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Evaluation of Breaking and Deshelling Machine of Roasted Cocoa Beans

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ABSTRACT

The manual cracking and separation of cocoa beans' husk result in low working productivity, a high percentage of broken beans, and the difficulty of separating cocoa nibs from the husk. This poses a challenge for both farmers and industrial players in cocoa bean management, leading to the development of a cocoa bean dehusking machine (desheller). This study was conducted to analyze the performance of the cocoa bean dehusking machine. The research involved motor speeds of 500, 700, and 900 rpm, combined with roasted cocoa bean grades AA, A, and B. The observed parameters included working capacity, yield, nib percentage, percentage of husk adhering to nibs, power transmission efficiency, and power requirements. The working capacity of the cocoa bean deshelling machine ranged from 17,413 to 41,481 kg/h, with yields between 73.83% and 80.83%. The nib percentage varied from 92.13% to 98.61%, while the percentage of husk adhering to nibs ranged from 1.08% to 6.92%. Power transmission efficiency was between 92.24% and 94.14%, and power requirements ranged from 601.33 to 645.33 watts. The best treatment in this study was found at a motor speed of 900 rpm with cocoa bean grade of AA.

1. INTRODUCTION

Cocoa (*Theobroma cacao* L.) is one of several plantation commodities in Indonesia that plays a significant role in the national economy for increasing foreign exchange (Hartuti *et al.*, 2020). Cocoa bean production in Indonesia was 593.3 thousand tons in 2015, rising to 767.28 thousand tons in 2018, representing an increase of 29.32% (BPS, 2019).

Post-harvest activities are essential for improving the quality of agricultural products. Various measures need to be taken for agricultural commodities after harvest until they reach the hands of consumers. According to Mutiarawati (2007), post-harvest activities for agricultural products (including cocoa) can be categorized into two types: primary processing and secondary processing. Secondary processing of cocoa aims to alter the physical or chemical form through several stages of processing. One crucial stage in secondary processing is the husk removal process for roasted cocoa bean. Separation of the husk from the cocoa nib after roasting is a critical step that significantly influences the final product's quality, both in food and beverage applications (Widyotomo *et al.*, 2007; Afoakawa, 2014).

The manual process of breaking cocoa beans involves pounding with a mortar made of stone or clay, while the separation of the husk (shell) from the cocoa nibs is done using a circular-shaped tray or winnowing basket made of woven bamboo. The manual bean breaking and husk separation methods have some drawbacks, including low working productivity and a high percentage of broken beans, making it challenging to separate the cocoa nibs from the husk (Widyotomo *et al*., 2007). This poses a challenge for farmers and industry players in cocoa bean management, leading to the development of a cocoa bean desheller machine. This study aims to analyze the performance of the cocoa bean desheller machine.

2. RESEARCH METHODS

2.1. Materials and Tools

The instruments used included a cracking and husking machine (Figure 1) for roasted cocoa bean. This desheller machine had overall dimensions (L x W x H) of 1030 x 730 x 1360 mm equipped with cylindrical knife type. The driving force was an electric motor with specifications of 0.5 HP power, single phase, 220 volts voltage, 4.5 amperes current, and 1400 rpm rotation speed. The power transmission system from the driving force to the cracking cylinder used pulleys and V-belts. In addition, the desheller machine is equipped with a blower to separate nibs from their husks, with specifications including a 76.2 mm hole diameter, single phase, 220-volt voltage, 2 ampere current, and 3000 rpm rotation speed. The research materials included roasted cocoa beans of AA grade (≤85 beans/100 grams), A grade (86-100 beans/100 grams), and B grade (101-110 beans/100 grams).

Figure 1. Desheller machine for cracking and husking the roasted cocoa beans

2.2. Research Method

This research was conducted from April to June 2022 at the Indonesian Coffee and Cocoa Research Center (PUSLITKOKA) located in Nogosari Village, Rambipuji District, Jember Regency. The research stages included field surveys, literature studies, preparation of tools and materials, machine performance tests, and data analysis. The machine testing were conducted with several observation parameters, including work capacity testing, yield, percentage of nibs, percentage of husks attached to nibs, power transmission efficiency, and power requirements for the cocoa bean cracking and husking machine. The data analysis used linear regression analysis and the effectiveness index method (DeGarmo *et al.*, 1984). The treatment labeling matrix in this research is presented in Table 1.

Table 1. Treatment labeling matrix for cocoa bean husk deshelling

Cocoa bean size post-roasting	Motor rotation speed (rpm)		
	500	700	900
AA	A1	B1	C1
A	A2	B2	C2
B	A3	B3	C3

Table 2. Characteristic of cocoa beans based on grade quality.

