The Effect of Rice (Oryza sativa L.) Types and Moisture Contents on Terminal Velocity

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Abstract. Terminal velocity (Vt) is one of the important parameters often required in the pneumatics processes of some postharvest activities. This value is influenced by many factors such as grain type and shape, moisture content, etc. and this is still very difficult to find in Indonesian references. Therefore, this study aims to investigate the effect of types and moisture contents on the terminal velocity of rice. Three rice types namely Javanica (Oryza sativa subsp. Javanica), Japonica (Oryza sativa subsp. Japonica), and Indica (Oryza sativa subsp. Indica) with 9%, 14%, and 19% (w.b) moisture contents (M) were investigated in factorial design 3 x 3 with three replications for each treatment combinations. Terminal velocity values were measured using a hot wire anemometer in a self-constructed apparatus. The results showed that rice types and moisture contents strongly affected the terminal velocity (p<0.05), however, there was no significant types and moisture contents’ interaction effect on the terminal velocity. Japonica was found to have the largest terminal velocity and Indica had the smallest. The relationship between the moisture content and terminal velocity was expressed as Vt= 0.060M+8.084, Vt= 0.061M+7.676 and Vt= 0.083M+7.056 for Japonica, Javanica, and Indica respectively.

Keywords: postharvest, rice, type, moisture content, terminal velocity

1. Introduction

Paddy (Oryza sativa L.) is the second-largest major cereal crop and a member of the grass family (Gramineae), which produces starchy seeds [1]. Furthermore, rice is the second most important crop in the world after wheat, with Asia being the largest producer and consumer [2]. The three world’s major rice-producing countries are China, India, and Indonesia, with the projected production in 2019/2020 to be 146, 114, and 37.4 million ton respectively [3].

The knowledge of the agricultural products’ physical properties is of fundamental importance during the harvesting of grains, transporting, design and dimensioning of correct storage procedure, as well as manufacturing and operating different equipment used in the postharvest main processing operations [4]. Designing such equipment without considering these tends to yield poor results [5]. Aerodynamic properties such as the agricultural products’ terminal velocity are important and required for designing...
Terminal velocity is the highest velocity attainable by the grains as they fall through the air. It occurs when the sum of the drag force and buoyancy is equal to the downward gravitational force acting on the grains [7]. This property is a very important parameter especially in separating the grains from their light impurities, such as in paddy’s cleaning process using air as the transport medium.

Materials’ terminal velocity is obtained experimentally and theoretically, and two different experimental methods have been studied. The first is the free fall method by graphing measured height versus time and differentiating at each time. In the second, particles are positioned on a screen with controlled airflow, and by increasing the airflow in gradual steps, the particles float at a certain height (suspension method). The measured air velocity at this height is equivalent to the terminal velocity [8]. Furthermore, other studies stated that the first method involves dropping the particles from a certain height whereby their terminal velocity is studied after a certain distance. The terminal velocity is measured from the distance versus time curves where it begins to become linear [6]. The advantage of the drop test for particles with lower terminal velocities is that it is less difficult to use than the suspension method [9].

As stated above that terminal velocity is an important parameter, its value is influenced by many factors such as moisture content, grain type and shape, etc. There are limited studies on the terminal velocity of rice and other grains, furthermore, the values are very difficult to find in Indonesia. Therefore, this study aims to investigate the effect of rice types and moisture contents on the terminal velocity.

2. Materials and Methods

2.1. Sample preparation

Three types of rice namely Javanica (IR-64), Japonica (Koshihikari), and Indica (Basmati) with different moisture contents (M) of 9%, 14% and 19% (w.b.) were used as the samples. To determine the desired moisture contents, the samples were subjected to wetting and drying processes. Single kernel weight and the rice kernel dimension were also measured consisting of the major (length), medium (width), and minor (thick) dimensions by applying image-J software. From these measured dimensions, the kernel sphericity was calculated using equation

$$Sphericity = \left(\frac{a \cdot b \cdot c}{a}\right)^{1/3} \quad \text{........................................ (1)}$$

Where a, b and c were major, medium, and minor dimensions respectively.

2.2. Terminal velocity measurements

The terminal velocities’ values were measured using the suspension method in a self-constructed apparatus designed for small grains (Figure 1). The main parts of this apparatus were an electric blower with adjustable rotation speed, then PVC and clear plastic pipes for airflow channel, wire screen or filter to put the rice samples, and a digital hot wire anemometer (Lutron AM-4204HA). On the plastic pipe, a small hole was made equipped with a cover to facilitate the airspeed measurement. In every measurement, 5 grams of rice was dropped in the plastic pipe and restrained on a wire screen. Then the blower was turned on, the air flowed upwards in the pipe from the bottom, and the air was used to lift the rice sample inside the clear plastic pipe. By adjusting the blower’s rotation speed, the samples were made to float stably at a certain level. In such condition, the speed of flowing air at that level was the same as the rice sample’s terminal velocity and this speed was then measured using a hot wire anemometer. Measurements were performed at three radial positions in the plastic pipe, which were at the centre, as well as the left and right sides. The average value obtained was used as the final terminal velocity of the rice tested. Three replications were taken for the rice types for each moisture contents.
2.3. Data analysis
The experiment was conducted in a completely randomized design, factorial 3 x 3 with three replications for each treatment combinations. The first factor was the rice type and the second was the moisture content. Data were analyzed using the SPSS software program in two-way analysis and the mean comparison was performed using Duncan’s Multiple Range Test (DMRT).

