Evaluation of watermelon ripeness using self-developed ripening detector

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Abstract. Currently the evaluation of watermelon ripeness is performed manually by tapping the surface of fruit or by visually evaluating from its appearance. However, these evaluations are subjective and inconsistent, therefore, it is necessary to develop and use a reliable instrument for this purpose. This study aimed to develop a ripening detector apparatus based on acoustic impulse response and to be used for evaluating the ripeness stage of watermelon. In this study, five different maturity ages of watermelon, namely 39, 43, 47, 51, and 55 days after planting were evaluated. The acoustic responses were recorded using Audacity 2.3.1. The dominant frequencies and magnitude were then analyzed using Matlab R2014b. The acoustic parameters were related to fruit weight and soluble solid contents to distinguish the different maturity stages. The results showed that the dominant frequencies and the magnitudes were clearly related to the fruit weight and soluble solid contents. As the frequencies and the magnitudes decreased the fruit weight and soluble solids contents consistently increased during maturity period. Therefore, this finding confirmed that the developed ripening detector was reliable to evaluate and distinguish the different ripeness stage of watermelon.

1. Introduction
Indonesia is a tropical country which has a diversity of fruits, one of them is watermelon. Watermelon is included in the non-climacteric group fruit. This fruit group cannot undergo a ripening process after being detached from the parent plant, thus, it is necessary to determine whether their ripening stage [1]. Determining the right time to harvest is very important because it relates to post-harvest handling and to improve the fruit quality [2].

Several methods of determining harvest time including visual aging index (shape, color, size, and acoustic properties), physical aging index (hardness, juice yield, and specific weight), chemical index (TSS, starch content, and titrated acid), physiological index (rate of respiration and ethylene production), and computation (plant age). These methods can be divided into 2 groups, namely destructive method and non-destructive method [3–5].

One simple method that is used by many farmers is tapping using their hand or other objects, but this method is still subjective [6]. This study aimed to evaluate the level of watermelon ‘JS Pamela’ maturity based on its acoustic properties using a self-developed ripeness detector prototype.

2. Materials and methods

2.1. Materials
The components used to build the ripeness detector is presented in Table 1. The supporting equipment in this research were digital scales and digital refractometer to measure fruit weight and total dissolved solids content of the fruit samples observed.
### Table 1. Components used to build the ripeness detector

| Material                        | Specification                                      |
|--------------------------------|----------------------------------------------------|
| Cylindrical wood               | 1 piece; length ± 8.2 cm; diameter 1.85 cm          |
| PVC pipe, 1/2 inch             | 2 pieces; length ± 11 cm and 17.3 cm               |
| PVC pipe, ¾ inch               | 1 piece; length ± 13 cm                            |
| PVC pipe, 1 inch               | 1 piece; length ± 13 cm                            |
| PVC pipe, 1 ¼                  | 1 piece; length ± 20 cm                            |
| round pipe cap, 1 inch         | 2 pieces                                           |
| Aluminium pipe                 | 2 pieces; ± 22.5 cm and 21.3 cm;⌀ 0.8 cm           |
| Spring press                   | 2 pieces; length 10 cm and 2.4 cm                  |
| Microphone                     | 1 piece, clip on 3.5 mm jack                       |
| Rubber ball                    | 1 piece; diameter 3.5 cm, weight 25.59 gram         |
| Screw                          | 1 piece                                            |
| Bolt                           | 1 piece                                            |
| Nut                            | 1 piece                                            |
| Ring                           | 2 pieces                                           |
| Handle                         | 1 piece                                            |

The self-develop ripeness detector that had been built could be seen in Figure 1. The working principle of this device is to replace manual tapping by hand. This device is used in front of the tested fruit. By releasing the trigger, rubber ball would knock the fruit and the resulted sound would be recorded by the microphone then inputted into the computer to be analyzed using a certain installed program. The result was more objective as compared to hand tapping, because of the uniformity in tapping strength given by the device to the fruit.

