

The Specific Energy Consumption of Robusta Coffee Bean Separating

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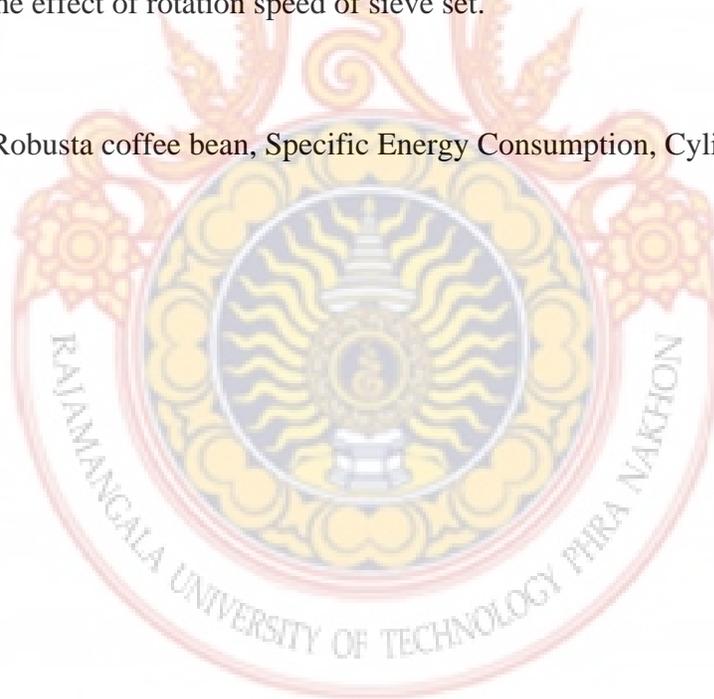
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Abstract

The aim of this research is to design and create the sorting machine within the engineering knowledge by using the three-layer sieve set cylindrical sorting machine under the various conditions of experimental. Furthermore, the Specific Energy Consumption [SEC] of Robusta coffee bean separates, the standard size of Robusta coffee bean, the total of product separated are regarded.

For the experiment condition, rotation speed adjustable to 9.6 and 14.4 rpm. The raw material flow through to sieve and determination the standard size for calculating the [SEC]. The result of experiment found that the average of total of product separated was 165.1 kg/hr. and 164.7 kg/hr or 99.57% from that were passed the criteria of standard according to the ministry of agriculture cooperative. In order to the [SEC], the cylindrical sorting machine was 0.01631 MJ/kg at 14.4 rpm of rotation speed. However, the values of [SEC] may be change from the effect of rotation speed of sieve set.

Key words: Robusta coffee bean, Specific Energy Consumption, Cylindrical sorting machine.



1. Introduction

In Thailand the Arabica and Robusta coffee are cultivated in northern and southern local. Arabica and Robusta coffee are discriminated by the chemical composition. By the ratios of Arabica and Robusta coffee product is 10:90 by volume [1,2,3,4]. With the quantity of product, the Robusta coffee is determined. For the Robusta coffee can be cultivates specially the southern local due to the weather in the southern of Thailand were the tropical with average temperature 25-34 degree Celsius and the rainfalls all the year. More than 60% of Robusta coffee was product from Kho Talu district on Chumphon province and remains on the Ranong, Suratthani, Krabi and Nakhon Si Thammarat provinces. Normally the all of Robusta coffee beans after harvested were dry and size chosen before wholesale to middleman.

If the agriculturist wants to enhance the cost of coffee such as the drying before bring grain have to small-sized, in order to process for coffee powder. But in fact, produce coffee many quantities append with a many capitals in the change status, the agriculturists can do just select coffee size according to standardized only.

For the coffee bean separation system, the size chosen based on labor experience in order to achieve the failure of period time and quality. However, the sale price of coffee bean depended on the sizing and quality according to the standard of the ministry of agriculture cooperative and the ministry of commerce, Thailand. Furthermore, the policy of ministry of energy that tries to give the entrepreneur considers the energy using which emphasizes to the energy requirement per unit of product so called Specific Energy Consumption [SEC]. Therefore; [SEC] should consider

for the advantage in the investment and also realized to the environmental effect.

