

Design Of A Cocoa Bean Grinding Machine With 0.5 Hp Power

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Abstract

This study aims to describe the design and construction of a cocoa bean grinding machine with a power of 0.5 hp. Based on the results of the cocoa bean grinding machine performance test and simple linear regression statistical data analysis using SPSS software in Chapter IV, several conclusions can be drawn as follows: Performance and Grinding Capacity of the Machine The grinding machine has a stable performance in producing fine products at a grinding duration of 2 minutes. At a variation of 1000 grams of input load, it produces an average of 358.33 grams of fine products, a 2000 gram load produces 733.33 grams, and a 3000 gram load produces 1066.67 grams. The Effect of Material Weight on Grinding Results (Regression Analysis): Fine Results: The weight of cocoa bean input has a positive and significant effect on fine results. Every 1 gram increase in cocoa weight will increase the fine results by 0.354 grams. Coarse Results: The weight of cocoa bean input has a positive and very significant effect on coarse results. Every 1 gram increase in cocoa weight causes an increase in coarse results by 0.642 grams. This shows that the majority of additional loads will tend to increase the coarse fraction if the grinding time is limited to only 2 minutes. Unmilled Material: The weight of cocoa bean input does not significantly affect the amount of unmilled material $0.212 > 0.05$. The amount of unmilled material tends to be constant at an average value of 325 to 333 grams, which indicates the existence of a certain mechanical limit/dead space in the machine's grinding chamber. Machine Noise Level: The machine operates with a high noise level, ranging from 96.6 dB to 99.5 dB, which has exceeded the safe threshold for human hearing for long duration (85 dB). Based on the regression analysis, the addition of material weight has a negative coefficient (-0.001) which means it slightly dampens the sound, but the effect of this material weight addition is statistically insignificant ($0.208 > 0.05$).

Keywords: Design, Grinding Machine, Cocoa Beans, Power 0.5 HP

INTRODUCTION

Indonesia is one of the world's largest producers of cocoa beans (*Theobroma cacao* L.). Data shows that national cocoa production has significant potential, but most is still sold as raw beans, resulting in low value-added (Nkouedjo et al., 2020).

To improve economic competitiveness and farmer welfare, the development of the downstream cocoa processing industry is necessary, particularly at the micro, small, and medium enterprise (MSME) level (Yovo & Adabe, 2022). In Pematangsiantar, specifically in the Siantar Marimbun District, many residents own cocoa plantations or fields, making equipment for processing cocoa beans essential (Wijaya et al., 2018).



Figure 1. Cocoa trees in Siantar Marimbun District

One of the most crucial stages in processing cocoa beans into derivative products is the grinding process. This process transforms roasted, peeled cocoa beans into cocoa paste (*cocoa mass* or *cocoa liquor*). This cocoa paste is a mandatory basic ingredient for the production of cocoa powder, cocoa butter, and all types of chocolate bars (Ernita et al., 2025). The final product quality is greatly influenced by the fineness of the resulting cocoa paste particles (Amoshie & Beem, 2022). Currently, MSMEs processing chocolate and farmers face a major challenge: the limited technology of large-scale industrial grinding machines, which are very expensive and not in accordance with MSME production capacity (Rahtika et al., 2022). Therefore, a specific cocoa bean grinding machine design is needed: efficient in energy use, has a capacity suitable for MSME scale (for example, 5-10 kg/hour), is easy to operate and maintain, and is capable of

producing chocolate paste with the appropriate level of fineness. This research seeks to address these needs through an engineering approach and prototype testing (Randy et al., 2024).

The reason I chose the title of this thesis "Design and Construction of a Cocoa Bean Grinding Machine with a Power of 0.5 HP" is based on several personal, academic motivations, and concerns about technological problems in the small industry sector, namely: Indonesia has great cocoa potential, but is often hampered by expensive processing technology (Andaluz, 2020). I see a technological gap between expensive large industrial machines and less efficient MSME-scale machines (Rahtika et al., 2022). This thesis is a real effort to contribute in providing appropriate technological solutions that are affordable and have optimal performance. The main motivation is to help local chocolate MSMEs and Local Farmers where I live to improve the quality of their products without having to rely on importing high-cost machines and selling unprocessed cocoa beans at low prices (Awe et al., 2024).