![Figure 1. Self-develop ripeness detector](image1)

Fruit samples used in this study were the red watermelon cultivar 'JS Pamela' with 5 different ripening stages, namely 39, 43, 47, 51, and 55 days after planting (DAP) as can be seen in Figure 2. These samples were obtained directly from farmers in Bantul, Yogyakarta, Indonesia.

![Figure 2. Watermelon samples at 5 different ripening stages](image2)
2.2. Methods

2.2.1. Acoustic properties. The experimental setup for acoustic data acquisition can be seen in Figure 3. First, the fruit sample was placed on a holder and then knocked by the device from a distance of 0.5cm at 3 different locations at the equator with 5 replications. For every ripeness stage, 3 different samples were tested at the same location. The knocking sound was then recorded using Audacity 2.3.1 software in wav format, then the data were analyzed using Matlab R2014b with source code by Agusta [7].

![Figure 3. Setup experiment for acoustic data acquisition](image)

2.2.2. Fruit weight. The weight of the fruit samples was measured using a digital balance for each different ripeness age of watermelon.

2.2.3. Soluble solid content (%Brix). The total dissolved solids content of watermelon flesh was measured using a digital hand refractometer (Pal α, ATAGO). A small amount of watermelon flesh was crushed, then the juice was poured on the glass sensor of the refractometer.

3. Results and discussion

3.1. Fruit weight
The changes of fruit weight during ripening period is shown in Figure 5. The results of statistical analysis showed that the ripeness age of watermelon had a significant effect on fruit weight (P<0.05). There was a trend of increasing fruit weight along with increasing ripeness age. This finding was correlated with the sound parameter to confirm fruit ripeness. The average fruit weight increased linearly throughout ripening period from 1.96 kg at harvest age 39 DAP to 5.28 kg at harvest age 55 DAP or increase 0.28 kg/day. In general, fruit weight increased in line with the increasing ripeness age [8–9].
3.2. Acoustic properties

Figure 6 shows typical sound signal obtained in acoustic impulse response of watermelon. For further analysis, the Fast Fourier Transform (FFT) was used to change the signal domain to determine the peak frequency.

3.2.1. Dominant frequency. The dominant frequency of watermelon at different ripeness age can be seen in Figure 7. The results of the statistical analysis showed that the ripeness age had a significant effect on changes of the dominant frequency ($P<0.05$). This finding was similar to the results reported by another research for two different melon cultivars [10], watermelon, papaya, banana [11] and orange [12].

The dominant frequency decreased with increasing harvest age from 161.89 Hz at 39 DAP to 148.77 Hz at 55 DAP, or decreased 0.82 Hz/day. High frequency respond was found from unripe watermelon indicated the frequency would gradually decrease when the fruit was ripened. According to this finding, the watermelon could be harvested when its dominant frequency was around 150Hz or less, as the harvesting was done by the farmer at 55 DAP.
3.2.2. **Magnitude.** The ripeness age of harvest affects the changes of the magnitude values of watermelons (P<0.05). The magnitude values of watermelon ‘JS Pamela’ sound signal decreased along with ripeness age (Figure 8), the same trend as the dominant frequency change. The average of magnitude decreased from 30.95 dB at 39 DAP to 25.27 dB at 55 DAP, or decreased 0.36 dB/day. This trend was similar as the results reported by another research [6, 11]. According to this finding, the watermelon could be harvested when its dominant frequency was around 25 dB.