No.	Cocoa bean size	Length (cm)	Width (cm)	Thickness (cm)	Weight (g)
1	AA	2.251	1.162	0.647	2.667
2	A	2.122	1.061	0.681	2.000
3	B	1.727	0.851	0.419	1.333

Furthermore, post-roasting cocoa bean cracking and husking using the machine depicted in Figure 1 were carried out to separate the bean contents from the husks (Fahrurrozi *et al*., 2020). Measuring the weight of post-roasting cocoa beans is also necessary to determine the weight per bean, facilitating the design of agricultural equipment or machinery, especially post-roasting cocoa bean cracking and husking machines. The dimensional and weight data of cocoa beans according to their quality grade was presented in Table 2.

2.3. Parameters

Important parameters to be observed were as the following.

1. Working capacity (K_{pi}) (BSN, 2013)

$$K_{pi} = \frac{M_t}{t} \tag{1}$$

where M_t is the weight of roasted cocoa beans (kg), and t is the time for the cracking and dehusking process (h).

2. Yield (BSN, 2013)

$$R_e = \frac{M_{kkb}}{M_t} \times 100\% \tag{2}$$

where R_e is yield (%), and M_{kkb} is the weight exiting from the nib outlet chute (kg).

3. Percentage of nibs (cocoa bean cleanliness level, B_{kb}) (BSN, 2013)

$$B_{kb} = \frac{M_{kb}}{M_{kkb}} \times 100\% \tag{3}$$

where M_{kb} is the weight of cocoa nibs from the nib outlet chute (kg).

4. Percentage of husks attached to nibs, KTN (Wicaksono *et al.*, 2017)

$$KTN = \frac{M_{bk}}{M_{kb}} \times 100\% \tag{4}$$

where KTN is in %, M_{bk} is the weight of husks adhered to nibs (kg).

5. Power transmission efficiency (Wicaksono *et al.*, 2017)

$$\eta = \frac{D_2 \times N_2}{D_1 \times N_1} \times 100\% \tag{5}$$

where η is the power transmission efficiency (%), D_1 and D_2 is the pulley diameter (m) of the driving motorand the rotating blade, N_1 and N_2 is the rotation speed (rpm) of the driving pulley and the driven pulley.

6. Power Requirement (Widyotomo *et al.*, 2005)

$$P = I \times V \tag{6}$$

where P is the electrical power (W), I is the electric current (A), and V is the electric voltage (V).

3. RESULTS AND DISCUSSION

In order to facilitate the design process of agricultural machinery and equipment, material dimensions are important parameters that need to be measured (Pangaribuan *et al*., 2016). Apart from that, to ensure that the performance of agricultural equipment and machinery can be operated optimally, it is necessary to carry out a work evaluation (Prabowo, 2020; Amran *et al*., 2017). It is also necessary to measure the weight of post-roasted cocoa beans to determine the weight per bean so that the design of agricultural equipment or machine, especially machine for breaking and peeling post-roasting cocoa beans, can be performed easily.

3.1. Working Capacity

Cocoa beans, once weighed, are fed into the hopper of the breaking and peeling machine. The relationship between the rotational speed of the desheller rotor and the working capacity of the breaking and peeling can be observed in Figure 2. Cocoa beans enter the breaking and peeling machine chamber and come out in chip form due to the friction mechanism between the inner chamber wall acting as the stator and the cylinder with blades acting as the rotor. Meanwhile, the process of separating the skin from the cocoa bean components is done using the using air suction from a centrifugal blower and make use of the mass desity differences. Cocoa bean skins, which are relatively lighter than the cocoa bean kernels, can be easily separated due to the air suction mechanism (Shahama *et al*., 2020).

