The performance of size grading machine of robusta green coffee bean using oscillating sieve with swing along width direction

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Abstract. Size grading is one of important processes for producing the Robusta green coffee bean because it can increase the value of green coffee bean and decrease the problem in the manufacturing process, especially roasting process. Therefore, the objective of this work was to investigate the effects of inclined angle and oscillating revolution speed on the performance of size grading machine of Robusta green coffee bean using oscillating sieve with swing along width direction. When increasing the inclined angle from 4 to 6 degree, the weight purity index and the clogging sieve percentage were decreased. For the size grading efficiency, it found that the size grading efficiency was increased when the inclined angle increased from 4 to 5 degree. However, the size grading efficiency was decreased when increasing the inclined angle from 5 to 6 degree. When considering in term of oscillating revolution speed, the increase of oscillating revolution speed provided the decrease of weight purity index, size grading efficiency and clogging sieve percentage. The appropriate condition for using the size grading machine of Robusta green coffee bean using oscillating sieve with swing along width direction is the inclined angle of 5 degree and the oscillating revolution speed of 185 rpm.

1. Introduction
Coffee is one of popular agricultural crops which are two most important coffee species such as Arabica and Robusta [1]. The Robusta coffee is the major coffee production in Thailand. It is cultivated annually in the South, especially in Chumphon, Ranong, Nakorn Si Thammarat, Phang-Nga, and Krabi province. Generally, coffee is internationally traded as green coffee bean, which is produced by either dry or wet processing. The dry processing is normally used for producing the Robusta green coffee bean. It consists of two different operations, namely drying and hulling. Coffee cherries were dried to the moisture content of 13 % (w.b.). Then, the dried coffee cherries were dehusked by a hulling machine to produce green coffee bean. After hulling operation, the green coffee bean has been classified according to size because the green coffee bean size directly affected the time and temperature in the roasting process. Furthermore, it also affects the taste and odor [2]. The size of green coffee bean in Thailand can be divided into four groups namely very large size (diameter ≥ 7.1 mm), large size (6.3 ≤ diameter ≤ 7), medium size (5.6 ≤ diameter ≤ 6.2) and small size (diameter ≤ 5.5) [3].

Nowadays, green coffee bean is graded by size grading machine using oscillating sieve with swing along length direction. This machine has the low performance because the green coffee beans were moved in the same direction with oscillating sieve. Moreover, the sieve cannot adjust inclined angle and
results in the slight distribution of green coffee bean. Subsequently, some green coffee beans are stuck on the sieve, leading to low grading capacity. To alleviate the clogging sieve problem, it should increase the distribution of green coffee bean. One of possible methods that increase the distribution of green coffee bean can be done by size grading machine using oscillating sieve with swing along width direction. This oscillating sieve is perpendicularly moved with the directional movement of green coffee bean. This would provide the good distribution of green coffee bean and lead to the low clogging sieve. Accordingly, the size grading performance may be improved. The objective of this work was therefore to investigate the effects of inclined angle and oscillating revolution speed on the performance of size grading machine of Robusta green coffee bean using oscillating sieve with swing along width direction. The performance of size grading machine was considered in terms of weight purity index, size grading efficiency and clogging sieve percentage.

2. Materials and methods

2.1. Materials
Robusta green coffee bean with an initial moisture content of 13% wet basis (w.b.) was used as the sample in this study. It was graded by size into four groups using the vibrating screening with standard sieves such as very large size (XL), large size (L), medium size (M) and small size (S). Each group was painted with different color as shown in figure 1.

![Robusta green coffee bean with different color](image)

Figure 1. Robusta green coffee bean with different color

2.2. Experimental set-up
A size grading machine using oscillating sieve with swing along width direction was used to screen the size of Robusta green coffee bean as presented by schematic diagram in figure 2. It consisted of four oscillating sieves (780×1,100 mm.) with difference hole sizes that is 4, 5, 6 and 7 mm. The green coffee bean was conveyed to sieve using feeding hopper with the capacity of 5 kg. All sieves were oscillated using a camshaft with reciprocated stroke of 25 mm which was driven by a 1HP motor. A brush was installed on each sieve to prevent the stuck coffee bean during oscillation. The green coffee bean after screening size was transferred to outlets each grade.