LITERATURE REVIEW

Cocoa

The Big Indonesian Dictionary defines that Cocoa is a chocolate tree whose seeds can be made into powder for drinks and so on. (KBBI. 2015.). The cocoa plant originates from America. Cocoa (*Theobroma cacao* L.) is a type of plant that grows in tropical areas that have high economic potential and play an important role in the Indonesian economy and is one of the main products in the plantation sub-sect (Bertulfo et al., 2024). Processed products from cocoa beans can generally be processed into three products, namely, chocolate paste, cocoa butter and cocoa candy or cocoa powder whose processing is interconnected (cyberx, 2020). Chocolate paste (*cocoa mass*) is the main semi-finished processed product in making all types of chocolate, namely, chocolate bars, cocoa powder, cocoa butter (Wahyudi, et al., 2008.). The chocolate processing process includes 3 stages, namely mixing, reducing, and forming chocolate paste (conching) (Piyarathna et al., 2024).

Cocoa Grinding Machine

In the Big Indonesian Dictionary, it is defined that "A machine is a tool for moving or making something that is run on wheels, driven by human power or a motor, using fuel oil or natural energy.

Types of Cocoa Bean Grinding Machines

To process chocolate into paste, in this modern era there are various types of cocoa bean grinding machines (Orungbemi, 2020).

How a Cocoa Bean Grinder Works

The main process of roasting cocoa beans in this grinding machine is achieved through a mechanism of intensive pressure and friction between the grinding rolls. Roasted cocoa beans (*nibs*) are fed through the inlet funnel and then into the grinder, gradually by gravity, slowly pushing the cocoa material into the grinding chamber (Lada, 2019). The key to this process is the pressure that occurs in the gap between the two grinding rolls. It is very important that the two grinding discs do not physically touch. Instead, the cocoa beans are the medium that is squeezed between the narrow gap, producing a friction force that breaks the cocoa cells. This rupture of cells releases the cocoa fat (*cocoa butter*) inside, which ultimately turns the solid material into a thick liquid known as cocoa paste (*cocoa liquor*), the end result of the grinding process (Pou et al., 2019).

Calculation Formula

The formulas used in the tool planning are as follows: Based on literature studies and the characteristics of dry cocoa beans, the average compressive strength value is set at 30 Newton (Komolafe, CA, et al., 2018). And According to Bart-Plange and Baryeh (2003), the density value of dry cocoa beans is 600 kg/m³. This parameter is used in this study to determine the operational capacity of the grinding room and calculate the mass load that will be processed by a 0.5 HP drive motor. The selection of the drive motor is a crucial stage to ensure the machine is able to produce sufficient torque in crushing cocoa beans (Abalo, 2021).

METHOD

This research was carried out during a certain period and took place at a predetermined location, in accordance with the needs of data collection and experimental implementation. The design time was started from the ratification of the design title by the Head of the Mechanical Engineering Study Program, Faculty of Engineering and Management of Water Resources Management, HKBP Nommensen University, Pematangsiantar and was carried out for approximately 6 months from October 2025 – April 2026 (Irwanto et al., 2022).

The design location for " Design and construction of a cocoa bean grinding machine with a power of 0.5 hp" is at HKBP Nommensen University, Pematang Siantar, on Jl. Sangnawaluh No.

4, Siopat Suhu, District. Siantar Tim., Pematang Siantar City, North Sumatra 21136.

The principle of the 0.5 HP cocoa bean grinding machine that will be made is to use an electric motor as the main driver then the shaft transmits the rotating motion and rotational power to crush the cocoa beans. During the rotating process, the object to be ground will be inserted through the hopper or material container before being ground (Prihadianto et al., 2022). After the cocoa beans enter, *the tooth roller will work to crush the cocoa beans*. The research method used in this study is a literature study with development experiments. Literature studies are used to find out the theoretical basis of the 0.5 HP cocoa bean grinding machine (Furtado et al., 2022).

In the design research of a 0.5 HP cocoa bean grinding machine, data collection on the cocoa bean grinding machine was in the form of capacity, efficiency of the time required and the electrical energy required to grind cocoa beans. In this study, a literature study was conducted on the design of a cocoa bean grinding machine. This step was carried out at the beginning to understand the basic theory in analyzing the rotation transmission process generated from the drive motor to rotate the shaft connected to the slam so that it can grind cocoa beans as desired, while the literature was obtained from the internet, books and journals (Delelegn, 2022).

