The development of a device and method to evaluate the precise harvesting time of tropical agricultural commodities based on acoustic properties

W A Pamungkas¹ and N Bintoro¹
¹Universitas Gadjah Mada, Yogyakarta, Indonesia

E-mail: nursigit@ugm.ac.id

Abstract. Non-climacteric agricultural products are the commodity that cannot mature after being harvested so it is necessary to determine the right harvesting time to obtain the best quality. Generally, farmer will determinate the maturity of those commodity using a sound response from fruit tapping in addition to seeing the visual appearance. However, this is subjective so it is necessary to develop a more reliable and practical method. In this study a knocker maturity detection tool had been build and was used to evaluate three types of non-climacteric commodity, namely seedless watermelon aged 51, 54, 57, 60 DAP, eggplants aged 42, 44, 46, 48 DAP and cucumbers aged 27, 28, 29, 30 DAP. The knocking sound was recorded using Audacity 2.3.1 and then analyzed the frequency and magnitude parameters using Matlab R2014b. The results obtained were related to the physicochemical parameters of the samples. The results showed that the constructed knocker was able to distinguish the level of fruit maturity. In addition, it was also known that the right time for harvesting watermelon was 89 Hz or 50 dB, eggplant 157 Hz or 54 dB, and cucumber was 218 Hz or 52 dB.

1. Introduction
As a tropical country, Indonesia has a variety of fruit and vegetable commodities. In the post-harvest point of view, agricultural commodities are divided into climacteric and non-climacteric products. Climacteric products are characterized by a high increase and sudden respiration bursts that accompany or precede maturation, through CO₂ and ethylene [1]. Whereas non-climacteric fruits are fruits that do not show an increase in CO₂ and ethylene production after being harvested. If a non-climacteric commodities are harvested improper time, before or after ripe, it will produce fruits of low quality. Therefore, to obtain good quality of the the commodity, harvesting on appropriate physiological maturity is necessary. As an indication of harvesting time that is commonly used is visual appearance or color [2]. Beside its visual appearance, products maturity are also determined by tapping the products, but this method is subjective because the hearing of each person in recognizing sounds produced from the knocking of commodity is certainly different. Sri et al. [3] conducted a research for measuring maturity level of red watermelons by analyzing the spectrum of sound produced for ripe, half-ripe and unripe watermelons. The results showed that the more mature the flesh of the fruit was, the more the frequency would decrease. Research by Kusumaliski [4] showed that there were no differences in melon fruit maturity parameters studied in the form of frequency, hardness, and total dissolved solids. Agusta [5] also conducted research on the detection of melon golden Apollo maturity using sound signal parameters in fruits 46, 53, 60, and 67 Days After Planting (DAP). In his study, it was known that the
frequency produced by tapping melons tended to decrease with the increasing the age of the fruit. The research was carried out using an acrylic pendulum as a knocker tied to an iron frame so that the tool would not practical to be used in the field. The purpose of this study was to develop a device and method to determine the right time to harvest tropical fruit based on the nature of acoustic reflection (sound) by using a knocker that was practical to be used in the field.

2. Material dan Methods

2.1. Material
In this study, three types of non-climacteric commodities were used, namely seedless watermelon, eggplant (purple color), and cucumber with different fruit ages. Seedless red watermelons used were 51, 54, 57 and 60 DAP. Whereas, the eggplants used were at 42, 44, 46, 48 DAP, while cucumber used were 27, 28, 29, and 30 DAP. All of these commodities were obtained directly from the farmer at around Yogyakarta City of Indonesia.

![Figure 1. Seedless watermelon sample aged of 51, 54, 57, 60 DAP](image)

Whereas, the eggplants used were at 42, 44, 46, 48 DAP, while cucumber used were 27, 28, 29, and 30 DAP. All of these commodities were obtained directly from the farmer at around Yogyakarta City of Indonesia.

![Figure 2. Eggplant sample aged of 42, 44, 46, 48 DAP](image)

![Figure 3. Cucumber sample aged of 27, 28, 29, 30 DAP](image)

2.2. Tools
The equipment used in this study included self constructed knocker and other equipment were used to support data collection during research.

Some text.

