The influence of types and moisture contents of coffee beans (Coffea sp) on sphericity and geometric means diameter

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Abstract. Moisture content and particle dimension of coffee beans are the two important characteristics which are often needed in many postharvest handling processes. This research was intended to investigate the effect of types and moisture contents on the changes of sphericity and geometric mean diameter of coffee beans. Three different types of coffee beans namely arabica, robusta, and liberica in three moisture contents of 9, 14, and 19% (w.b) were investigated in factorial design 3 x 3 with five replications. The dimensions of coffee bean were determined using ImageJ process and the values of sphericity and geometric mean diameter were then calculated. It was found that bean types, moisture contents, and the interaction between them were strongly affected the dimensions, sphericity, and geometric mean diameter of coffee beans (p<0.05). Robusta was found to have biggest sphericity and geometric mean diameter. As the moisture contents increased, it tends to produce higher geometric mean diameter, but this not applied to sphericity. The relationship between moisture content and sphericity could be expressed as polynomial of degree 2 equations, while geometric mean diameter can be correlated in linear regression equations for all types of coffee beans in this research.

1. Introduction
Coffee is one of very famous drink and widely consumed all over the world. As amount of 66% of world coffee produced is arabica coffee, and other 34% is robusta coffee, meanwhile liberica is the rarest coffee type [1]. Among ASEAN countries, Indonesia known as producer and second largest coffee exporter after Vietnam [2]. In the world, Indonesia is the fourth largest coffee producer and exporter after Brazil, Vietnam, and Colombia [3]. This shows that in international level, coffee production in Indonesia is very huge amount, however, its postharvest handling is still not optimal, and mostly conducted manually. To mechanically handling, it requires information on various physical properties of coffee beans for handling purposes.

Knowledge of physical properties of agricultural products and foods are important for designing the equipment for processing, transportation, sorting, separation, and storing [4]. One of these physical properties is the dimension of the products. Knowledge of the coffee bean dimension is necessary for several activities, such as sorting from foreign objects, grading, and evaluating product quality. Dimension of coffee bean is influenced by many factors such as the type, moisture content, temperature, relative humidity, and etc.
Dimensions can be measured directly using length measure apparatus such as calipers, however to be more accurate, its can be done by incorporating a computer program or software [5]. Dimensions of agricultural products including length, width, thick, perimeter, and area can be determined using a computer program software namely Image-J. From these measured dimensions the other parameters such as sphericity and geometric mean diameter can be calculated. Geometric mean diameter may be used as representation of diameter of a non-spherical bean which is calculated from the length, width, and thickness of the beans. In here, sphericity indicating the roundness of a beans [6]. Image-J software is a powerful program, various options on the tool bar enable analysis of an images rapidly [7]. Image-J is a Java-based digital image processing software created by Wayne Rasband from the Research Services Branch, National Institute of Mental Health, Bethesda, Maryland, USA [8]. According to mentioned information, this research was aimed to investigate the effect of types and moisture contents on dimension of coffee beans.

2. Materials and methods

2.1. Materials
Three types of coffee beans namely robusta, arabika, and liberika in three different moisture contents 9, 14 and 19% (w.b.) were used in this research. To adjust the moisture contents, beans were undergoing wetting and/or drying processes until the desired moisture contents were obtained. Figure 1 shows the physical appearances of the three coffee beans types, visually its shows different dimension between type. 

![Figure 1. Physical appearances of robusta (A), arabica (B), and liberica (C) coffee beans](image)

2.2. Dimension measurement
In this study, to measure bean dimensions was done by using application called Image-J (Figure 2). This software provides data on length, width, thickness, perimeter, and area. Before the measurement analysis coffee beans were photographed on a white background. Image then loaded in the software, then processed to obtain its dimension. This measurement was carried out in five replications for each type of coffee and moisture content.

![Figure 2. Image-J application](image)

2.3. Data analysis
Experiment was done in factorial completely randomized design 3 x 3 with five replications for each treatment combinations. The first factor was type of coffee beans and second factor was the moisture content. Data were analyzed by two-way ANOVA and the mean comparison was done using Duncan’s Multiple Range Test (DMRT). All the statistical analysis was performed in SPSS.
2.3.1. Geometric mean diameter. The primary dimension included length (l), width (w), and thickness (t) were measured using Image-J application. The secondary dimension included Geometric mean diameter and Sphericity [9]. Geometric mean diameter of beans was calculated using equation 1 [10].

\[ D_{mg} = (l \times w \times t)^{1/3} \]  

(1)

2.3.2. Sphericity. Sphericity is a measure of how closely the shape of an object resembles that of a perfect sphere [11]. Sphericity of beans were calculated using equation 2 [12].

\[ S_p = \frac{(l \times w \times t)^{1/3}}{l} \]  

(2)

