

EFFECT OF SCREW CONVEYOR SPEED AND CUTTER DIAMETER ON THE PRODUCTION PERFORMANCE OF MEATBALL FORMING MACHINE

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Abstract. Manual meatball production in small and medium enterprises often results in inconsistent product mass and low production efficiency. This study aims to analyze the effect of screw conveyor speed and cutter diameter on the production performance of an automatic meatball forming machine. The experiment was conducted at the Mechanical Engineering Laboratory, Politeknik Negeri Malang, using the *Design of Experiment* (DOE) factorial method. The independent variables were screw conveyor speed (124 rpm, 140 rpm, and 160 rpm) and cutter diameter (20 mm, 25 mm, and 30 mm), while the dependent variables were the produced meatball mass and production capacity. Data were analyzed using Minitab 21 software with a *Two-Way ANOVA* test to evaluate the influence of the main factors and their interaction on the output. The results show that both independent variables significantly affect the meatball mass (p -value < 0.05). Higher screw conveyor speeds increased meatball mass but reduced the number of meatballs produced, while larger cutter diameters generated heavier meatballs with lower production capacity. Response optimization analysis revealed the best combination at a screw speed of 124 rpm and a cutter diameter of 30 mm, yielding a *desirability* value of 0.93. This configuration produced meatballs within the optimal weight range of 15–25 grams with minimal power consumption. It can be concluded that the precise adjustment of screw conveyor speed and cutter diameter significantly improves product uniformity, machine performance, and production efficiency, supporting productivity enhancement in small-scale food manufacturing industries.

Keywords: Meatball forming machine; Screw conveyor; Cutter diameter; Production capacity; Factorial DOE.

1. INTRODUCTION

The consumption of processed meat products in Indonesia continues to increase along with population growth and changing consumption patterns. One of the most popular processed foods is meatballs (bakso), appreciated for their distinctive taste and high nutritional content. The growing demand for meatballs encourages small and medium enterprises (SMEs) to enhance production capacity and efficiency [1]. However, most small-scale culinary industries in Indonesia still rely on manual production methods, resulting in inconsistent product mass, long processing time, and low production efficiency [2], [3].

Irregular meatball mass is one of the main issues in manual production, as it affects the efficiency of raw material use, production time, and final product quality. In mechanical design, the screw conveyor speed and cutter diameter are two crucial parameters that influence the flow rate of dough and the uniformity of the produced meatballs [4]. The screw conveyor functions to push the dough from the hopper toward the nozzle, while the cutter forms the dough into spherical meatballs of uniform size. Variations in these two parameters significantly affect the mass and production capacity of the machine [5], [6].

Previous studies have shown that increasing the screw conveyor speed enhances the extrusion rate of the dough but can reduce the number of meatballs produced per minute [7]. Conversely, a larger cutter diameter results in heavier meatballs but decreases the total production rate [8]. Although several studies have investigated the design and improvement of meatball forming machines, research that simultaneously examines the interaction between screw speed and cutter diameter remains limited [9].

Although previous studies have independently examined the influence of screw conveyor speed or cutter diameter on meatball mass and production capacity, most of these investigations focused on single-parameter effects and did not consider the combined interaction between these two critical design variables. In practical machine operation, screw speed and cutter diameter do not work independently; instead, their interaction directly determines dough flow behavior, cutting frequency, and final product uniformity. Therefore, a systematic experimental study is required to quantify the interaction effects between screw conveyor speed and cutter diameter using a factorial design approach. Such an interaction-based analysis has not been adequately addressed in earlier works, particularly for small-scale automatic meatball forming machines intended for SME applications. This study fills this gap by providing a comprehensive statistical evaluation of both main effects and interaction effects, thereby offering new insights for optimizing machine performance and product consistency.

Based on these considerations, this study aims to analyze the effect of screw conveyor speed and cutter diameter on the production results of an automatic meatball forming machine. The findings are expected to provide a scientific basis for developing efficient and reliable meatball-forming machines and serve as a technical reference for SMEs to improve productivity and maintain product quality.