RESULTS

Research Data



Figure 2. Cocoa Bean Grinding Machine

Test Data with comparison of cocoa bean weight

In testing this machine, three cocoa bean weight ratios were used during the 2-minute grinding process: 1000 grams, 2000 grams, and 3000 grams. These ratios are used as a guide and to facilitate the user's use of the grinding machine (Tuanama-Aguilar et al., 2025).

Cocoa Beans Weighing 1000 Grams

The first test using cocoa beans weighing 1000 grams can be seen in the image below.



Figure 3. Mass of 1000 grams of cocoa beans

In the first test according to the test table with a mass of 1000 grams (Ahouansou et al., 2023). The results of the first test a. For the results of fine grinding for 2 minutes, the chocolate mass was 360 grams and can be seen in the image below the rough grinding results The rough results in 2 minutes of grinding obtained a bean mass of 300 grams. and unground beans can be seen below For unground cocoa beans in the 2-minute test, they have a mass of 340 grams (SHIRIN et al., 2023).

Testing of Cocoa Beans Weighing 2000 Grams

In the first test according to the test table with a mass of 2000 grams. The results of the first test. For the results of fine grinding for 2 minutes, the chocolate mass was 740 grams. and can be seen in the picture below the rough grinding results The rough results in the second 2-minute grinding obtained a bean mass of 920 grams. and unground beans can be seen

below For unground cocoa beans in the second 2-minute test with a cocoa bean mass of 2000 grams, it has a mass of 340 grams (Onwuka et al., 2025).

Calculation

Driving Power Calculation

$$Pd = f_c \times P$$

$$Pd = 2,0 \times 0,373 \text{ kw}$$

$$Pd = 0,746 \text{ kw}$$

Dimana :

P_d = daya rencana (Kw)

f_c = factor koreksi 1,5 (rata rata gaya yang diperlukan)

P = daya motor Hp

Axis Planning

Torsional Moment:

$$\begin{aligned} T &= 9,47 \times 10^5 \frac{pd}{n^1} \\ T &= 9,47 \times 10^5 \frac{0,746}{1400} \\ T &= 947.000 \times \frac{0,746}{1400} \\ T &= 947.000 \times 0,0005328 \\ T &= 519,0 \text{ kg} \cdot \text{mm} \end{aligned}$$

Dimana :

T = Torsi(kg/m)

pd = Daya motor(kw)

n^1 = Putaran\ motor

Allowable shear stress ($\tau\alpha$):

The material chosen is S45C with tensile strength (Idawati et al., 2024).

$$\tau\alpha = \frac{\sigma b}{sf_1 \times sf_2}$$

$$\tau\alpha = \frac{58}{6,0 \times 2,0}$$

$$\tau\alpha = \frac{58}{12}$$

$$\tau\alpha = 4,83 \text{ kg/mm}^2$$

Dimana :

$$sb = \text{kekuatan tarik poros} = 58 \frac{\text{kg}}{\text{mm}^3}$$

sf_1 = faktor pengaruh massa material = 6,0

sf_2 = faktor pengaruh kekasaran poros = 2,0

Find the shaft diameter:

$$ds \text{ poros} = \left[\frac{5,1}{\tau\alpha} K_t \times C_b \times T \right]^{\frac{1}{3}}$$

$$ds \text{ poros} = \left[\frac{5,1}{4,8} 1,5 \times 1,0 \times 519,0 \right]^{\frac{1}{3}}$$

$$ds \text{ poros} = [1,0559 \times 2,0 \times 2,0 \times 519,0]^{\frac{1}{3}}$$

$$ds \text{ poros} = [2192,04]^{\frac{1}{3}}$$

$$ds \text{ poros} = 12,99 \text{ mm}$$

Dimana:

$\tau\alpha$ = Tegangan geser izin (kg. mm)(jenis baja tinggi)

ds = Diameter poros (mm)

kt = Faktor koreksi = 2,0

cb = faktor akhir lenturan = 2,0

T = torsi (kg. mm)

Shear stress that occurs

$$\tau = \frac{5,1 T}{14^3}$$

$$\tau = \frac{5,1 \times 519,0}{14^3}$$

$$\tau = \frac{2646,9}{15.625}$$

$$\tau = 0,9646 \text{ kg/mm}^2$$

dimana :



τ = tegangan geser yang terjadi (Becerra et al., 2024).