2.3. Grading experiments
500 g of each Robusta green coffee bean group was well-mixed as a sample (total sample of 2 kg) and fed into the grader at feed rate of 30 kg/h. The experiment conditions were set at inclined angles of 4-6° and oscillating revolution speeds of 170-200 rpm. The oscillating sieve could separate the Robusta green coffee bean as four sizes viz., size I (very large size, >7.1 mm), size II (large size, 6.3 – 7 mm), size III (medium size, 5.6 – 6.2 mm) and grade IV (small size, < 5.5 mm). When no Robusta green coffee bean was observed in the oscillating sieve, the mass of Robusta green coffee bean from each outlet were removed and weighed for calculating the performance of machine.
2.4. Performance evaluation

The performance of size grading machine of Robusta green coffee bean using oscillating sieve with swing along width direction evaluated in terms of weight purity index, size grading efficiency and clogging sieve percentage. The weight purity index and size grading efficiency of machine were determined by applying the equation proposed by Tabatabaekoloor and Hashemi [4] as shown in equation (1)- equation (2), respectively.

\[ P_W = \sum P_{gi} W_i \]  
\[ E_W = \frac{\sum P_{gi} W_i G_i}{QP} \]  

Where,
- \( P_W \) weight purity index (%)
- \( E_W \) size grading efficiency (%)
- \( P_{gi} \) fraction of green coffee bean size \( i \) to total green coffee bean dropping into receiving tray size \( i \)
- \( W_i \) fraction of green coffee bean size \( i \) at the beginning of sizing to total green coffee bean at the beginning of sizing
- \( G_i \) outflow rate of green coffee bean size \( i \) (kg/h)
- \( P_i \) fraction of size \( i \) to total green coffee bean at the beginning of sizing
- \( Q \) feed rate (kg/h)

The clogging sieve percentage was calculated by the following equation (3):

\[ C_W = \frac{w_C}{w_T} \times 100 \]

Where,
- \( C_W \) clogging sieve percentage (%)
- \( w_C \) weight of green coffee bean with clogging sieve in all sieves (kg)
- \( w_T \) total weight of green coffee bean
2.5. Statistical analysis
These experiments were performed using a full factorial design (3×3) with two main factors (three inclined angles and three oscillating revolution speeds). All experimental data were analyzed using the analysis of variance (ANOVA). Duncan’s multiple-range tests were used to determine the differences between mean values at a confidence level of 95%.

3. Results and discussion

3.1. The weight purity index (Pw)
Table 1 shows the weight purity index (Pw) of size grading machine using oscillating sieve with swing along width direction at various inclined angles and oscillating revolution speeds. The experimental result showed that the inclined angle and oscillating revolution speed were significantly affected the value of Pw. The increase of inclined angle and oscillating revolution speed provided the lower value of Pw. The values of Pw were in the ranges of 76.57-94.03%. The lower value of Pw was due to the movement of green coffee bean. When increasing the inclined angle and oscillating revolution speed, green coffee bean rapidly moved and dropped to incorrect category, leading to lower value of Pw. From surveying the size grading machine of Small and Medium Enterprises (SMEs) in Chumphon province, it was found that the maximum Pw value of size grading machine was about 74.25%. This Pw value was acceptable for size grading and used as the standard of weight purity index. When comparing the value of Pw between size grading machine using oscillating sieve with swing along width direction and the size grading machine of SMEs in Chumphon province, the size grading machine using oscillating sieve with swing along width direction can provide the higher Pw value than the size grading machine of SMEs in Chumphon province in every condition. All above results confirmed the potential of size grading machine using oscillating sieve with swing along width direction in term of increase of weight purity index (Pw) in the size grading machine.

Table 1. The weight purity index (Pw) of size grading machine using oscillating sieve with swing along width direction at various conditions.

| Inclined angle (Degree) | Oscillating revolution speed (RPM) | Weight purity index (Pw; %) |
|------------------------|-----------------------------------|-----------------------------|
|                        | 170                               | 94.03 ± 0.24               |
|                        | 185                               | 92.91 ± 0.37               |
|                        | 200                               | 82.20 ± 0.71               |
| 4                      | 170                               | 88.43 ± 0.40               |
|                        | 185                               | 86.11 ± 0.28               |
|                        | 200                               | 80.78 ± 0.33               |
| 5                      | 170                               | 86.49 ± 0.48               |
|                        | 185                               | 81.15 ± 0.22               |
|                        | 200                               | 76.57 ± 0.40               |

* * Means with different superscripts in the same column are significantly different (p<0.05)

3.2. The size grading efficiency (Ew)
Table 2 shows the size grading efficiency (Ew) of size grading machine using oscillating sieve with swing along width direction at various inclined angles and oscillating revolution speeds. It was found that the oscillating revolution speed remarkably affected the Ew value; the Ew value was significantly lower when the oscillating revolution speed was higher. The decrease of Ew value is due to the movement of green coffee bean as already explained in the previous section. A similar result was found by Preetha et al. [5] who reported that the speed of grading affected the grading efficiency of tomato.
Abd and Magda [6] also reported that the total grading efficiency tended to decrease slightly from 94.34 to 94.2 % when the revolving speed of riddle was increased from 55 to 65 rpm.