![Figure 8. Magnitude of watermelon at different ripeness age](image)

3.3. **Total soluble solid (%Brix)**
The total soluble solids content (TSS) increased as the ripeness age increased (Figure 9). Ripeness age significantly affects the changes of TSS values (P<0.05). TSS was initially at 4.09 %Brix at 39 DAP and reached 9.20 %Brix at 55 DAP, or increased 0.31%/day. The observed TSS of watermelon samples during measurement period could reach a final value of sweetness level (9.20%) which was clearly acceptable by consumers in Indonesia, where the limit value was 8% Brix [13]. Other research reported that as the fruit ripeness increased the TSS of the fruit would also increase for melon ‘Golden Apollo’ [6], melon ‘Zard-Eyvanekey’ and ‘Sousky-Sabz’ [8], and watermelon [9] respectively.

![Figure 9. Total soluble solids content of watermelon during ripeness age](image)

3.4. **Relationship between parameters**
The relationship between acoustic parameter dominants, including dominant frequency and magnitude and the physicochemical parameter of fruit samples could be seen in Figure 10.

Those relations could be well described using linear regression and shown that both dominant frequency and the magnitude decreased along with the increased of fruit weight and TSS. The rate of frequency reduction was found to be significantly larger as compared to the magnitude value. When the ripening age reached 55 DAP or on the harvesting time, the dominant frequency and magnitude values was 150 Hz or less and around 25 dB respectively. At that time the fruit weights were approximately 5 kg with the total dissolved solids 9% or more.
Figure 10. The relationship between acoustic properties and physicochemical parameters of watermelon.

4. Conclusion
The self-developed ripeness detector was able to distinguish the change of acoustic parameter that were dominant frequency and magnitude of watermelon at different ripeness age. Dominant frequency and magnitude showed a decreasing pattern with increasing ripeness age. According to the dominant frequency and magnitude value, watermelon could be harvested when its dominant frequency was approximately 150Hz or less and its magnitude value 25 dB. The values of physicochemical parameters that were fruit weight and TSS increased with increasing ripeness age. The relationship between acoustic parameter and physicochemical parameters could be described using linear regression equations.

References
[1] Zeng W, Huang X, Müller Arisona S and McLoughlin I V 2014 Journal Personal and Ubiquitous Computing 18 1753–62
[2] Yahia E M, Ornellass-Paz J D J and Gonzales-Aguilar G A 2011 Postharvest biology and technology of tropical and subtropical fruits vol 1 ed Yahia E M (Cambridge: Woodhead Publishing Limited) pp 21–78
[3] Ahmad U 2013 Teknologi Penanganan Pascapanen Buahan dan Sayuran Cetakan 1 (Yogyakarta: Graha Ilmu)
[4] Benkeblia N, Tennant D P F, Jawanda S K and Gill P S 2011 Postharvest biology and technology of tropical and subtropical fruits vol 1 ed Yahia E M (Cambridge: Woodhead Publishing Limited) pp 112–142e
[5] Erkan M and Dogan A 2019 Postharvest Technology of Perishable Horticultural Commodities ed Yahia E M (Cambridge: Woodhead Publishing) pp 129–59
[6] Agusta W and Ahmad U 2016 Jurnal Keteknikan Pertanian 4 195–202
[7] Agusta W 2016 Deteksi Kematangan Buah Melon (Cucumis melo L.) Varietas Golden Apollo Menggunakan Parameter Sinyal Suara Tesis (Bogor: Sekolah Pascasarjana, Institut Pertanian Bogor)
[8] Khoshnam F, Namjoo M, Golbakhshi H and Dowlati M 2016 Yuzuncu Yil University Journal of Agricultural Sciences 26 135–44
[9] Soteriou G A, Kyriacou M C, Siomos A S and Gerasopoulos D 2014 Food Chemistry 165 282–9
[10] Khoshnam F, Namjoo M and Golbakhshi H 2015 Journal Agriculturae Conspectus Scientificus 80 197–204
[11] Suciyati S W, Surtoto A and Fahmi M 2007 Jurnal Sains MIPA Unila 13 261–6
[12] Jun W and Pereira A G 2006 Journal Food Quality 29 392–404
[13] Badan Standarisasi Nasional 2009 Semangka SNI 7420:2009