T = torsi (newton)

d_s^3 = shaft diameter (mm)

Pulley planning

Calculating the Turn Rasio

$$n_2 = n_1 \times \frac{d_p}{D_p}$$

$$n_2 = 1400 \times \frac{76,2 \text{ mm}}{254 \text{ mm}}$$

$$n_2 = 1400 \times 0,3$$

$$n_2 = 420 \text{ rpm}$$

Where = n_1 = Dynamo Rpm

n_2 = Roller Rpm

D_p = Large pulley diameter

d_p = Small Pulley Diameter

The force acting on the pulley (Fc)

$$Fc = \frac{2 \times T}{D_p}$$

$$Fc = \frac{2 \times 519,0}{254} = \frac{1038}{254} = 4,087 \text{ kg}$$

V-belt planning

Linear velocity of the belt:

$$V = \frac{\pi \times d_p \times n_1}{60 \times 1000}$$

$$V = \frac{3,14 \times 76,2 \times 1400}{60000}$$

$$V = \frac{334975,2}{60000}$$

$$V = 5,58 \frac{m}{s}$$

Dimana :

V = Linear Velocity of the belt

d_p = Diameter pulley penggerak

n_1 = Electric motor rotation = 1400 rpm

Belt circumference length: (Warandi et al., 2024).

$$L = 2C + \frac{\pi}{2} (D_p + d_p) + \frac{(D_p - d_p)^2}{4C}$$

$$L = 2(400) + \frac{3,14}{2} (254 + 76,2) + \frac{(254 - 76,2)^2}{4 \times 400}$$

$$L = 800 + 1,57(330,2) + \frac{(177,8)^2}{1600}$$

$$L = 800 + 518,41 + \frac{31612,84}{1600}$$

$$L = 800 + 518,41 + \frac{31612,84}{1600}$$

$$L = 1338,17 \text{ mm } L_{inch} = \frac{1338,17}{25,4} = 52,68 \text{ inch}$$

Dimana :

d_p = diameter pully penggerak

D_p = diameter pully yang digerakkan

C = Jarak antara sumbu

Determining bearing reaction:

Bearing A Reaction

$$R_A = \frac{F_c \times b}{a}$$

$$R_A = \frac{4,087 \times 80}{250}$$

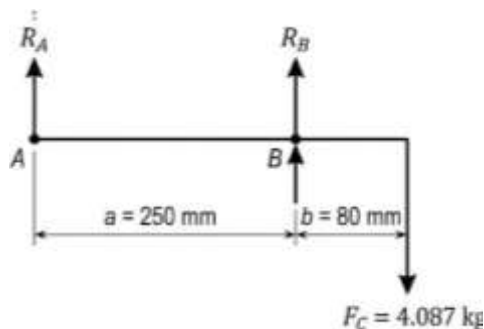
$$R_A = \frac{326,96}{250} = 1,31 \text{ kg}$$

Bearing B Reaction

$$R_A = \frac{F_c \times (a + b)}{a}$$

$$R_A = \frac{4,087 \times 250 + 80}{250}$$

$$R_A = \frac{1348,7}{250} = 5,39 \text{ kg}$$



Power validation

$$R_b - R_a = F_c$$

$$5.39 - 1.09 = 4.08 \text{ Valid}$$

Where = R_A = Bearing A Reaction
 F_C = Force on Pulley
 b = Distance from Bearing to Large Pulley
 a = Distance from bearing a to bearing b

Current required

Apparent electric current power (Salazar-Camacho et al., 2024).

$$VA = V \times I$$

$$VA = 220 \times 3,1$$

$$VA = 682 \text{ VA}$$

2. Electric current voltage:

$$V = \frac{VA}{I}$$

$$V = \frac{682}{3,1}$$

$$V = 220 \text{ Volt}$$

3. Electric current energy:

$$W = p \times t$$

$$W = 370 \times 1$$

$$W = 370 \text{ kWh}$$

Keterangan :

S=Daya arus semu (VA)

V=Tegangan arus(Volt)

I=Kuat arus listrik (ampere)

This test was repeated 3 times with different materials to get better results. We can see the results of the first test in table 4.1 and we can see the graph in figure 4.14.

Table 1. First Test with Cocoa Bean Weight of 1000 grams

No.	Weight (grams)	Time (minutes)	Results		
			Fine	Rough	Not ground
1.	1000	2	360	300	340
2.	1000	2	350	320	330
3.	1000	2	365	330	305

Based on three repeated tests, the average fineness yield was 358.33 grams, indicating that the machine has a fairly stable performance in producing fine products. However, there is still an average amount of unmilled material that needs to be evaluated (Andaluz, 2020).