2.2.1. Knocker. Knocking device consisted of 2 PVC pipes, 3.5 hands-free clip on microphone, pendulum with the tip of a rubber ball weighing 25.58 grams, a 10 cm long spring and a trigger. The first pipe with a diameter of 2.54 cm with a length of 21.5 cm was used as a tube to put the spring and pendulum which had been fitted with a trigger. While the second pipe which is 2 cm in diameter and 11 cm long was used to keep pendulum straight after the trigger was released. A spacer between the fruit and knocker was added to the top of the second pipe. The construction of knockers is shown in Figure 4.
Figure 4. Knocker

2.2.2. Supporting equipment. Supporting equipment in this study consisted of digital scales, refractometers (Atago), 500 ml measuring cups, electric oven (Memert), saucers, knives, cameras, and computer with an Intel Core i3 2.3 GHz processor.

2.3. Methodology
This research was conducted at the Laboratory of Agricultural Building and Environmental Engineering, Gadjah Mada University, Yogyakarta. The research procedures carried out was as follows.

2.3.1. Measurement of unit weight. The first step in this study was to measure the weight and volume of the samples to calculate unit weight. Samples weight were measured by digital scales (0.01 g precision) while fruit volume was determined using immersion method. Unit weight of the sample was calculated using following equation:

\[
\text{Unit weight} = \frac{W_a}{(W_a - W_w) \text{ both} - (W_a - W_w) \text{sinker}}
\]  (1)

Where:
- \(W_a\) = weight in the air (kg)
- \(W_w\) = weight in the water (kg)

2.3.2. Testing of Acoustic Properties. To obtain acoustic properties for each sample or commodity at each different harvest age, tapping was carried out on the fruit surface using the constructed knocker device. The knocker is positioned horizontally and within around 2 cm of the sample surface to be tested. The measured sound were recorded using Audacity 2.3.1 software with a project rate of 44100 Hz with the duration of 1 second, which was then stored in file (format. Wav). Data were then processed using Matlab R2014b to find the dominant frequency and sound level at each age of the samples using source code by Zhivomirov [6].

Figure 5. Scheme of testing acoustic properties

2.3.3. Brix
Percentage of brix is a value that states the level of sweetness of the commodity. For the fruit, commonly the more ripe of the fruit the more sweeter it will be [7]. The higher the Brix value indicates the higher the sugar content and the taste is sweeter [8]. Brix values are measured using the refractometer (ATAGO). First, the fruit was crushed and the juice was then placed on the refractometer to be measured. The results of the Brix reading by the refractometer are expressed in percent (%).
2.3.4. **Water Content (AOAC 2000)**. Measurement of water content of the sample was carried out using a gravimetric method. A piece of sample was weighed first (A) and then that sample was weighed together with a cup and dried at 105 °C for 24 hours to obtain the dry weight of the material (B). Calculation of water content is carried out using Equation 2.

\[
\text{Water Content (\% w.b)} = \frac{A - B}{A} \times 100\%
\]  

(2)

2.4. **Data analysis.**

Data from the acoustic properties of each commodity that has been previously stored were analyzed by using the Matlab R2014b software to find frequency and sound level parameters. Those parameters were then related to the results of the physicochemical parameter. After that, the exact harvest time of each commodity under study could be determined.

3. **Results and Discussion**

3.1. **Unit weight (\( \gamma \))**

Based on the measurements results it could be found that for all of tested samples (watermelon, eggplant, and cucumber), the values of unit weight decreased with increasing the age of those samples. This might occur due to the formation of cavities in the sample material or it might because the texture of sample flesh becomes softer along with the increase in the age of the sample. This might cause that even though the shape of the fruit becomes larger than before but the weight of the samples decreased (Fig 6 – 8).

![Figure 6. Unit Weight of Watermelon](image1)

![Figure 7. Unit Weight of Eggplant](image2)

![Figure 8. Unit Weight of Cucumber](image3)
3.2. Acoustic properties

3.2.1. Frequency. Frequency of the studied samples are depicted in Figures 9-11. Frequency values of watermelon tended to decrease along with the increase of sample age, and this result was same as one found by Sri et al. [3].

However, for eggplant and cucumber were found that generated frequency tended to increase with the increasing samples age. This found indicated that each of samples had different sound character in view of its frequency, it was suggested to have the correlation with their unit density values, and it had to be investigated more rigorously to find precise answer.

