Crushing Mung Beans Using Ball Mill Tool: Base on Fraction Size Sieving Results

B Haryanto¹, B Trisakti², Y Wangi², H Khosman² and A W Sinaga²

¹Center of Excellence for Sustainable Energy and Materials, Universitas Sumatera Utara, Medan, Indonesia.
²Chemical Engineering, Faculty of Engineering, Universitas Sumatera Utara, Padang Bulan, Medan, Indonesia

Email: bode.haryanto@usu.ac.id

Abstract. Ball mill is an operating unit used to grind various types of solid materials into finer particle sizes. The purpose of this study was to determine the best variation of operating conditions of mung bean milling in a ball mill by varying the grinding time, weight of raw materials and the number of balls used. In this study, the raw material used is mung bean. After grinding, the beans are then sifted through sieves 70, 140 and 200 mesh where the fraction of green beans that passes each sieve was obtained. From the studies, it can be concluded that the best operating conditions of mung bean milling in the ball mill are at 60 minutes grinding time, the weight of the raw material is 45 grams and the number of balls size is 8 medium balls and 6 small balls.

1. Introduction

Mung bean (Vignaradiata L.) widely grown in south and south East Asia. Over 80% of the Mung bean is produced in South Asia. The popularity of Mung bean cultivation stems from its ability to be digested by the human body, growth flexibility, and the short time it needs to be harvested [1]. Mung bean is one of the plantation products that are widely consumed by the community besides rice. Because of its high use in the community, mung bean is highly demanded in the market [2]. Application for Mung bean is mainly for human consumption or food industry. In addition to fulfilling domestic needs, national Mung bean production is also a big opportunity to supply part of the world mung bean market so that it can contribute to the country's economy [3].

Composition of mung beans has carbohydrate (51 %), protein (24-26 %), mineral (4 %), vitamins (3 %) and fat (1 %). Mung beans are an important source of digestible protein for vegetarians [4]. Mung bean seeds consist of three main parts, namely testa (12,2-23,5%), cotyledons (76,5-87,2%) and embryo (2,3%). Most of the protein in mung bean is present in the cotyledons. Mung bean contains minerals such as phosphorus (P), calcium (Ca), and iron (Fe). Calcium is primarily present in the seed coat (30-50%), iron in the embryo (23 mg/100 g dry weight) and phosphorus in cotyledons (341 mg/100 g dry weight) [5]. In Indonesian market, there are only two types of Mung bean quality, namely large sized Mung beans and small seeded Mung beans. Large sized mung bean is used for porridge and flour, while those with small seeded are used for growing bean sprouts [6].

Ball mill are widely used in the grinding process in the mineral industry. The grinding process in the ball mill was caused by collision and friction between the material and the balls in the mill which
caused the material to reduce in size. Generally, these balls are either made of steel, ceramic or metal. The basis of the grinding process is that the strain produced by the ball when breaking down the material must be higher than the hardness of the material so that the breakdown process can occur [7]. Therefore, as the feed grain size decreases, the size of the ball that is necessary for milling also decreases [8]. For each grain size there is a specific ball size that is most suitable for grinding [9]. Previous research has reported ball mill as a tool for crushing coffee and cocoa beans based on fraction size sieving results [10].

The aim of this research is to analyze the grinding operation of ball milling mung bean as a sample. The idea is to determine the optimum operating conditions during the milling process of the mung bean. In order to know the effect of grinding time, weight of raw materials and variations in the number of balls used in the grinding process.

2. Material and methods

Mung beans are washed first with water and then dried naturally with the help of sunlight to dry completely. The weight of the material used is in accordance with variations of 30-65 grams and placed in a ball mill. Enter the number of balls according to the variations used and put in the ball mill. The ball mill is run with time according to the variation, which is between 30-60 minutes. After range of time, the ball mill is stopped, and the milled material is removed and placed in a container. The material is then sifted with sieves of 70, 140 and 200 mesh. The fractions of material that passes through and detained in the sieve are then weighed. This procedure is repeated according to the variation specified. The ball specification is shown in Table 1 and the variation is shown in Tables 2.