3. Results and Discussion
Figure 2 shows the three rice types’ physical appearances and it can be seen that they have a very different dimension. According to the result of dimension measurement followed by simple calculation using equation 1, Japonica had the largest sphericity, while Indica had the smallest. The same was true for the single kernel weight’s value (Table 1), but for both parameters, Javanica was found to lie between the two rice types.

Figure 1. Apparatus for terminal velocity measurement

Figure 2. Physical appearances of Javanica (a), Japonica (b), and Indica rice (c).
Table 1. Sphericity and single kernel weight of rice samples

| Rice Type | Sphericity | Kernel weight (g) |
|-----------|------------|-------------------|
| Indica    | 0.368      | 0.020             |
| Javanica  | 0.435      | 0.022             |
| Japonica  | 0.614      | 0.025             |

The results showed that both the rice types and moisture contents significantly affected the sample’s terminal velocity, however, there was no significant interaction effect between the type and moisture content on terminal velocity (p<0.05). These findings indicated that the effect of the types on terminal velocity did not depend on the moisture contents. The mean comparison analysis using DMRT found that Japonica types had the largest terminal velocity and Indica had the smallest, while that of Javanica was smaller than Japonica but larger than Indica rice. This was because Japonica had the largest sphericity and single kernel weight values and the smallest ones were for Indica. This showed that the larger the kernel’s sphericity and weight the larger its terminal velocity. O’hara et al. [10] reported that wheat grain which had larger sphericity than cheat grain also had a larger terminal velocity.

Considering the moisture content, the largest terminal velocity was found for 19% moisture contents and the smallest was for 9% (p<0.05, Table 2). It can be seen that as the moisture contents increased, the terminal velocity’s values also increased consistently. Furthermore, the moisture content increased proportionally to the kernel. But it seemed that the kernel weight increment had more effect on the terminal velocity. It was also reported that the mean value of lentil’s terminal velocity increased from 6.751 to 7.396 m/s by increasing the moisture content from 8 to 24% (w.b.) [11]. Poomsa-ad et al. [12] reported the same trend of increment for sorghum grain.

Table 2. Mean comparison analysis using DMRT based on moisture content

| Moisture content | N  | Subset  |
|------------------|----|---------|
|                  |    | 1       | 2       | 3       |
| 9%               | 9  | 8.2111  |         |         |
| 14%              | 9  | 8.5733  |         |         |
| 19%              | 9  | 8.8922  |         |         |
| Sig.             | 1.000 | 1.000 | 1.000  |         |

*) Values in different columns or subsets indicate a significant difference.

Table 3. Mean comparison analysis using DMRT based on rice types

| Variety  | N  | Subset  |
|----------|----|---------|
|          |    | 1       | 2       | 3       |
| Indica   | 9  | 8.2178  |         |         |
| Javanica | 9  | 8.5300  |         |         |
| Japonica | 9  | 8.9289  |         |         |
| Sig.     | 1.000 | 1.000 | 1.000  |         |

*) Values in different columns or subsets indicate a significant difference.

The relationship between moisture content and terminal velocity was expressed as $V_t=0.060M+8.084$, $V_t=0.061M+7.676$ and $V_t=0.083M+7.056$ for Japonica, Javanica, and Indica types respectively (Figure 3-5). Gupta et al. [13] stated that terminal velocity increased linearly with moisture content from 6.2 to 14.17% (d.b.) for the three different varieties of sunflower seed tested. Other studies showed that by changing the grain moisture content from 10 to 22% (w.b.), the average terminal velocity significantly increased from 9.228 m/s to 11.368 m/s [14]. Considering the coefficient of the equations, Indica had the largest terminal velocity increment as its moisture content increased, while Japonica had the smallest. This also implied that the Indica type’s terminal velocity was susceptible to the moisture content increment.
4. Conclusions

It can be concluded that the rice types and moisture contents strongly affected terminal velocity, however, there was no significant interaction effect between the type and moisture content on terminal velocity. Japonica had the largest terminal velocity and Indica had the smallest, while Javanica lay in between them. It was found that the sphericity and weight of the kernel were directly proportional to its
terminal velocity. Also, it was found that as the moisture contents increased the terminal velocities' values consistently increased too. The relationship between moisture content and terminal velocity was expressed as $V_t= 0.060M+8.084$, $V_t= 0.061M+7.676$ and $V_t= 0.083M+7.056$ for Japonica, Javanica, and Indica types respectively.

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