3.2.2. Sound level (M). Figure 12 to 14 show the values of sound level of the three tested samples. It can be seen that for watermelon the sound level experienced an upward trend along with the increase of sample age. While for eggplant and cucumber were decreased with the increasing samples age. These conditions the same as one found for the values of frequency above. It was suggested that in the watermelon the flesh firmness might decrease lager than in the eggplant and cucumber, and result in higher value of sound level. However, it could be observed that for both the eggplant and cucumber, the rate of sound level change initially large and gradually decreased or almost created a constant values.
3.3. Percentage of brix
The results of the measurement of sugar levels in watermelon are shown in Figure 15. Based on these images it could be seen that in general, there was an increase of brix values along with the increased of fruit age, and the highest value was obtained for 60 DAP. The increase of brix value in watermelon was found to be higher (11.23%) than those for eggplant (1.04%) and cucumber (4.56%), as watermelon was fruit while eggplant and cucumber were vegetable. Figure 16 shows brix value of the eggplant, a different brix phenomenon change was observed, where the maximum values occurred at 44 – 46 DAP. Brix values of the eggplant in this study ranged from 0.9 to 1.16%. The Brix value of cucumber is shown in Figure 17 where the brix value ranges from 3.13% to 4.56% and there was an upward trend of the brix along with the increase in sample age. This one showed the same phenomenon as for watermelon.

3.4. Water content
Water content of the samples studied in this research are shown in Figure 18 to 20. In both the three samples, the change of water content seemed to follow a curvilinear pattern. In the watermelon, initially water content tended to increase then decreased at 60 DAP, with the maximum value occurred at 57 DAP. In eggplant, water content continuously decreased with the age. Initially, water content decreasing rate was large and gradually fall off with the age of sample. Figure 20 shows the change of water content...
for cucumber. For this sample it could be observed that the trend was almost constant along with sample age. It seemed to have no significant change from 27 to 30 DAP as the range was quite short.

Figure 18. Water Content of Watermelon

Figure 19. Water Content of Eggplant

Figure 20. Water Content Cucumber

3.5. Harvesting Time Determination
Based on the measurements results, it could be seen that for watermelon, knocking sound frequency increased with the increase of sugar content. The highest brix (sugar content) occurred at 60 DAP, as this sample was a fruit, for that reason it was suggested that the most proper harvesting time for this sample was at 60 DAP or by using the constructed apparatus was at around 89 Hz and sound level was around 50 dB. For eggplant, if it was correlated between frequency and brix content, it was found that the most appropriate harvesting time was around 46 DAP (highest brix and unit weight and constant water content) or at around 157 Hz and around 54 dB. While for cucumbers the best harvesting time to be 29 DAP or around 218 Hz or around 52 dB, as at that time brix value and water content were almost maximum and unit weight was the largest one.

4. Conclusions
The acoustic properties of sound obtained from knocking test indicated that the constructed knocker was able to distinguish different frequency and sound level from different fruit maturities. For the three types of commodities examined in this study, watermelon was best be harvested at around 89 Hz or 50 dB that was at 60 DAP. While eggplant was at around 157 Hz or 52 dB that was at 46 DAP and finally for cucumber was at around 218 Hz or 52 dB that was at 29 DAP.

References
[1] Widodo S E, Zulferiyenni, and Kusuma D W 2013 Pengaruh Penambahan Benziladenin Pada Pelapis Kitosan Terhadap Mutu dan Masa Simpan Buah Jambu Biji ‘Crystal’ Agrotek Tropika. 1 (1) 55 – 60
[2] Fransiska, Supratomo, and Faridah 2017 Sebaran Suhu Buah Terung Belanda (Chyphomandra betacea) pada Berbagai Tingkat Kematangan Selama Proses Pendinginan (Hydrocooling) J. AgriTechno 10 (2) 123-134

[3] Sri W S, Surtono, Arif, Hafidz, and Fahmi M 2007 Analisis spektrum frekuensi bunyi dari beragam daging buah dengan berbagai tingkat kematangan berbasis komputer J FMIPA Unila. 13 (3) 261-266

[4] Kusumaliski N 2015 Pengembangan metode deteksi kematangan melon (Cucumis melo L.) dengan Respon Impuls Akustik (Bogor Agricultural University)

[5] Agusta W 2016 Deteksi kematangan buah melon Golden Apollo Menggunakan Parameter Sinyal suara (Bogor Agricultural University)

[6] Zhiyomiroy H 2014 Sound Analysis with MATLAB Implementation

[7] Angelia I O 2017 pH Content, Total Acidified Acid, Dissolved Solids and Vitamin C in Some Horticultural Commodities J Agritech Science. 1 (2) 68-74

[8] Suhendy D 2010 The Non-destructive Method to Determine Soluble Solids Content in BW Orange Fruit Using Near Infrared Spectroscopy AGRITECH 30 (1) 32-37