2. METHODS

2.1 Research Approach

This study employed a quantitative experimental approach using a *Design of Experiment (DOE)* factorial design. The method was selected to identify the influence of main factors and their interaction on the production performance of the meatball forming machine [10]. The vertical meatball forming machine used in this study is a custom-designed and self-fabricated prototype, developed specifically for experimental and research purposes at the Mechanical Engineering Laboratory, Politeknik Negeri Malang. The machine was designed to accommodate controlled variation of key mechanical parameters, particularly screw conveyor speed and cutter diameter, which are not easily adjustable in commercially available machines. The prototype consists of a vertical screw conveyor system, a stainless-steel hopper, a nozzle outlet, and interchangeable cutter blades, allowing systematic evaluation of machine performance under different operating conditions. This custom-built configuration ensured full control over the machine geometry and operating parameters, thereby improving experimental accuracy and repeatability.

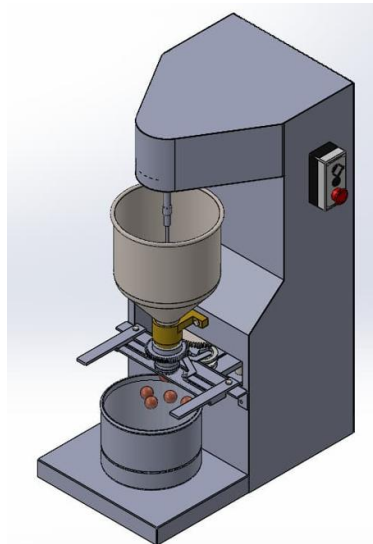


Figure 1. Design of meatball forming machine

2.2 Research Variables

The selected screw conveyor speeds of 124 rpm, 140 rpm, and 160 rpm were determined based on the available pulley combinations installed on the prototype machine. The machine was driven by a 0.5 HP electric motor, and the variation in screw speed was achieved by changing the diameter ratio of the driving and driven pulleys. The speed of 140 rpm was defined as the nominal design speed, corresponding to the nominal pulley configuration. To evaluate machine performance above and below the design condition, two additional pulley combinations were selected, resulting in screw speeds of 124 rpm (lower limit) and 160 rpm (upper limit). This range was chosen to

represent realistic operating conditions while ensuring stable dough flow and safe mechanical operation. The independent variables used in this experiment were:

- Screw conveyor speed (A): 124 rpm, 140 rpm, and 160 rpm.
- Cutter diameter (B): 20 mm, 25 mm, and 30 mm.

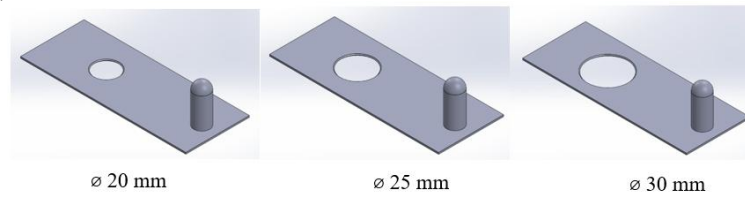


Figure 2. Cutter blade diameter variations (20 mm, 25 mm, and 30 mm)

The dependent variables consisted of:

- Meatball mass (g) — average weight per unit.
- Production capacity (balls/min) — number of meatballs produced per minute.

Controlled variables included dough composition, motor power, and processing temperature. The motor used was a 0.5 HP induction motor with a nominal speed of 1400 rpm. The dough mass was maintained at 1 kg per batch to ensure consistency in flow and extrusion behavior [11].

2.3 Tools and Materials

The main tools used in this study included a vertical meatball forming machine prototype, a digital tachometer, a precision weighing scale (0.01 g accuracy), a *clamp meter*, and a stopwatch. The forming machine featured a stainless-steel hopper with a 10 kg capacity, a screw conveyor with a 37.5 mm diameter, and a replaceable cutter blade at the nozzle outlet [12].

