The effect of types and moisture contents of soybeans (*Glycine max*) on terminal velocity

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Abstract. Terminal velocity of grain product is one of aerodynamics properties which needed for design machines or handling agricultural grains in pneumatics bulk handling systems. Terminal velocity is influenced by many factors, the two important factors are type of grain material and moisture content. This research was aimed to investigate the effect of types and moisture contents on terminal velocity of soybeans grain. Three different types of soybeans namely local, import, and local black soybean in three different moisture contents of 10, 13, and 16% (w.b) were investigated in this study, using factorial design 3 x 3. Each combination was replicate three times. Terminal velocities were investigated using self-constructed apparatus and the velocities were measured using hot wire anemometer. Result shows that types of soybeans and moisture contents significantly affected terminal velocity (p<0.05), however there no significant interaction was found. The higher moisture contents, the higher would be the terminal velocities value. Imported soybean had highest terminal velocity and local black soybean is the lowest ones. The relationship between terminal velocity and moisture content could be expressed in linear regression equations for these three types of soybean.

1. Introduction

Soybean is one of strategic grain commodities as it as source of healthy protein with low price, then it became very famous in Indonesia. Soybean commonly use as raw material of foods namely tofu, tempeh, tauco, oncom and soymilk, and also widely used as raw material in many industries [1]. According to that demand, therefore the soybean need in Indonesia is always high every year. Statistically, Indonesian people consume 2.2 million tons per year of soybean, meanwhile the domestic production is only about 35% of the national consumption. For that, more than 65% must be imported to fulfil the need.

The amount of imported soybean in last five years was more than 2 million tons, in 2015 there was 2,256,931.7 tons imported and the amount is increased to 2,670,086.4 tons in 2019 [2]. This mean every day, abundant soybean needs to be handled. However, to the date, soybean handling is still carried out manually, to be more efficient this need mechanical handling process in bulk condition. To do mechanical handling, its need information about soybean properties. For instance, to be able to separate soybean from its impurity’s material, its needs to know the aerodynamics properties of soybean and the impurities. In general, information of physical properties of agricultural product are
needed to design and to adjust the machines which applied during harvesting, separating, cleaning, handling and storing, also when the agriculture materials are converted into food, feed, and fodder [3].

The aerodynamic properties such as terminal velocity of agricultural products is necessary in design the pneumatic conveying systems, fluidized bed dryer, and for cleaning products from foreign materials [4]. Terminal velocity of grain can be measured using two methods. First method is using estimated time during free fall of an object from various heights. The second method is placing a particle in a vertical air stream, then the air velocity is adjusted until particle is suspended. Since the forces of acting on the body is in equilibrium state, the air velocity is equal to terminal velocity of the particle [5]. As mentioned, terminal velocity is one of important parameters, this value is influenced by many factors such as moisture content, grain type, shape of grain, and others. For that, this research was aimed to investigate the effect of the types and moisture contents of soybean on the terminal velocity parameter.

2. Materials and methods

2.1. Materials

Three types of soybean grain namely local soybean (Galunggung), imported soybean (from American), and local black soybean (Mallika) in three different moisture contents of 10, 13 and 16% (w.b) were used in this study. To adjust the moisture contents, soybean samples were treated with drying or wetting processes until desired moisture obtained. Figure 1 shows physical appearances of the three soybean types. According to its kernel weight (Table 1), heaviest grain was found in imported soybean, while local black soybean was the lightest (Table 1).

![Figure 1. Physical appearances of Local soybean (a), Imported soybean (b), Local black soybean (c)](image)

| Soybean type   | Kernel weight (g) |
|----------------|-------------------|
| Local          | 0.191             |
| Imported       | 0.220             |
| Local black    | 0.143             |

Table 1. Single kernel weight of soybean samples
2.2. Terminal velocity measurement