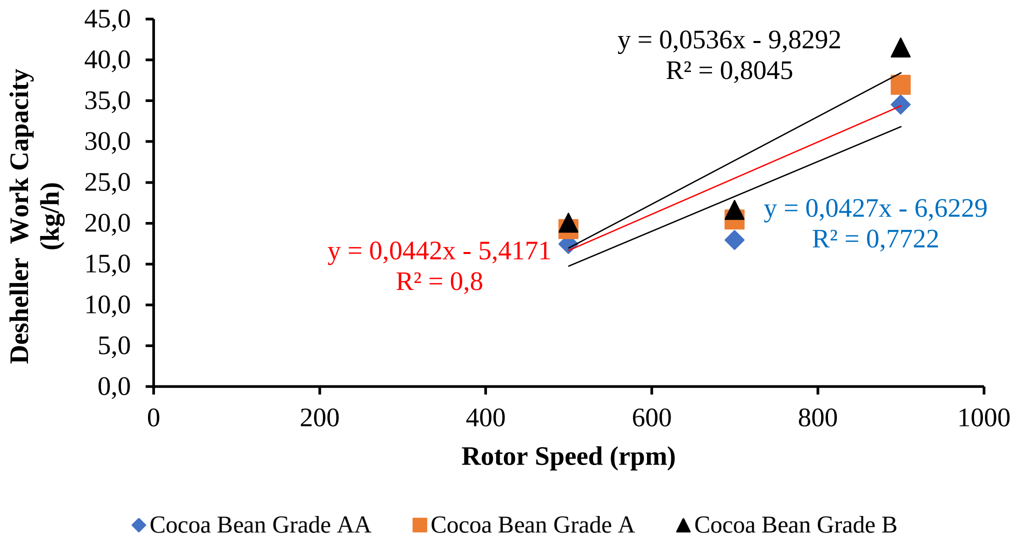

Figure 2. Relationship between the rotational speed of the desheller rotor and working capacity for different cocoa bean grades

Based on Figure 2, the rotational speed of the cocoa bean breaking and peeling machine rotor has a positive correlation with the working capacity of the machine for all bean grades. This is because the faster the rotor rotation, the shorter the time required to break and peel cocoa beans. With the increase in the rotational speed of machine rotor, the frequency of encounters between the rotor and stator also increases, resulting in more cocoa beans being broken and peeled (Widyotomo *et al.*, 2005). This consistent with the research conducted by Wicaksono *et al.* (2017), stating that an increase in the rotational speed of the rotary blades enhances the frequency of friction between cocoa beans and rotary blades, as well as among cocoa beans themselves. On the other side, Andasuryani *et al*. (2015) stated that the volume and surface area of cocoa beans are strongly influenced by the axial dimensions of the cocoa beans. The greater the volume and surface area of the cocoa beans, the larger the size group of the cocoa beans.

3.2. Yield

Yield is the ratio between the weight of the broken and peeled products that come out of the chute and the initial weight of roasted cocoa beans (BSN, 2013). The relationship between the rotational speed of the machine rotor and the yield of the breaking and peeling process can be seen in Figure 3. According to Figure 3, the highest yield is obtained at a rotor speed of 900 rpm for cocoa beans grade B, namely 87.75%. The yield in this study has met the requirements according to SNI 7805:2013 regarding quality requirements and test methods for cocoa bean breaking and skin separating machines, which stipulate a minimum yield of 80% for cocoa bean breaking and peeling machines. Figure 3 also shows that as the rotor speed increases, the yield obtained also increases. The relationship between variable X (rotor rotational speed) and variable Y (yield of breaking and peeling) at various rotor speeds (500, 700, and 900 rpm) has R^2 values of respectively 0.9821, 0.9007, and 0.8037. According to Raykov & Marcoulides (2013), R^2 values of 0.8 – 0.99 imply a very strong correlation between variable X and variable Y.

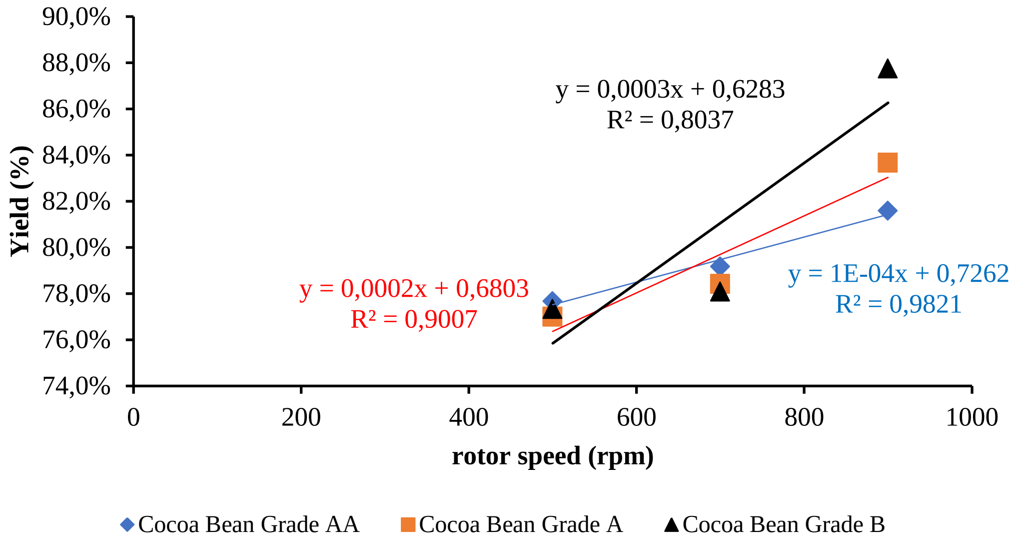

Figure 3. Relationship between the rotor speed of the desheller and yield for different cocoa bean grades