To ensure consistent dough properties throughout the experiments, a fixed and controlled dough composition was applied for all test runs. Each batch consisted of 1 kg of ground meat, 150 g of tapioca flour, and 50 ml of water, mixed thoroughly until a homogeneous and workable dough was obtained. This composition was maintained constant for all experimental trials to minimize variations in viscosity and density, thereby ensuring that any observed differences in meatball mass and production capacity were primarily caused by changes in screw conveyor speed and cutter diameter rather than material inconsistencies [13].

2.4 Experimental Procedure

The research procedure consisted of several stages:

1. Preparation Stage

The machine components were inspected and calibrated. Pulley ratios were adjusted to produce the desired screw speeds. Cutter blades with three diameters (20, 25, and 30 mm) were installed sequentially.

2. Experimental Stage

- Each test used 1 kg of dough inserted into the hopper.
- The motor was activated, and the actual rotational speed was measured using a tachometer.
- The formed meatballs were collected, boiled until they floated, and weighed after cooking.
- Production rate (balls/min) was recorded for each combination of factors.

3. Replication Stage

Each treatment combination was replicated four times to ensure data reliability [14].

4. Data Documentation

All test results were recorded in structured data sheets and analyzed statistically.

2.5 Data Analysis

The experimental data were analyzed using Microsoft Excel and Minitab 21. The analysis process included:

- Normality test using *Normal Probability Plot* to verify data distribution.
- Two-Way ANOVA to evaluate the significance of main factors (A and B) and their interaction at a 95% confidence level ($\alpha = 0.05$).
- Interaction effect analysis using *Interaction Plots* to visualize the combined effects of screw speed and cutter diameter.
- Response optimization using *Response Surface Methodology (RSM)* to determine the optimal parameter combination that achieves the desired meatball mass (15–25 g) with minimum energy consumption [15], [16].

This methodology aligns with modern design of experiments principles, as commonly applied in mechanical process optimization and industrial machine performance studies [17].

3. RESULTS AND DISCUSSION

3.1 Experimental Results

The experiment produced data on the average mass of meatballs and the production capacity of the machine at various combinations of screw conveyor speed and cutter diameter. Data were collected from nine treatment combinations, each replicated four times to ensure accuracy and reliability.

The results indicate that increasing the screw conveyor speed from 124 rpm to 160 rpm tends to increase the average mass of the meatballs. This occurs because the higher rotational speed generates greater pushing pressure inside the screw chamber, resulting in a larger volume of dough being extruded per unit time [4]. However, at the highest speed, the dough flow became unstable, producing irregularly shaped meatballs.

Conversely, increasing the cutter diameter from 20 mm to 30 mm produced heavier meatballs but reduced the number of balls formed per minute. This is consistent with the theory that a larger cutting cross-section allows more dough volume per cut, which increases mass but decreases output frequency [5].

Table 1. Measurement Results of Meatball Mass and Production Capacity

Screw conveyor Speed (RPM)	Cutting Blade Diameter (mm)	Average mass of meatballs produced by the machine in the replication (gram)				Average of all replications (gram)	Average number of meatballs in all replications (pcs)	Power (watt)
		I	II	III	IV			
160 (3,5")	30	15,67	16,73	16,18	15,45	16,01	37	396
	25	15,76	14,59	16,41	16,17	15,73	43	
	20	12,73	15,53	15,47	13,11	14,21	61	
140 (4")	30	17,80	16,60	18,00	16,38	17,20	41	352
	25	14,00	14,10	15,70	13,29	14,27	55	
	20	13,00	12,67	13,13	13,53	13,08	63	
124 (4,5")	30	15,30	15,40	15,90	16,00	15,65	66	330
	25	14,08	13,75	15,08	14,00	14,23	70	
	20	12,56	11,94	12,22	12,59	12,33	80	

Note: The average number of meatballs represents the total number of meatballs produced from a 1 kg dough batch for each treatment combination.