2. Standard and policy in Thailand

The criteria of the Robusta coffee bean in Thailand was specified for 2 standards by the garden plants research institute standard of the ministry of agriculture cooperative and the standard of department of internal trade of the ministry of commerce. Both standards were issued to lay down regulation of Robusta coffee bean quality and the contentment with every side.

2.1 The garden plants research institute standard [5]

According to this standard, (12 species of Thai and 3 species for foreign countries), the quantity of weight (15.97-17.95 g) per 100 coffee beans by dry weight was determined.

2.2 Department of internal trade standard [6]

The criteria of the department of internal trade will be use the quantity of fault and contamination of coffee beans which shown as following:

- (a) The coffee beans must be having been natural color and smell, not be rotten and moldy.
- (b) The total moistness must be not exceed to 13%
- (c) The total fault must be not exceed to 7% by weight

2.3 The policy of ministry of energy [7]

Nowadays, the [SEC] is that wish topmost of the policy of ministry of energy in Thailand. There are need to control the energy using in the industries include the comparison with the same kind of product. By the values of [SEC] will introspect from the energy requirement per quantity of products. The equation for [SEC] is derived in the following (Eq-1) and the energy requirement shown in (Eq-2):

$$[SEC] = \frac{*3.6Q_e + Q_{th}}{Q_p} \quad (\text{Eq-1})$$

$$Q_e = \frac{PT}{1000} \quad (\text{Eq-2})$$

Where:

[SEC]= Specific Energy Consumption
(MJ/kg)

Q_e = Electrical energy requirement
(kW-hr)

Q_{th} = Thermal energy requirement
(MJ)

Q_p = Quantity of products (kg)

P = Power of electrical (W)

T = Using electrical time (hr)

Note: *3.6 is the factor to convert the unit of electrical energy into the unit of thermal energy.

3. Methodology for investigation of Specific Energy Consumption

To achieve this objective, the Specific Energy Consumption [SEC] of Robusta coffee bean separates with the various conditions of experimental such as rotation speed, angle incline and the standard size of Robusta coffee bean are considered by using the three-layer sieve set cylindrical sorting machine (see Fig 1) and the sorting machine specification illustrated in Table 1.

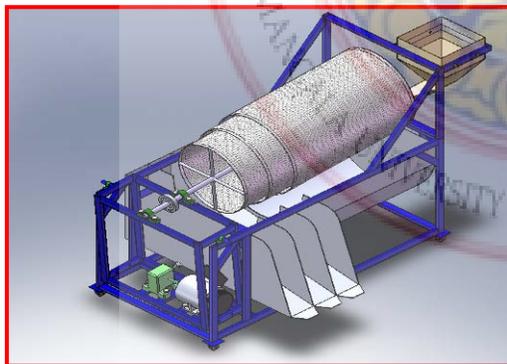


Fig 1. The three-layer sieve set cylindrical sorting machine

Table 1. Sorting machine specification

| Item | Value |
|---|-----------------|
| Dimension W x L x H (m) | 0.8 x 1.7 x 1.4 |
| Distance, CG to longitudinal (m) | 0.86 |
| Diameter of three - layer sieve set (inner, middle and outer) (m) | 0.5, 0.6, 0.7 |
| Diameter of hole sieve (inner, middle and outer) (mm) | 4, 6, 7.5 |
| Total weight (kg) | 87 |
| Power of electrical motor (W) | 746 |
| Rotation speed of sieve set (rpm) | 14.4, 9.6 |

3.1 Preparation of Robusta coffee bean

Before sort out the coffee bean (Pato species, Thai coffee), it was firstly removed the outermost shell so call green coffee (see Fig 2a) by using the milling machine. Then the green coffee was making a dry on 13% of total moistness. By the total moistness was solution with dry out by sun on the cement filed, approximate 15-20 days [5] and rechecked the total moistness by using the moisture meter model Lutron MS-7000 (see Fig 2b).