The principle of breaking and peeling cocoa beans using a desheller is to utilize friction between the beans and the rotor and friction between beans themselves so that the beans break and the husk peels off. Therefore, increasing the rotor rotational speed will increase the frequency of friction between cocoa beans and the rotor, as well as friction between cocoa beans themselves. Using rotor speeds of 500, 600, 750, and 900 rpm, Hasyim (2015) found a proportional increase in the yield obtained with the speed increasing of disk-type cocoa bean skin peeler. This is because the higher the disk speed, the fewer the percentage of unpeeled beans or poorly peeled beans, resulting in increased peeling effectiveness.

3.3. Nib Percentage

The process of separating nibs from their skin is a process that must be done after cocoa beans are roasted and have undergone tempering. Nibs are the main part of cocoa beans that will be processed into food or beverages. The percentage of nibs resulted using a desheller can be seen in Figure 4. High working capacity of the desheller machine does not guarantee the best operational condition of the machine because the working capacity of the cocoa bean breaking and peeling machine is not directly proportional to the percentage of nibs produced. According to Widyotomo *et al.* (2005), a high work capacity of the cocoa bean breaking and peeling machine cannot be used as a reference for determining the optimal operating conditions of the machine because the quality of the breaking and skin separating results of cocoa beans is also determined by the percentage of bean fragments (nibs) and the percentage of skin attached to the nib obtained from the chute. Based on Figure 4, the percentage of nibs at various rotor speeds decreases as the size of the beans decreases. The highest nib amount at a rotor speed of 500 rpm is found in size AA cocoa beans with a nib percentage of 98.61%. Furthermore, at a rotor speed of 700 rpm, the highest nib percentage is found in size AA cocoa beans at 97.69%. Similarly, at a rotor speed of 900 rpm, the highest nib percentage is also found in size AA cocoa beans at 97.47%. This indicates that as the quality of cocoa bean size decreases, the obtained nibs also decrease. This study is in line with the research conducted by Wicaksono et al. (2017) using AA, A, and B sized cocoa beans, which produced the highest nibs in AA sized cocoa beans at rotor speeds of 100, 175, and 250 rpm.