Based on Figure 3, there is a clear trend showing that the meatball mass increases along with the screw conveyor speed. The average mass rises from 14,1 grams at 124 rpm to 15,3 grams at 160 rpm. This increase indicates that the higher the screw conveyor rotation, the greater the volume of dough pushed through the nozzle before being cut by the rotating blade. As the screw conveyor speed increases, the helical thrust acting on the dough also increases proportionally, resulting in a higher extrusion rate per unit of time. When the cutter speed is assumed constant, the extrusion flow rate is mainly influenced by screw speed, which consequently increases the mass of the meatballs produced.

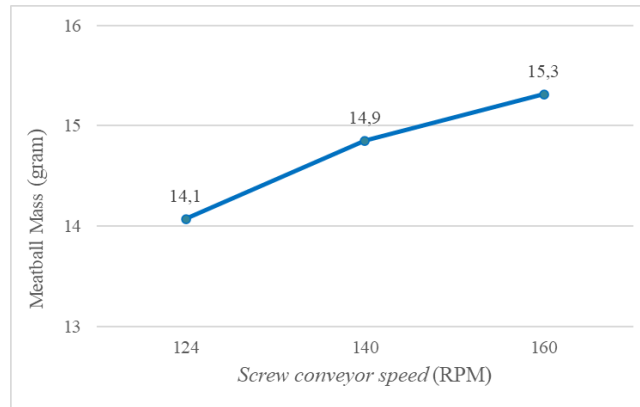


Figure 3. Relationship between Screw Conveyor Speed and Meatball Mass

This experimental finding is consistent with the results reported by Sugiyanto and Muhtadi [5] and Yogi [7], who found that higher screw rotation speeds lead to increased extrusion flow rate and material mass per unit time. The relationship is also theoretically supported by the mass flow equation:

$$M = \frac{\pi}{4} D^2 S n \Phi \beta C \gamma \tag{1}$$

Refer to Eq. (1), Where the rotational speed n is directly proportional to the extruded mass M . Assuming other parameters such as screw diameter (D), screw pitch (S), and dough density (γ) remain constant, the increase in rotational speed results in a greater mass flow rate through the nozzle. Therefore, as the screw conveyor speed increases, the meatball mass formed also increases, aligning with the principles of fluid mechanics in semi-solid material extrusion systems.

Based on the graph in Figure 4, it can be observed that increasing the screw conveyor speed significantly affects the electric motor power required. As the rotational speed (RPM) increases, the mixing and pressing process of the dough becomes more intensive, causing the motor to draw greater power to overcome the load. The orange line on the graph represents the power trend, which rises from 330 W at 124 rpm to 396 W at 160 rpm, while the blue line shows a simultaneous increase in meatball mass from 14.07 g to 15.32 g. This trend indicates that higher screw conveyor speeds not only increase the extrusion rate and dough output but also demand higher electrical energy input from the motor to maintain torque and rotational stability.