Considering inclined angle, it is seen that the Ew value was increased when increasing inclined angle from 4° to 5°. The Ew values were in the ranges of 70.69-73.74% and 74.07-79.07% at inclined angles of 4° and 5°, respectively. The increase of inclined angle can decrease the time for size grading, leading to higher size grading efficiency. However, the Ew value was significantly decreased when increasing inclined angle from 5 to 6°; the Ew values were decreased to the ranges of 69.69-73.22%. Although the size grading time was decreased when increasing inclined angle from 5 to 6° but the increase of inclined angle from 5 to 6° provided the excess movement speed of green coffee bean, leading to the higher incorrect category dropping, and resulting in the decrease of size grading efficiency. This result was similar to that reported by Gunathilake et al. [7] who observed the evaluation of a size grading machine for onion. They stated that the grading efficiency was higher when increase of inclined angle from 2 to 3° and it was lower with increasing inclined angle from 3 to 4°. When comparing the Ew value between size grading machine using oscillating sieve with swing along width direction and the size grading machine of SMEs in Chumphon province, it seem that the size grading machine using oscillating sieve with swing along width direction provided the higher Ew value than the size grading machine of SMEs in Chumphon province (60.09%) in every condition.

**Table 2.** The size grading efficiency (Ew) of size grading machine using oscillating sieve with swing along width direction at various conditions.

| Inclined angle (Degree) | Oscillating revolution speed (RPM) | Size grading efficiency (Ew; %) |
|-------------------------|----------------------------------|---------------------------------|
|                         | 170                              | 71.47 ± 0.27                    |
|                         | 185                              | 73.74 ± 0.36                    |
|                         | 200                              | 70.69 ± 0.82                    |
| 4                       | 170                              | 75.23 ± 0.51                    |
|                         | 185                              | 79.07 ± 0.19                    |
|                         | 200                              | 74.07 ± 0.48                    |
| 5                       | 170                              | 71.99 ± 0.40                    |
|                         | 185                              | 73.22 ± 0.27                    |
|                         | 200                              | 69.69 ± 0.39                    |

**Means with different superscripts in the same column are significantly different (p<0.05)**

**Table 3.** The clogging sieve percentage (Cw) of size grading machine using oscillating sieve with swing along width direction at various conditions.

| Inclined angle (Degree) | Oscillating revolution speed (RPM) | Clogging sieve percentage (%) |
|-------------------------|----------------------------------|-------------------------------|
|                         | 170                              | 18.29 ± 0.83                  |
|                         | 185                              | 12.87 ± 1.32                  |
|                         | 200                              | 2.52 ± 0.52                   |
| 4                       | 170                              | 6.05 ± 0.88                   |
|                         | 185                              | 2.89 ± 0.19                   |
|                         | 200                              | 1.96 ± 0.09                   |
| 5                       | 170                              | 3.10 ± 0.32                   |
|                         | 185                              | 2.32 ± 0.22                   |
|                         | 200                              | 1.06 ± 0.05                   |

**Means with different superscripts in the same column are significantly different (p<0.05)**
3.3. The clogging sieve percentage (Cw)

The results for clogging sieve percentage (Cw) of size grading machine using oscillating sieve with swing along width direction at various inclined angles and oscillating revolution speeds are given in Table 3. The Cw value of Robusta green coffee bean which was graded by the size grading machine of SMEs in Chumphon province was about 28.38%. When using size grading machine using oscillating sieve with swing along width direction, it was found that all of the Cw values were lower than 28.38%.

As shown in Table 3, the inclined angle and oscillating revolution speed were significantly affected the Cw value. The Cw values were decreased when increasing inclined angle and oscillating revolution speed. These results implied the size grading machine using oscillating sieve with swing along width direction can increase the distribution of green coffee bean, leading to lower green coffee bean press and resulting in the low Cw value.

4. Conclusions

The size grading machine of green coffee bean using oscillating sieve with swing along width direction can improve the performance of size grading machine. It provided the high weight purity index (94.03% maximum) and size grading efficiency (79.07% maximum) and low clogging sieve percentage (1.06% minimum). The appropriate condition for using the size grading machine of Robusta green coffee bean using oscillating sieve with swing along width direction is the inclined angle of 5 degree and the oscillating revolution speed of 185 rpm. This condition provided the weight purity index of 86.11%, the size grading efficiency of 79.07% and clogging sieve percentage of 2.89%. These performance values were better than the performance values of size grading machine of SMEs in Chumphon province. In addition, the performance of size grading machine was decreased when increasing oscillating revolution speed. When increasing the inclined angle from 4 to 6 degree, the weight purity index and the clogging sieve percentage were decreased. The size grading efficiency was increased with increasing the inclined angle from 4 to 5 degree and decreased when increasing the inclined angle from 5 to 6 degree.

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