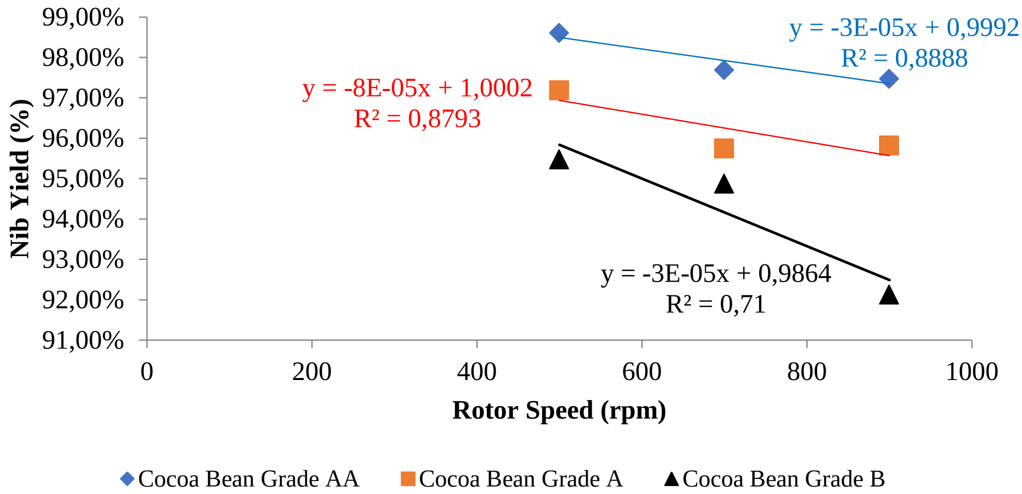

Figure 4. Percentage of cocoa bean nibs for different cocoa bean grades

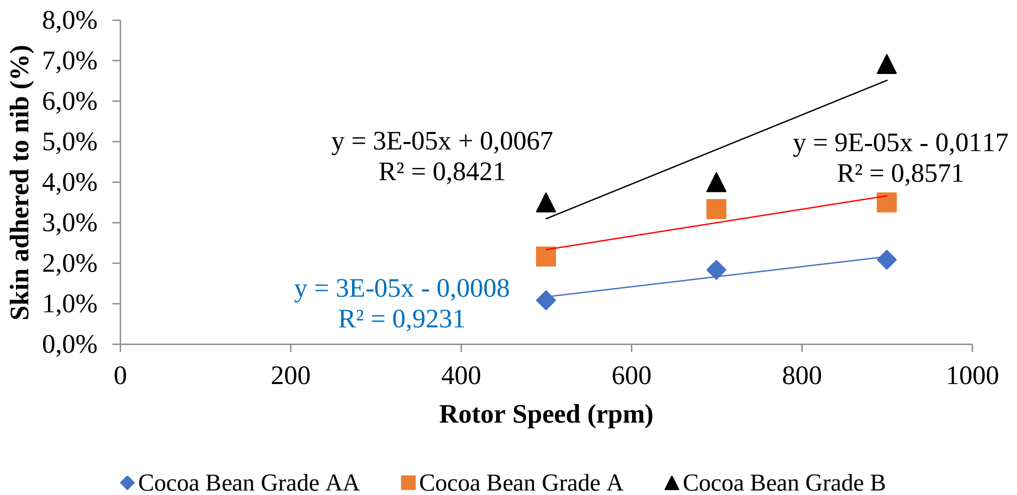

Figure 5. Percentage of skin adhered to nibs for different cocoa bean grades

3.4. Percentage of Skin Adhered to Nibs

Cocoa beans consist of two main components: nibs and shells or skins. Skin adhered to nibs is the percentage of skin mixed with nibs in the product chute. The percentage of skin adhered to nibs is calculated based on the ratio of skin weight to the total weight of roasted cocoa beans. This skin separation process is critical as it directly relates to the purity of the final product. The percentage of skin adhered to nibs using a desheller can be seen in Figure 5. Based on Figure 5, the percentage of cocoa bean husk increases with the rotor speed. The highest husk percentage is found at a rotor speed of 900 rpm with a cocoa bean size of B measuring 6.92%. Meanwhile, the lowest husk percentage is found at a rotor speed of 500 rpm, measuring 1.08%. Figure 4.8 also indicates that higher rotor speeds result in higher percentages of husk adhering to the nib. Faster rotation of the rotary blades leads to an increased frequency of bean breakage, resulting in smaller nib and cocoa husk chip sizes. Smaller cocoa husk chip sizes tend to facilitate mixing and adherence to the surface of nib particles rich in fat. This phenomenon causes more cocoa husk chips to be mixed within the cocoa bean pieces with faster rotation of the rotary blades (Widyotomo *et al*., 2005).

Figure 5 also shows that the percentage of husk adhering to the nib increases as the cocoa bean size decreases at various rotor speeds. Wicaksono *et al.* (2017) stated that smaller cocoa bean sizes contain higher husk contents, thus resulting in fewer nib contents. According to the Indonesian National Standard (BSN, 2009) on cocoa mass, the maximum tolerance limit for adhering husk is 1.75%. Excessive husk percentages adhering to the nib result in high cellulose content, which impacts the subsequent processing of the nib. Therefore, adjusting the distance between the rotor and stator is considered an alternative to minimize husk adhering to the nib in the desheller. By adjusting the distance between the rotor and stator, cocoa bean cracking and peeling machines can adapt to the predetermined cocoa bean size, thus achieving effective peeling. According to Widyotomo *et al.* (2011), adjusting the distance between the rotor and stator in a three-cylinder horizontal fruit skinning machine can yield good peeling results.

3.5. Power Transmission Efficiency

Power transmission efficiency is one of the performance test parameters for determining the optimal operating conditions of a machine. The power transmission efficiency of cocoa bean cracking and peeling machines is determined based on the difference in rotation values between the driving motor and the peeling unit (rotor). The power transmission efficiency of cocoa bean cracking and peeling machines can be seen in Figure 6. The power generated by the driving motor is transmitted to the peeling unit (rotor) through a specific power transmission system. The power transmission system used in cocoa bean cracking and peeling machines is pulleys and V-belts. Choosing the appropriate transmission system can minimize power loss during machine operation. According to Widyotomo *et al.* (2011), the advantages of