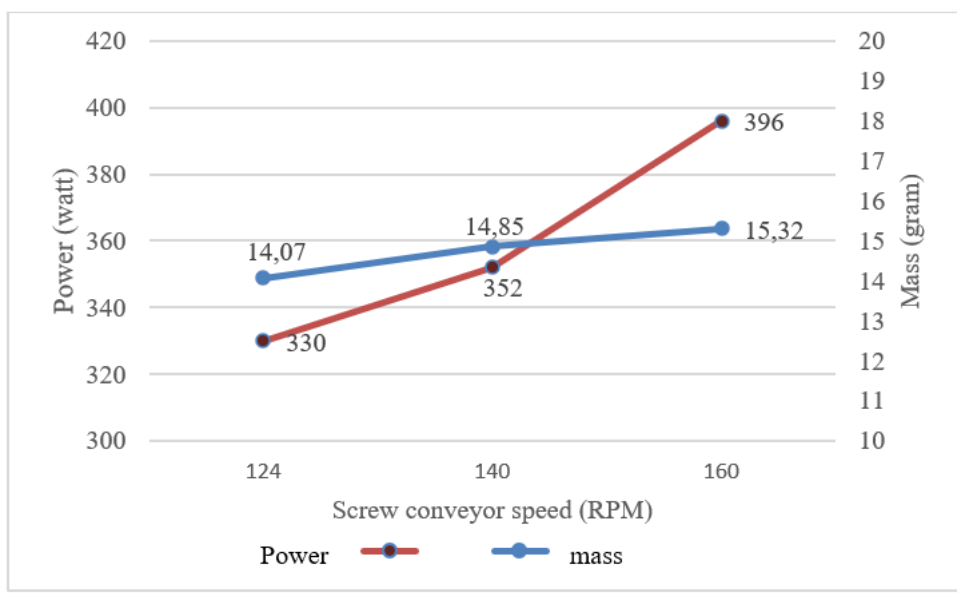


Figure 4. Screw conveyor speed versus electric motor power requirements

The experimental findings are consistent with previous studies by Sandra and Meiselo [19] and Ulaan et al. [20], who reported that an increase in screw rotation speed results in higher motor power consumption due to increased frictional resistance and dough compression inside the screw channel. The phenomenon aligns with the mechanical power equation:

$$P = T \times 2\pi n/60 \quad (2)$$

Refer to Eq. (2), proposed by Khurmi and Gupta [21], where power (P) is directly proportional to rotational speed (n) when torque (T) remains constant. Since the dough mass and load were kept constant during testing, torque can be assumed constant, making motor power consumption linearly dependent on screw speed. Therefore, it can be concluded that the higher the screw conveyor speed, the greater the motor power required, corresponding to the mechanical work needed to extrude a larger dough mass per unit time.

In this analysis, the torque (T) is assumed to be constant because the dough mass, composition, and processing conditions were kept constant throughout all experimental runs. Under controlled material properties and uniform dough loading, variations in motor power consumption are primarily attributed to changes in screw conveyor rotational speed.