3. Results and discussion

Two-way statistical analysis showed that both types and moisture contents significantly affected dimension of the bean’s samples, and there was significant interaction effect between these factors to length, width, thickness, perimeter, area, geometric mean diameter, and sphericity (p<0.05). Mean comparison analysis using DMRT showed that the largest dimension was found for robusta types and the narrowest was for arabica, while Liberica lay in between the two beans types (Table 1). According to earlier report on the characteristics and evaluation of physical and mechanical properties of arabica beans, differences types and sizes would affect to the value of coffee beans dimensions [13]. The physical characteristics of the beans varied in shape and size, this was due to the genetic nature of the coffee. The endosperm content also affected the width of the beans, the higher endosperm content the thicker the cell walls so that the dimensions of the beans were also bigger. This cause the variation in shapes and sizes of coffee beans [14].

Table 1. Mean comparison using DMRT for dimension parameters of the three coffee beans

| Parameter          | Moisture Content (%) | Robusta | Arabica | Liberica |
|--------------------|----------------------|---------|---------|----------|
| Length (cm)        | 9                    | 1.056aA | 0.887bA | 0.965cA  |
|                    | 14                   | 1.084aB | 0.963bB | 1.066cB  |
|                    | 19                   | 1.275aC | 1.063bC | 1.226cC  |
| Width (cm)         | 9                    | 0.853aA | 0.664bA | 0.636cA  |
|                    | 14                   | 0.855aB | 0.735bB | 0.761cB  |
|                    | 19                   | 0.889aC | 0.756bC | 0.856cC  |
| Thickness (cm)     | 9                    | 0.545aA | 0.473bA | 0.476cA  |
|                    | 14                   | 0.666aB | 0.575bB | 0.557cB  |
|                    | 19                   | 0.675aC | 0.553bC | 0.666cC  |
| Area (cm²)         | 9                    | 0.623aA | 0.456bA | 0.455cA  |
|                    | 14                   | 0.795aB | 0.646bB | 0.645cB  |
|                    | 19                   | 0.892aC | 0.738bC | 0.877cC  |
| Perimeter (cm)     | 9                    | 3.065aA | 2.556bA | 2.774cA  |
|                    | 14                   | 3.316aB | 3.074bB | 2.964cB  |
|                    | 19                   | 3.653aC | 3.227bC | 3.432cC  |
| Mean geometric diameter (cm) | 9         | 0.789aA | 0.653bA | 0.664cA  |
|                    | 14                   | 0.855aB | 0.741bB | 0.774cB  |
|                    | 19                   | 0.916aC | 0.778bC | 0.890cC  |
| Sphericity (%)     | 9                    | 75aA    | 74bA    | 75cA     |
|                    | 14                   | 74ab    | 73bB    | 73eb     |
|                    | 19                   | 72ac    | 72bc    | 72cc     |

*) In each parameter, the values followed by the same small letter at the same row were not significant different. While the values followed by the same capital letter at the same column were not significant different.
Figure 3. Relationship between dimension parameters and moisture content for (A) Length, (B) Width, (C) Thickness, (D) Area, (E) Perimeter, (F) Geometric mean diameter, and (G) Sphericity.
In view of moisture content, it was found that the biggest dimension parameters including length, width, thickness, geometric mean diameter, perimeter and area was found in 19% moisture content and the smallest one was for 9% (p<0.05). The dimensions of coffee beans were known to be influenced by moisture content. High moisture content caused the coffee bean dimensions to increase, this was caused by the fact that higher water content would cause empty pores of beans filled with water and caused increase in beans volume [15]. In the contrary, the largest sphericity value was found in 9% moisture contents and the smallest ones was in 19% (p<0.05). Clearly it could be seen that as the moisture contents increased, the sphericity value was decreased consistently. In the view of bean type, robusta had largest sphericity and the narrowest ones was liberica. The sphericity value would increase with the decreasing of beans size [16].

The relationship between dimension parameters and moisture content of the evaluated coffee beans could be described using linear regression with quite high coefficient determination. From the figures above, we know that as the moisture contents increased the value of length, width, thickness, area, perimeter, and geometric mean diameter also will be increase. On the contrary the values of sphericity decreased with the increase of moisture content. This phenomenon has demonstrated in earlier study which found the linear relationship between physical properties of grain and moisture content e.g for paddy [17], kenaf seed [18], and sorghum grain [19].

4. Conclusion
It is concluded that types and moisture contents strongly affected coffee bean dimension parameters. The increase of moisture content would also increase length, width, thickness, area, perimeter, and geometric mean diameter of the bean, but this is not applied to sphericity. Geometric mean diameter of robusta was found to be the largest, and arabica was the smallest, in here liberica was lay in between them. Robusta was found to have largest sphericity and liberica was the smallest ones. The relationship between geometric mean diameter, moisture content and its physical properties could be expressed as linear equation in this study.

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