(a)

(b)

Fig 2: (a) green coffee (b) moisture meter

3.2 Test condition

The experiment in this research will consider the quantity comes to that sorting out for green coffee which has standard size with the various rotation speed and angle incline. By two the relation between rotation speed and angle incline are significant to the total product after separated. Because of the highest product separated will occurring at the maximum efficiency of sorting machine and effect to the low electrical energy requirement. Moreover, the [SEC] will confirm to the standard size of green coffee only. By the way, the standard size of green coffees were enforced with the size of sieve and rechecked by weight measurement with digital balancing.

To obtain the rotation speed, there are two types of speeds application with low and hi speed by 9.6 and 14.4 rpm. respectively. In past of angle incline, there are adjustable with 2, 3 and 4 degrees.

3.3 Procedure in the experiment

Firstly, bring the green coffee has that the moistness not exceed to 13% and then flows in to the raw material container. The second set the rotation speed at 9.6 rpm. and also the angle incline was set at 2 degree. Then the green coffee was separated throughout the several holes sieve within 1 hour by 3 times to find the average of total product and change the angle incline to 3 and 4 degree respectively. After success in the first rotation speed, the second speed is determined and changed the angle incline like a first condition. Finally, the results of green coffee separated must be inspected for using to calculate the [SEC]. The procedure of experiment displayed in Fig 3.



(a)



(b)

Fig 3: (a) green coffee (b) coffee bean separated by sorting machine

4. Results and discussion

4.1 Investigation [SEC] with low speed

Under the low speed condition (9.6 rpm), the green coffees were separated throughout the three-layer sieve set cylindrical 7.5, 6 and 4 mm (see Fig 4). with angle incline 2, 3 and 4 degree. The result of experiment illustrated in Table 2, 3 and 4 respectively.

Table 2. Angle inclines at 2 degree

| No | Weight of green coffee (kg) | | | | |
|------|-----------------------------|------|------|---------------|-------|
| | 7.5 mm | 6 mm | 4 mm | remnant < 4mm | total |
| 1 | 12.4 | 72.4 | 27.6 | 0.4 | 112.8 |
| 2 | 12.0 | 73.2 | 28.8 | 0.2 | 114.2 |
| 3 | 12.8 | 74.0 | 28.4 | 0.2 | 115.4 |
| Avg. | 12.4 | 73.2 | 28.3 | 0.27 | 114.1 |

Table 3. Angle inclines at 3 degree

| No | Weight of green coffee (kg) | | | | |
|------|-----------------------------|------|------|---------------|-------|
| | 7.5 mm | 6 mm | 4 mm | remnant < 4mm | total |
| 1 | 15.0 | 65.2 | 66.4 | 0.4 | 147.0 |
| 2 | 14.0 | 76.0 | 67.2 | 0.2 | 157.4 |
| 3 | 14.2 | 74.0 | 66.0 | 0.4 | 154.6 |
| Avg. | 14.4 | 71.7 | 66.5 | 0.34 | 153 |

Table 4. Angle inclines at 4 degree

| No | Weight of green coffee (kg) | | | | |
|------|-----------------------------|------|-------|---------------|-------|
| | 7.5 mm | 6 mm | 4 mm | remnant < 4mm | total |
| 1 | 12.0 | 78.8 | 67.0 | 0.2 | 158.0 |
| 2 | 14.0 | 76.6 | 62.0 | 0.4 | 153.0 |
| 3 | 13.6 | 78.0 | 65.2 | 0.4 | 157.2 |
| Avg. | 13.2 | 77.8 | 64.74 | 0.34 | 156.1 |

From Table 2, 3 and 4, shows the highest product separated was 156.1 kg on an angle incline at 4 degree. However, the green coffees must be checked according to the standard of Thailand. These results are illustrated in Table 5.