Based on three repeated tests, the average fineness of the mill was 733.33 grams, indicating that the machine has fairly stable performance in producing a fine product. However, there is still an average amount of coarse material in the milling results (Amine et al., 2023).

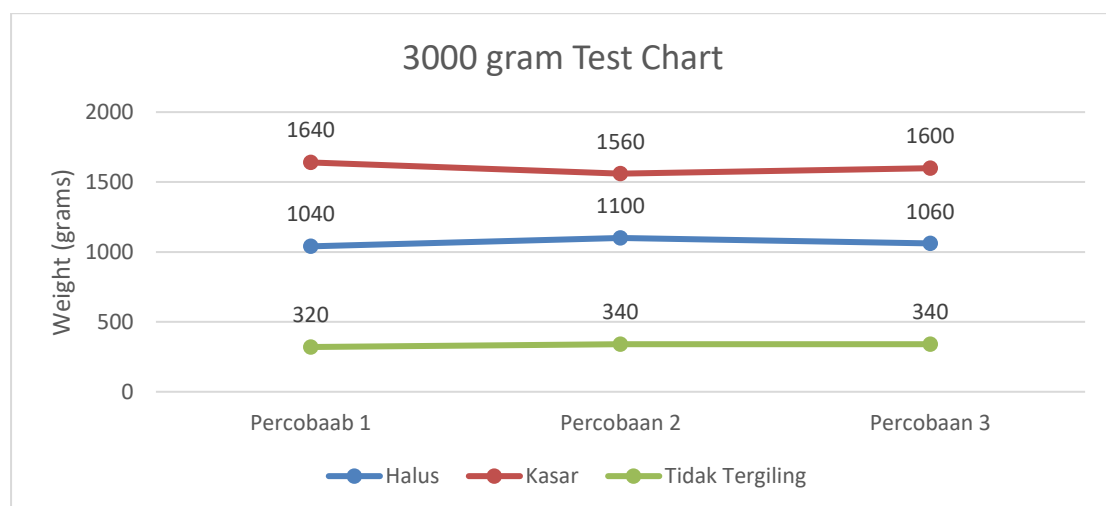


Figure 3. Third Test Graph with a cocoa bean weight of 3000 grams

Based on three repeated tests, the average fineness yield was 1066.67 grams, indicating

the machine's relatively stable performance in producing a fine product. However, there was still some coarse material in the milling results. (Surono et al., 2026)

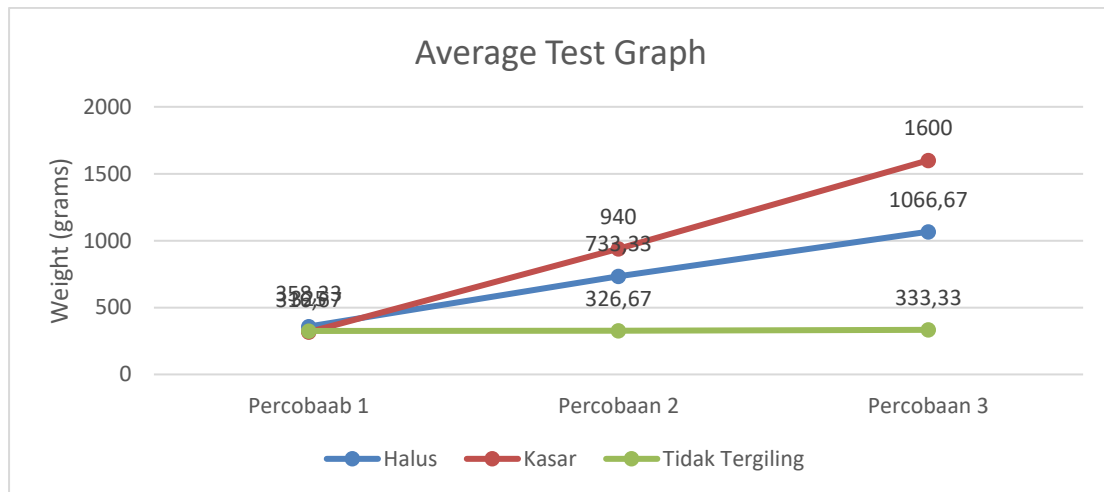


Figure 4. Graph of average cocoa bean test results

From the results of three times where testing was carried out on the cocoa bean grinding machine, we can see the average results (Docdoc et al., 2024).