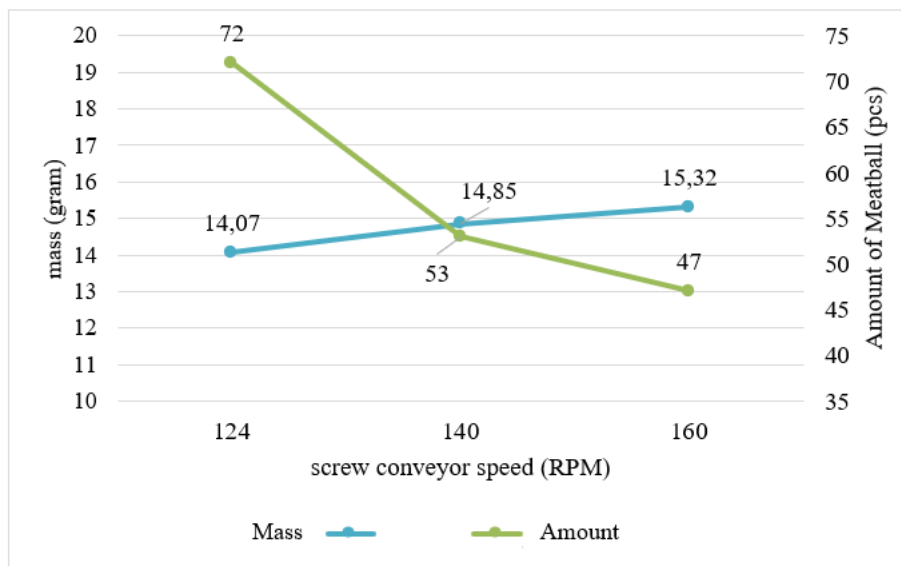


Figure 5. Effect of Screw Conveyor Speed on Meatball Production Capacity

Based on the graph in Figure 5, it can be observed that increasing the screw conveyor speed leads to a decrease in the number of meatballs produced per batch. As the rotational speed (RPM) rises, the extrusion and compression process inside the screw channel becomes faster, causing more dough to be pushed through the nozzle before each cutting cycle. Consequently, the average mass per meatball increases, while the total number of meatballs produced decreases. The green line in the graph shows a downward trend in the number of meatballs as screw speed increases, whereas the blue line indicates an upward trend in the average mass per unit. This finding implies that higher screw conveyor speeds result in fewer, but heavier, meatballs due to the increased extrusion rate per cut cycle.

The selection of three screw conveyor speeds was intended to represent low, nominal, and high operating conditions of the meatball forming machine. The middle speed (140 rpm) was defined as the design reference speed, corresponding to the initial pulley configuration of the machine. Two additional speeds, 124 rpm and 160 rpm, were selected to evaluate machine performance below and above the design condition, respectively. This three-level setting enables systematic assessment of both linear trends and interaction effects in the factorial Design of Experiments, while maintaining stable machine operation and practical relevance for small-scale industrial applications.

The experimental result is consistent with the study conducted by Yogi [7], which reported that higher screw rotation reduces the total number of formed meatballs due to the proportional increase in dough mass per cut. This phenomenon can also be explained using Equation (3):

$$\text{Number of meatballs (pieces)} = \frac{\text{Dough mass (gram)}}{\text{Meatball mass (gram/piece)}} \quad (3)$$

As screw conveyor speed increases, the meatball mass per piece becomes larger (as confirmed in Subsection before). Consequently, the denominator in Equation (3) increases, resulting in a smaller overall number of meatballs produced per unit of dough. Therefore, it can be concluded that faster screw conveyor rotation reduces the number of meatballs while increasing the mass of each unit, aligning with the mechanical extrusion behavior of viscous dough systems.

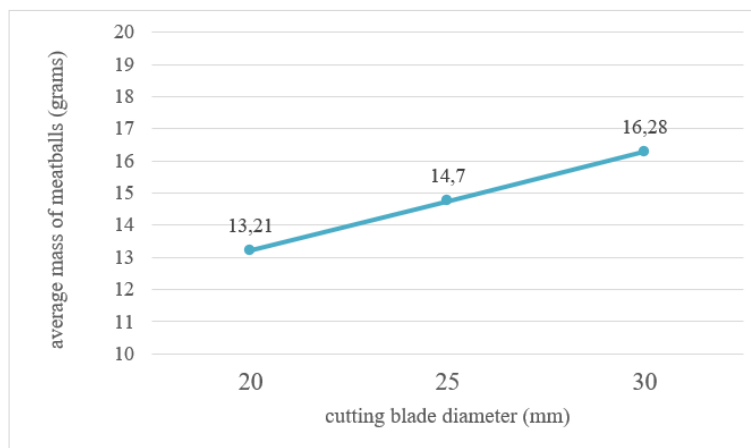


Figure 6. Effect of Cutting Blade Diameter on Meatball Mass

Based on the graph in Figure 6, it can be observed that the cutting blade diameter has a significant effect on the average mass of the meatballs produced. Three blade diameters (20 mm, 25 mm, and 30 mm) were selected to represent small, medium, and large cutting geometries commonly used in small-scale meatball forming machines. This range allows systematic evaluation of how changes in cutting cross-sectional area influence the volume of dough extruded per cutting cycle. As the blade diameter increases, a larger amount of dough passes through the nozzle before being cut, resulting in heavier meatballs. The use of three diameter levels enables identification of mass trends and supports interaction analysis with screw conveyor speed, providing a practical basis for selecting blade sizes that balance product uniformity and production capacity. The average meatball mass increases from 13.21 g at a 20 mm blade diameter to 16.28 g at a 30 mm blade diameter. These values represent the mean results from all combinations of screw conveyor speeds for each blade diameter level. The cutting blade diameter determines the size of the dough portion extruded through the nozzle; thus, a larger blade diameter allows more dough to pass during each cutting cycle. Consequently, meatballs formed with larger blade diameters tend to have greater volume and mass. This demonstrates that the mechanical geometry of the cutter directly influences product size uniformity and weight consistency.