(b)



(c)



(a)



(d)

Fig 3: (a) 7.5mm (b) 6 mm (c) 4 mm (d) remnant

Table 5. Comparing the green coffees between both standards

| Sieve size (mm) | Standard | | | |
|-----------------|--------------------|------|------|------|
| | 1 (15.97-17.95) | 2 | | |
| | | (a) | (b) | (c) |
| 7.5 | 17.44 (pass) | pass | pass | pass |
| 6 | 16.82 (pass) | pass | pass | pass |
| 4 | 16.35 (pass) | pass | pass | pass |
| remnant | 9.27 (not) | not | pass | not |

Note:

Standard 1 = the garden plants research institute standard

Standard 2 = department of internal trade standard

The result from Table 5 was disclosed to the product after sorting out by three-layer sieve set can be passed to the both standards. But in case of the remnant can be passed in order to standard 2(b) only. Thus, the total product from sieve size 7.5, 6 and 4 mm. can be used to calculate the value of [SEC] and revealed in Table 6.

Table 6. Results of calculating [SEC]

| Angle incline | Q_p (kg) | Q_e (kW-hr) | Q_{th} (MJ) | [SEC] (MJ/kg) |
|---------------|---------------|------------------|------------------|------------------|
| 2 | 113.87 | 0.746 | 0 | 0.02358 |
| 3 | 152.67 | 0.746 | 0 | 0.01759 |
| 4 | 155.73 | 0.746 | 0 | 0.01724 |

The results from Table 6 shown that the highest product (Q_p) separated occur at the maximum angle incline and continuously decrease when the angle incline decreases. For the electrical energy requirement (Q_e) of every cases are valuable be equal because of the time using in experiment is 1 hour. In order to the thermal energy requirement (Q_{th}) was disappeared due to sorting machine

uses especially electrical energy only. In case of [SEC] is calculated by applying the Eq-1 and Eq-2. Based on the highest (Q_p) and constant (Q_e), the values of [SEC] was lowest at the maximum angle incline or there is depended on (Q_p).

4.2 Investigation [SEC] with hi speed

Based on hi speed condition (14.4 rpm), the procedure of experiment is the same with the low speed condition. The results of test revealed in Table 7-9. By the standard comparison and [SEC] calculating were disclosed in Table 10 and 11.

Table 7. With 2 degree of angle incline

| No | Weight of green coffee (kg) | | | | |
|------|-----------------------------|------|------|---------------|-------|
| | 7.5 mm | 6 mm | 4 mm | remnant < 4mm | total |
| 1 | 16.0 | 76.0 | 48.0 | 0.4 | 140.4 |
| 2 | 11.6 | 78.0 | 47.2 | 0.4 | 137.2 |
| 3 | 12.4 | 78.4 | 48.4 | 0.4 | 138.6 |
| Avg. | 13.3 | 77.5 | 47.5 | 0.4 | 138.7 |

Table 8. With 3 degree of angle incline

| No | Weight of green coffee (kg) | | | | |
|------|-----------------------------|------|------|---------------|-------|
| | 7.5 mm | 6 mm | 4 mm | remnant < 4mm | total |
| 1 | 16.0 | 92.4 | 40.0 | 0.4 | 148.8 |
| 2 | 16.8 | 94.8 | 43.2 | 0.4 | 155.2 |
| 3 | 16.4 | 93.6 | 41.2 | 0.4 | 151.6 |
| Avg. | 16.4 | 93.6 | 41.5 | 0.4 | 151.9 |

Table 9. With 4 degree of angle incline

| No | Weight of green coffee (kg) | | | | |
|------|-----------------------------|-------|------|---------------|-------|
| | 7.5 mm | 6 mm | 4 mm | remnant < 4mm | total |
| 1 | 16.4 | 106.0 | 43.2 | 0.4 | 166.0 |
| 2 | 20.0 | 102.4 | 43.2 | 0.4 | 166.0 |
| 3 | 19.2 | 99.6 | 44.0 | 0.4 | 163.2 |
| Avg. | 18.5 | 102.7 | 43.5 | 0.4 | 165.1 |