Regression Analysis of the Effect of Cocoa Weight on Milling Results

To determine how much influence the weight of the cocoa beans tested had on the grinding results (fine, coarse, and unground), a simple linear regression analysis was carried out using SPSS software.

Stages of Processing Test Result Data

Before drawing conclusions regarding the performance of the cocoa bean grinding machine, the raw data from the test results in table 4.4 were processed using simple linear regression statistical analysis .

1. Identification of Variable Determination (Surono et al., 2026).

The independent variable is the weight of cocoa bean input with testing variations of 1000 grams, 2000 grams, and 3000 grams. and the dependent variable is the average fine, coarse, and unground grind.

2. Data input

Data from the machine test results sheet is entered into the SPSS program.

3. Performing Regression Commands

Statistical processing was carried out using SPSS software which produced the following image.

Model Summary					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	
1	.999 ^a	.999	.998	17.00762	
a. Predictors: (Constant), Berat					

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	250872.778	1	250872.778	867.294	.022 ^b
	Residual	289.259	1	289.259		
	Total	251162.037	2			
a. Dependent Variable: Hasil Halus						
b. Predictors: (Constant), Berat						

Coefficients ^a						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	11.103	25.980		.427	.743
	Berat	.354	.012	.999	29.450	.022
a. Dependent Variable: Hasil Halus						

Figure 5. Results of Regression Testing Using SPSS Software

The Effect of Cocoa Weight on Fine, Coarse, and Unground Results (Vega Espinosa, 2022).
Based on



Figure 6. Graph of the results of the regression analysis of the effect of cocoa weight on milling results.

Based on the table and graph above, three simple linear regression equation models were obtained for each characteristic of the milling results, the relationship and contribution of the influence of cocoa weight on the milling results can be described as follows:

Smoothed Result Variable Analysis

The cocoa weight variable has a very strong contribution of 99.9% ($R^2 = 0.999$) on the fine results, the Sig. Value of $0.022 < 0.05$ shows that this influence is significant, the regression equation has a positive coefficient of 0.354 grams which means that for every 1 gram increase in cocoa weight, the fine results weight increases by 0.354 grams (Shamna et al., 2025).

Crude Result Variable Analysis

The cocoa weight variable has a 100% contribution ($R^2 = 1.000$) to the variation in the weight of the coarse yield. A significance value of $0.011 < 0.05$ indicates that the weight of the cocoa input has a significant effect on the coarse yield obtained. The regression equation has a positive coefficient of 0.642 grams, which means that for every 1 gram increase in cocoa weight, the weight of the fine yield increases by 0.642 grams (Shamna et al., 2025).

Unmilled Variable Analysis

Based on statistical testing on the unmilled material variable, a significance value of $0.212 < 0.05$ was obtained, so it can be concluded that the weight of cocoa input does not have a significant effect on

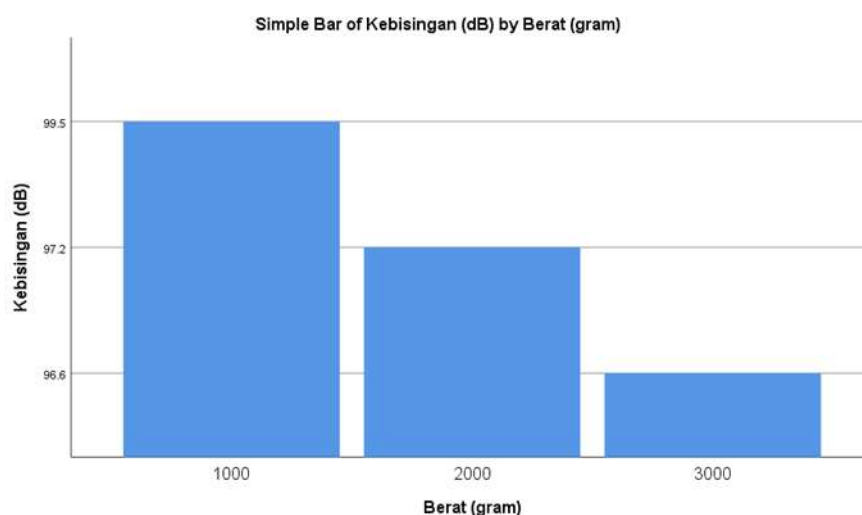


Figure 7. Noise Test Graph



Noise level testing was conducted to determine the intensity of the sound produced by the machine. Based on the graph above, the highest noise level recorded was 99.5 dB. This indicates that the machine operates within the normal range of human hearing for extended periods (Soekarno et al., 2024).