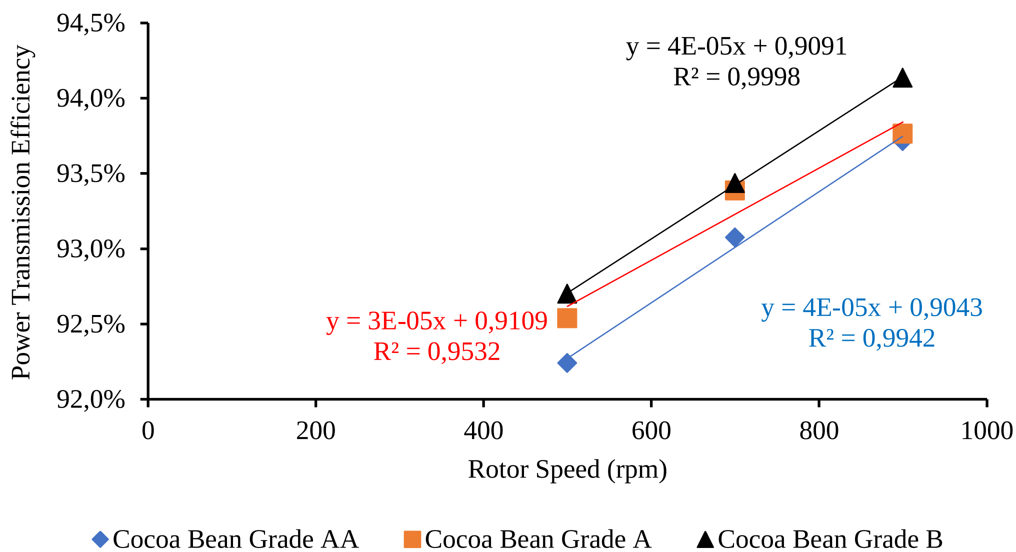

Figure 6. Percentage of skin adhered to nibs for different cocoa bean grades

using a pulley and V-belt transmission system include ease and affordability in terms of maintenance and replacement of transmission components, and, most importantly, if a sudden process jam occurs, it will not immediately negatively impact both the driving motor and the peeling unit (rotor). However, the disadvantage of using the pulley and V-belt transmission system is that not all driving power can be transmitted to the peeling shaft due to a decrease in transmission efficiency. A decrease in power transmission efficiency can occur due to insufficient grip of the rubber belt on the pulley or the rubber belt surface becoming smooth due to heat generated during the process (Firmanto *et al*., 2016).

Based on Figure 6, power transmission efficiency increases with the increasing rotor speed of cocoa bean cracking and peeling machines. The highest power transmission efficiency is obtained at a rotor speed of 900 rpm and the lowest at a rotor speed of 500 rpm. This occurs because higher speeds result in rapid friction between the rotor and cocoa beans, allowing the rotary blades to rotate without hindrance. According to Wicaksono *et al.* (2017), their research showed an increase in power transmission efficiency with increasing rotor speed. The highest power transmission efficiency is obtained at the highest rotor speed of 250 rpm, measuring 80.21%. Additionally, applying load during machine operation leads to a decrease in rotor speed caused by friction between the material and the surface of the cracking and peeling cylinder, and friction between materials during the cracking and peeling process (Widyotomo *et al*., 2011).

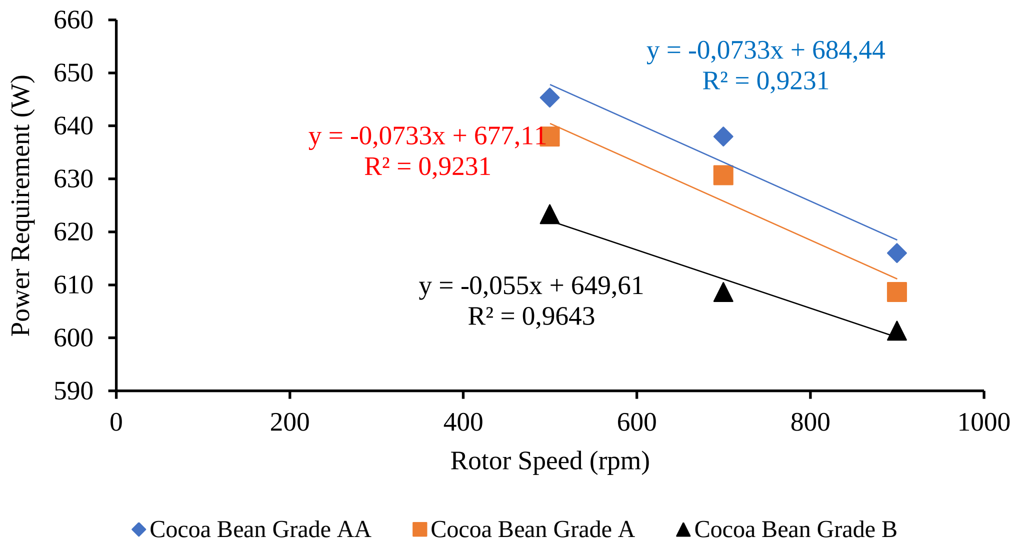

Figure 7. Relationship between desheller rotor speed and desheller power requirements for different cocoa bean grades