The terminal velocities were measured using self-constructed apparatus as shown in Figure 2. The main parts of this apparatus were electric blower equipped with a sliding gate or speed regulator at the blower input to control air flow speed. PVC pipe was used for air flow channel and clear plastic pipes was used to observe the grain when its float or suspended. Wire screen or filter was used to put soybean samples, and digital hot wire anemometer (Lutron AM-4204HA). On the clear plastic pipe there was a small hole equipped with a cover to insert the anemometer sensor probe for measuring terminal velocity of the tested grain. In every measurement, 10 grams of soybean was dropped in the plastic pipe and would be restrained on wire screen, then blower was turned on. At the beginning, air flow speed from the blower was adjusted at minimum condition by turning the sliding gate to almost closed blower inlet. In this condition, air flow would lift soybean sample into clear plastic pipe but in unstable condition. Then air flow rate was gradually increased by adjusting blower sliding gate until soybean sample float stably at a certain level around the measurement hole in the plastic pipe. The speed of flowing air was then measured using a hot wire anemometer. In such condition, the speed of flowing air at that level was the same as the terminal velocity of the soybean sample. Measurement of terminal velocity were done at three radial positions in the plastic pipe, there were at the left, center and right sides of the pipe. The average value from these three measurements was used as final value of terminal velocity of tested soybean.

![Figure 2. Apparatus for measuring terminal velocity](image)

2.3. Data analysis

Experiment was done in factorial completely randomized design 3 x 3, with three replicate for each treatment combinations. The factors were soybean type and the moisture content, each has 3 levels. Data were analyzed using two-way ANOVA, and mean comparison between groups were done by Duncan’s Multiple Range Test (DMRT). All the statistical analysis was performed in SPSS program.

3. Results and discussion

Statistical analysis showed that type and moisture content of soybean were significantly affect terminal velocity (p<0.05), however there was no significant interaction between both factors (p>0.05). These findings indicated that the effect of types on terminal velocity did not depend on the moisture contents. Mean comparison analysis found the highest terminal velocity was in imported soybean, while the lowest was in local black soybean (Table 2). This finding might associate with fact that imported soybean had highest values of single kernel weight compared to the local black soybean. The genetic characteristics of each type of soybean would affect its kernel properties and later in its
kernel weight. This finding gave a clue that heavier kernel then the higher would be its terminal velocity. In the view of moisture content, it was found that the highest terminal velocity was found in 16% of moisture contents and the lowest was in 10% (p<0.05). As the moisture content increased, the weight of kernel also increase, then this affected to the increment of terminal velocity value. Therefore, its clear that when moisture contents are increase, the value of terminal velocities were consistently increased too. The same phenomenon was also reported by earlier study, where the values of terminal velocity of soybean increased along with moisture content for all tested soybean varieties [6].

| Type of soybean | Vt (m/s) | Moisture content (wb) | Vt (m/s) |
|-----------------|----------|-----------------------|----------|
| Local black     | 12.3033\(^a\) | 10%                   | 12.8989\(^a\) |
| Local           | 13.6111\(^b\) | 13%                   | 13.4156\(^b\) |
| Imported        | 14.3700\(^c\) | 16%                   | 13.9700\(^c\) |

\(^*) the values of Vt followed with the same letter in the same column were not significant difference

The relationship between moisture content (M) and terminal velocity (Vt) could be expressed in linear regression as shown in the Figures 3 to 5. The relationships were found to be Vt=0.1778M+11.3 for local type soybean; Vt=0.1633M+12.247 for imported type soybean, and Vt=0.1944M+9.7756 for local black type soybean. El-Gamal et al. reported that by increasing moisture content from 7.8 to 31.8% (w.b.) the terminal velocity of soybean increased from 12.42 to 12.65 m/s [7]. Considering the coefficient of the equations, it could be seen that local black soybean seemed to have largest increment of terminal velocity as its moisture content increased. This also implied that terminal velocity of this soybean would be susceptible to the increment of moisture content. The coefficient determination (R\(^2\)) for those equations were close to 1, which imply that these regression equations might be used to predict terminal velocity of those types of soybean precisely.
4. Conclusion
The types and moisture contents of soybean were affecting terminal velocity. Imported soybean was found to have highest terminal velocity, while local black soybean was the lowest ones. The heavier single kernel of soybean the higher would be its terminal velocity. Moreover, the moisture contents would increase the value of terminal velocities. According to the linear regression analysis, terminal velocity could be predicted using moisture content information.

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