Regression Analysis of the Effect of Cocoa Weight on Noise

To find out how much influence the weight of the cocoa beans tested has on the noise level produced by the cocoa bean grinding machine during operation, a regression analysis was carried out using SPSS software. Based on the table and graph above, the regression equation model was obtained as follows: the regression coefficient value is negative at -0.001, this shows the direction of the relationship where every additional 1 gram of incoming material then the noise level decreases by 0.001 dB, although the weight of the material has a strong influence contribution of 89.7% to the change in sound intensity, the results of the statistical test state that the influence is not significant because the significance value of 0.208 is greater than the standard of 0.05, thus it can be concluded that the addition of the weight of the cocoa bean material does not actually provide a drastic change or decrease in noise on this cocoa grinding machine.

Calculating Sound Pressure on an Engine

1. Calculation of 1000 gram data

$$P = P_{ref} \times 10^{\left(\frac{SPL}{20}\right)}$$

$$P = 0,00002 \times 10^{\left(\frac{99,5}{20}\right)}$$

$$P = 0,00002 \times 10^{4,975}$$

$$P = 0,00002 \times 94.406,0875$$

$$P = 1,8881 \text{ N/m}^2$$

2. 2000 gram Data Calculation

$$P = P_{ref} \times 10^{\left(\frac{SPL}{20}\right)}$$

$$P = 0,00002 \times 10^{\left(\frac{97,2}{20}\right)}$$

$$P = 0,00002 \times 10^{4,86}$$





$$P = 0,00002 \times 72.443,5960$$

$$P = 1,4489 \text{ N/m}^2$$

3. 3000 gram Data Calculation (Raju, 2023)

$$P = P_{ref} \times 10 \left(\frac{SPL}{20} \right)$$

$$P = 0,00002 \times 10 \left(\frac{96,6}{20} \right)$$

$$P = 0,00002 \times 10^{4,83}$$

$$P = 0,00002 \times 67.608,2975$$

$$P = 1,3522 \text{ N/m}^2$$

CONCLUSION

Based on the results of testing the performance of the cocoa bean grinding machine and the analysis of simple linear regression statistical data using SPSS software in Chapter IV, the following conclusions can be drawn:

Performance and Capacity of Grinding Machine:

The grinding machine performed consistently in producing fine products within a 2-minute grinding time. At a 1000-gram input load, the average fine product yielded 358.33 grams, at a 2000-gram load, 733.33 grams, and at a 3000-gram load, 1066.67 grams.

Effect of Material Weight on Milling Results (Regression Analysis):

Fineness Yield: The weight of cocoa bean input has a positive and significant effect on fineness yield. Every 1 gram increase in cocoa weight increases the fineness yield by 0.354 grams.

Rough Yield: The weight of cocoa bean input has a positive and very significant effect on the rough yield. Every 1 gram increase in cocoa weight causes an increase in the rough yield by 0.642 grams. This indicates that the majority of additional loads will tend to increase the coarse fraction if the grinding time is limited to only 2 minutes. **Unmilled Material:** The weight of cocoa bean input does not significantly affect the amount of unmilled material $0.212 > 0.05$. The amount of unmilled material tends to be constant at an average value of 325 to 333 grams, which indicates the existence of certain mechanical limits/dead space in the machine's grinding chamber.





Engine Noise Level:

The machine operates at high noise levels, ranging from 96.6 dB to 99.5 dB, which has exceeded the safe threshold for human hearing for long duration (85 dB). Based on the regression analysis, the addition of material weight has a negative coefficient (-0.001) which means it slightly dampens the sound, but the effect of this additional material weight is statistically insignificant ($0.208 > 0.05$).

Suggestion

The suggestions that can be given are:

1. It is necessary to reset the grinder gap so that the fine percentage can be more dominant.
2. Considering that the noise is above the average limit of human hearing comfort, it is recommended that operators wear ear protection during operation.
3. It is necessary to understand the materials that will be processed in the cocoa grinding machine to get satisfactory results.

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