3.6. Power Requirements

Power requirements are related to the amount of power expended by a tool or machine to perform work within a certain period. The power requirements of cocoa bean cracking and peeling machines can be seen in Figure 7. Based on the figure, the rotor speed of cocoa bean cracking and peeling machines has a negative correlation with machine power requirements for all bean sizes. The power requirements of cocoa bean cracking and peeling machines in this study are determined by the rotor speed of the machine. This occurs because at a rotor speed of 500 rpm, the pulley used is heavier than the pulley used to change the rotor speed to 700 and 900 rpm. Thus, the power requirements generated at each rotor speed differ with the same post-roast cocoa bean size. According to Ahmed and Rahman (2012), determining the power requirements for grinding or reducing the size of a material for a specific job is difficult. The type of material, moisture content of the material, fineness of the ground or reduced material, feed rate, type and condition of grinding or material reduction machine, etc., all affect power requirements.

3.7. Best Treatment

In this study, to determine the best treatment of cocoa bean cracking and peeling machines, the method of effectiveness index (DeGarmo *et al*., 1984) is employed. The principle of determining the best treatment using the effectiveness index method involves identifying observation parameters and assigning their respective weight values (WP), normal weights (NW), worst data, best data, and treatment data to calculate the effectiveness value (EV). The final step involves determining the result value (RV) obtained by multiplying the effectiveness value (EV) by the normal weight (NW). The treatment with the highest result value (RV) is considered the best treatment. The best treatment for cocoa bean cracking and peeling machines is found at a rotor speed of 900 rpm with cocoa bean size AA. The detailed values for the treatment at a rotor speed of 900 rpm with cocoa bean size AA are shown in Table 3. The prioritization of observation parameters in this study focuses on the working capacity of the roasted cocoa bean cracking and peeling machines because it pertains to the machine's ability to operate and produce products in weight units per time.

Table 3. Detailed values for treatment at rotor speed 900 rpm with cocoa bean size AA

Parameter	Result	Unit
Working capacity	34.499	kg/h
Yield	81.58	%
Nib percentage	97.47	%
Percentage of husk adhering to nib	2.08	%
Power transmission efficiency	93.72	%
Power requirement	601.33	watt

The percentage of husk adhering to the nib is an observation parameter that needs analysis. Post-roasted cocoa bean husks contain a high cellulose content, making them unsuitable for human consumption as they can cause irritation. Additionally, the husk content of cocoa beans also determines the mechanical breaking capacity (Widyotomo *et al*., 2005). The percentage of husk adhering to the nib in the best treatment resulting from this study is 2.08%. According to the Indonesian National Standard (BSN, 2009) on cocoa mass, the maximum tolerance limit for husk adhering is 1.75%. The percentage value of husk adhering to the nib does not meet the established standard. Therefore, adjusting the distance between the rotor and stator is expected to be a solution to minimize the husk adhering to the nib that comes out of the outlet of cocoa bean cracking and peeling machines post-roasting.

4. CONCLUSION

Testing cocoa bean cracking and peeling machines yielded working capacities between 17.41 – 41.48 kg/h, yield results between 77 – 87.75%, nib percentages between 92.13 – 98.61%, percentages of husk adhering to nib between 1.08 – 6.92%, power transmission efficiencies between 92.24 – 94.14%, and power requirements between 601.33 – 645.33 watts. The best treatment for cocoa bean cracking and peeling machines is found at a rotor speed of 900 rpm with cocoa bean grade AA. Testing cocoa bean cracking and peeling machines resulted in high percentages of husk adhering to the nib with increasing rotor speed and decreasing cocoa bean size. Therefore, efforts are needed to minimize husk adhering to the nib by adjusting the rotor-stator distance of cocoa bean cracking and peeling machines post-roasting.

REFERENCES

Afoakwa, E.O. (2014). *Cocoa Production and Processing Technology*. Florida: CRC Press.

Ahmed, J., & Rahman, M.S. (2012). *Handbook of Food Process Design*. New Jersey: Wiley Blackwell.

Amran, A.F., Munir, A.P. & Harahap, L.A. (2017). Rancang bangun alat pengupas kulit tanduk kopi mekanis. *Jurnal Rekayasa Pangan dan Pertanian*, ***5***(1), 149–155.

Andasuryani, A., Putra, N., & Sutan, S.M. (2015). Kajian sifat-sifat fisik buah dan biji kakao (*Theobroma cocoa* L.). *Jurnal Teknologi Pertanian Andalas*, ***19***(1), 1–9.