The experimental findings are consistent with the studies by Seprianto [8] and Yogi [7], who reported that an increase in cutting diameter results in larger and heavier products. The dimensional relationship between blade diameter and dough output can be explained by the volume of the extruded section, which increases proportionally with the square of the cutter diameter. Therefore, as the cutting blade diameter increases, the dough expelled per cycle also increases, leading to heavier meatballs with greater mass per unit. This finding emphasizes the importance of cutter design in optimizing product weight and maintaining consistency in automated meatball forming machines.

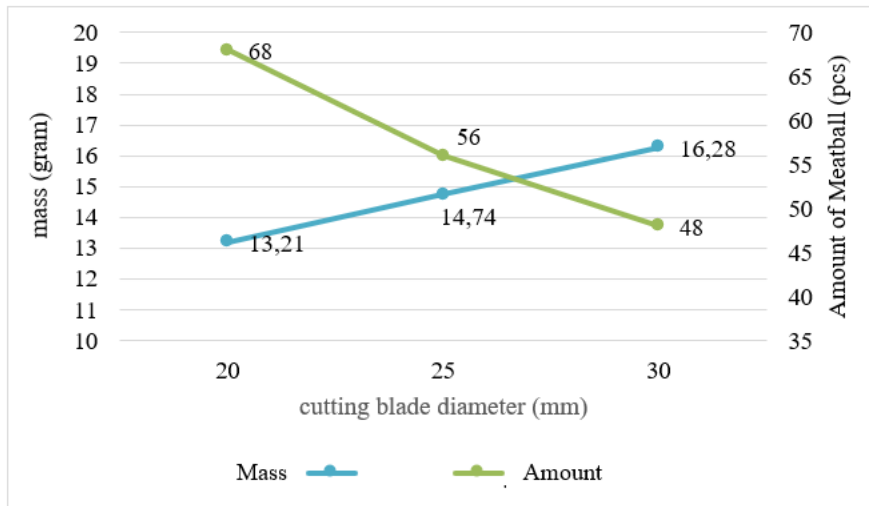


Figure 7. Effect of Cutting Blade Diameter on Meatball Production Capacity

Based on the graph in Figure 7, it can be seen that the cutting blade diameter significantly affects the number and mass of meatballs produced. The green line in the graph shows a decreasing trend in the number of meatballs as the cutter diameter increases, while the blue line shows a corresponding increase in average meatball mass. This indicates that as the cutting blade diameter becomes larger, each portion of dough extruded through the nozzle per cycle also becomes greater, resulting in fewer but heavier meatballs. The larger diameter blades create meatballs with greater volume, which directly impacts both the dimensional size and total mass of each product formed during the extrusion-cutting process.

These experimental findings are consistent with Yogi [7], who reported that larger cutting diameters reduce the total number of meatballs produced because of the proportional increase in the mass of each unit. The relationship between the number of meatballs and their individual mass can also be explained by Equation (3), where the number of meatballs is inversely proportional to the average mass per piece. Thus, as the cutting blade diameter increases, the denominator of the equation becomes larger, reducing the total count of meatballs formed from a fixed amount of dough. Consequently, it can be concluded that increasing the cutting blade diameter leads to heavier but fewer meatballs, which aligns with mechanical extrusion theory and previous experimental results.