### Table 1. Ball size in ball mill

| Ball size            | Diameter | Weight  |
|----------------------|----------|---------|
| Medium (metal)       | 3.56 cm  | 123.17g |
| Small (ceramics)     | 1.63 cm  | 16.06g  |

### Table 2. Variations applied

| Variable             | Variable range |
|----------------------|----------------|
| Weight of raw material | 30 – 65 grams   |
| Ball size             | Medium, small   |
| Operation time        | 30 – 60 minutes |

3. Result and Discussion

3.1 Effect of Milling Time on Mass Fractions in Sieves

Effect of grinding time with variations for Run I: 40 grams with 9 medium balls, 8 small balls and 30 minutes operating time. Run II, III and IV have the same number of balls and the weight of the raw material with the milling times of 40, 50 and 60 minutes, respectively. Figures 1A and B show the relationship of the mass fraction that is held back and passes to the sieve number with the variation of the grinding time used. It was found that the longer the grinding time, the retained mass fraction decreases.
Where $S_i = \text{material selection function based on size } i$, $t = \text{milling operation time}$, $w_i(t) = \text{mass fraction with initial size in mill at time } t$, $b_{ij} = \text{another mass fraction at size of mill } j$ [11].

From the equation 1, it can be concluded that the longer the grinding time ($t$), the retained mass fraction will decrease, causing the particle size to be larger. But according to Mukhtar et al [12], particle size reduction occurs in the initial stages of grinding will continue until then there is an equilibrium between re-agglomeration and de-agglomeration. Which after passing the equilibrium time, the particle size is likely to be agglomerated so that a reduction in particle size occurs.

The results obtained in the chart are in accordance with the existing theory where in Run IV with a 60-minute grinding time has a smaller retained mass fraction compared to other runs with less grinding time.

### 3.2 Effect of Raw Material Weight on Mass Fraction in Sieves

**Figure 2.** Chart of mass fraction to sieve number with variations in raw material weight
Effect of weight of raw material with variations for run I: 35 grams with 9 medium balls, 8 small balls, and 30 minutes operating time; run II: 45 grams with 9 medium balls, 8 small balls, and 30 minutes operating time; run III: 55 grams with 9 medium balls, 8 small balls, and 30 minutes operating time; run IV: 65 grams with 9 medium balls, 8 small balls, and 30 minutes operating time. Figures 2A and B show the relation between the mass fraction that is retained and those that pass the sieve number with the variation in the weight of the raw material used. It was obtained that the higher weight of raw material, the retained mass fraction will increase.

Based on the theory of the relation between the mass fraction retained with the weight of feed weight can be seen from the following equation:

\[ A = \frac{6m}{\Phi_x \rho_p D_p} \]

\[ A_w = \frac{6m}{\Phi_x \rho_p \sum x_i D_{pi}} \]

Where \( A \) = particle surface area, \( A_w \) = specific surface area, \( m \) = mass, \( \Phi_x \) = sphericity, \( X_i \) = retained mass fraction, \( D_{pi} \) = average particle diameter [13].

From the above equation it can be concluded that the relation between \( m \) and \( X_i \) which the increase of mass will increase the retained mass fraction. The results obtained on the chart are suitable with Run IV which the weight of the 65-gram raw material has a value of \( X_i \) (retained mass fraction) higher than the other run. While for Run I with the smallest raw material weight of 35 grams has the least value of retained mass fraction.

3.3 Effect of the Ball Size to Mass Fraction in the Sieve

\[ \text{Figure 3. Chart of mass fraction to sieves number with variations in amount of ball size} \]

Effect of the number of ball sizes with variations for Run I: 6 medium balls, 8 small balls; Run II: 8 medium balls and 8 small balls; Run III: 10 medium balls and 8 small balls; Run IV: 12 medium balls and 8 small balls. The mass fraction is 45 grams with 30-minute operating time for each variation. Figures 3A and B show the relationship of the mass fraction that is held back and passes to the sieve number with the variation in the number of balls used. It was found that the more the size of the ball, the smaller the fraction of the retained mass.
\[
S_i = \sum_{k=1}^{m} m_k S_i(d_k) = \sum_{k=1}^{m} m_k S_i(d_k)
\]  
(4)

Where \( m_k \) = the function of relative ball mass with \( dk \) size, \( S_i(d_k) \) = particle size affected by ball size \( (dk) \) [14].

From the above equation, it can be concluded that, as the ball mass increases (the diameter of the ball gets larger), the particle size increases so that the fraction of the retained mass will decrease. The size of the grinding media (ball) is a variable that affects the level of damage from the raw material to be milled. The use of larger balls will result in more efficient damage and reduce the required power consumption [11].

The results obtained from the chart are suitable which the more balls are used, the smaller retained mass fraction will be. This is shown in Run IV where the number of balls used is the most and the lowest retained mass fraction compared to another Run.

4. Conclusion

Ball mill can be used for crushing and grinding of various types of raw materials from larger particle sizes to smaller and finer particle sizes. From the studies conducted it can be concluded that the best operating conditions that will provide the most subtle particle size in Mung beans are at 60 minutes grinding time, the weight of the raw material is 45 grams and the number of balls is 8 medium balls and 6 small balls.

5. References

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