BPS (Badan Pusat Statistik). (2019). *Statistik Kakao Indonesia*. Jakarta: Badan Pusat Statistik.

BSN (Badan Standarisasi Nasional). 2009. *Standar Nasional Indonesia 3749:2009 Tentang Kakao Massa*. Jakarta: Badan Standarisasi Nasional.

BSN (Badan Standarisasi Nasional). 2013. *Standar Nasional Indonesia 7805:2013 Mesin Pemecah Biji Dan Pemisah Kulit Kakao - Syarat Mutu Dan Metode Uji*. Jakarta: Badan Standarisasi Nasional.

DeGarmo, E.P., Sullivan, W.G., & Canada, J.R. (1984). *Engineering Economy*. 7th Ed. New York: Macmillan Publishing Company.

Fahrurrozi, F., Lisdiyanti, P., Ratnakomala, S., Fauziyyah, S., & Sari, M.N. (2020). *Teknologi Fermentasi dan Pengolahan Biji Kakao*. Jakarta: LIPI Press.

Firmanto, H., Aklimawati, L., & Abdurrizal, B.S. (2016). Performance of roasted cocoa bean winnower for small holder chocolate producers. *Pelita Perkebunan*, ***32***(2), 120–129.

Hartuti, S., Juanda, J., & Khatir, R. (2020). Upaya peningkatan kualitas biji kakao (*Theobroma cacao* L.) melaui tahap penanganan pascapanen (ulasan). *Jurnal Industri Hasil Perkebunan*, ***15***(2), 38-52. http://dx.doi.org/10.33104/jihp.v15i2.6318

Hasyim, M.F. (2015). Modifikasi Desain Dan Uji Kinerja Kontrol Sistem Input Mesin Pengupas Kulit Biji Kakao Tipe Piringan Tunggal. [*Undergraduate Thesis*]. Faculty of Agricultural Technology, Institut Pertanian Bogor.

Mutiarawati, T. (2007). Penanganan pasca panen hasil pertanian. *Workshop Pemandu Lapangan, Sekolah Lapangan Pengolahan dan Pemasaran Hasil Pertanian, Departemen Pertanian*: 1–17.

Pangaribuan, S., Nuryawati, T., & Suprapto, A. (2016). Sifat fisik dan mekanik serta pengaruh penyosohan terhadap sifat fisik dan mekanik biji sorgum varietas Kd 4. *Prosiding Seminar Nasional Pengembangan Teknologi Pertanian*: 81–86.

Prabowo, A. (2020). Sinergitas Pengelolaan Alat Dan Mesin Pertanian (Alsintan) dan Pelayanan Laboratorium Uji Alat dan Mesin Pertanian (Alsintan) Dalam Rangka Meningkatkan Kinerja Di Bidang Pertanian. *Laporan Proyek Perubahan*. Jakarta: Kementrian Pertanian.

Raykov, T., & Marcoulides, G.A. (2013). *Basic Statistics: An Introduction with R*. Lanham: Rowman and Littlefield Publishers.

Shahama, K., Anjaly, M.G., Rajesh, G.K., Sneha, M., Sanjay, P., Palakkeel, A., Narayanan, A., Suresh, A., & Nasrin, J. (2023). Development and performance evaluation of a cocoa bean sheller cum winnower. *International Journal of Environment and Climate Change*, ***13***(4), 56–63. https://doi.org/10.9734/ijecc/2023/v13i41712

Wicaksono, A., Hendrawan, Y., Sutan, S.M., & Firmanto, H. (2017). Uji performansi mesin pengupas kulit ari (desheller) kakao (theobroma cacao l.) skala home industri tipe pisau putar in home industry scale. *Jurnal Keteknikan Pertanian Tropis Dan Biosistem*, ***5***(3), 208–217.

Widyotomo, S., Ahmad, H., Soekarno, S.T., & Mulato, S. (2011). Kinerja mesin pengupas kulit buah kopi basah tipe tiga silinder horisontal. *Pelita Perkebunan*, ***27***(1), 36–54.

Widyotomo, S., Mulato, S., & Suharyanto, E. (2005). Kinerja mesin pemecah biji dan pemisah kulit kakao pascasangrai tipe pisau putar. *Pelita Perkebunan*, ***21***(3), 184–199.

Widyotomo, S., Mulato, S., & Suharyanto, E. (2007). Pengaruh penggilingan biji kakao pascasangrai terhadap perubahan distribusi ukuran keping biji. *Pelita Perkebunan*, ***23***(1), 72–88.