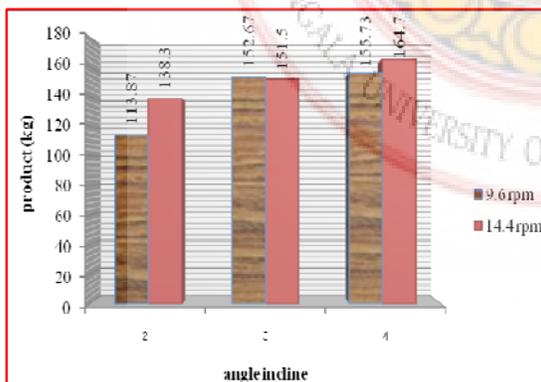
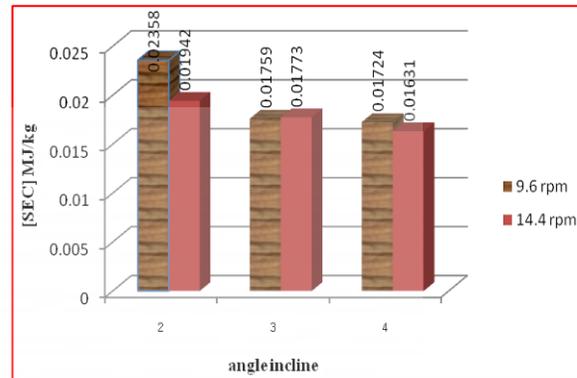
Table 10. Standard Comparison of hi speed

| Sieve size (mm) | Standard | | | |
|-----------------|--------------------|------|------|------|
| | 1 (15.97-17.95) | 2 | | |
| | | (a) | (b) | (c) |
| 7.5 | 17.69 (pass) | pass | pass | pass |
| 6 | 16.68 (pass) | pass | pass | pass |
| 4 | 16.17 (pass) | pass | pass | Pass |
| remnant | 8.19 (not) | not | pass | not |

Table 11. Calculating result of [SEC] with hi speed condition

| Angle incline | Q_p (kg) | Q_e (kW-hr) | Q_{th} (MJ) | [SEC] (MJ/kg) |
|---------------|---------------|------------------|------------------|------------------|
| 2 | 138.3 | 0.746 | 0 | 0.01942 |
| 3 | 151.5 | 0.746 | 0 | 0.01773 |
| 4 | 164.7 | 0.746 | 0 | 0.01631 |

The results from Table 7-9 disclosed to 4 degree of angle incline can be provided the maximum sorting out with 165.1 kg or highest efficiency. Alternatively, the sieve size 7.5, 6 and 4 can be passed according to the standard of Thailand. By the way, the lowest [SEC] has been 0.01631 MJ/kg. It was related between angle incline and sorting out quantity that standardized. However, the highest product separated and [SEC] between low and hi speed are compared and displayed in Fig 4 and 5.

**Fig 4. Product separated comparison****Fig 5. [SEC] comparison**

By the results of product separated comparison, the hi rotation speed can be provided the quantity of green coffee more than low speed arrives to 17.7% at lowest angle incline. At the same time, another angle inclines never affect to amount of product neither low or hi rotation speeds. In additional, the results of [SEC] comparison were similar with product separated, because the value of [SEC] depended on amount of product separated.

5. Conclusions

An amount of Specific Energy Consumption [SEC] was directly affected from the sorting out quantity that standardized with optimum point of design of Robusta coffee bean separating machine by engineering knowledge. In additional the results of test can be indicated to the ability of this machine to prepare the green coffee that standardized which important factor to [SEC]. This research is not only to consider the [SEC]. But, it benefits to agriculturist who want to enhance the value produces.

6. Acknowledgements

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7. References

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