency and measure output vibration by laser doppler. The signal of output vibration are taken for automatic maturity classification of relationship between velocity of vibration and elastic constant. And it can be classified into two groups, immature durian and mature durian, with 95% of accuracy rate.

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