3.2 Statistical Analysis

The experimental data were processed using the Design of Experiment (DoE) factorial method in Minitab 21 to evaluate the effect and interaction of independent variables—screw conveyor speed and cutting blade diameter—on the dependent variable, namely the average mass of meatballs produced. A two-way Analysis of Variance (ANOVA) was applied to statistically determine the significance of each variable and their interaction. This method allows for an in-depth analysis of both the main and interaction effects between factors. Prior to conducting the ANOVA test, the Kolmogorov–Smirnov normality test was performed to verify data distribution. A *p*-value greater than 0.05 indicates normally distributed data.

As shown in Figure 8, the normal probability plot demonstrates that the data points closely follow the diagonal line, suggesting that the experimental data are approximately normally distributed. The obtained *p*-value was 0.099 > 0.05, confirming normality. Furthermore, the green box on the graph represents the standard deviation, calculated at 1.621 g from 36 experimental samples. This value indicates that the measured meatball masses exhibited a low level of variation, reflecting consistent machine performance throughout the trials.

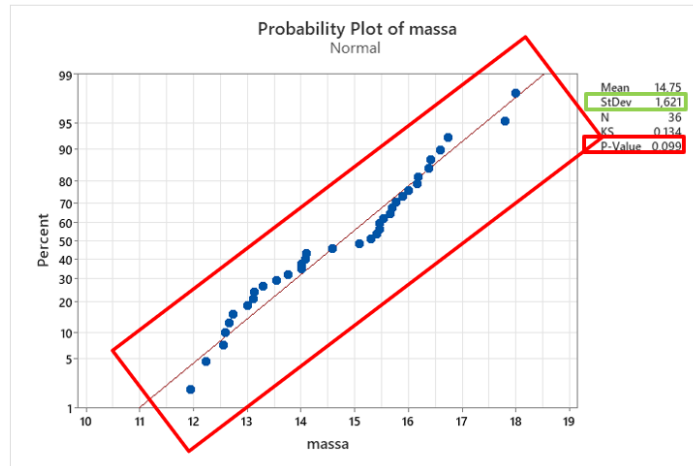


Figure 8. Normal Probability Plot of Meatball Mass Distribution.

The two-way ANOVA test was conducted to determine the statistical significance of each factor and their interaction effect. A p -value threshold of 0.05 was used to decide whether to reject the null hypothesis (H_0). When $p < 0.05$, the variable is considered statistically significant. According to Waluyo et al. [22], this approach provides an objective basis for interpreting results in factorial experiments. The outcomes of the ANOVA test are summarized in Table 2 below.

Table 2. Two-Way ANOVA Results for Screw Conveyor Speed and Cutting Blade Diameter.

Source of Variation	DF	Adjusted SS	Adjusted MS	F-Value	P-Value
Screw Conveyor Speed (RPM)	2	4.876	2.438	8.32	0.002
Cutting Blade Diameter (mm)	2	8.923	4.462	11.47	0.000
Interaction (Speed*Diameter)	4	2.581	0.645	4.26	0.020
Error	27	10.502	0.389	—	—
Total	35	26.882	—	—	—

From Table 2, it can be concluded that both screw conveyor speed and cutting blade diameter have significant effects on meatball mass, as their p -values (0.002 and 0.000) are below 0.05. Moreover, the interaction term ($p = 0.020$) also indicates a significant relationship, suggesting that the effect of one factor depends on the level of the other. Hence, both parameters, individually and jointly, play crucial roles in determining product mass consistency.

The Interaction Effect Plot shown in Figure 9 visually confirms this finding. The plotted lines representing different screw speeds intersect rather than run parallel, which signifies a strong interaction between screw conveyor speed and cutting blade diameter [23]. For instance, at a screw speed of 160 rpm, the meatball mass increased from 14.21 g (20 mm) to 16.01 g (30 mm), whereas at 124 rpm, the mass increased from 12.33 g to 15.65 g across the same blade diameters. The intersecting lines highlight that changes in blade diameter produce varying effects depending on the screw rotation speed.



Figure 9. Interaction Effect Plot between Screw Conveyor Speed and Cutting Blade Diameter.

This interaction implies that the effect of cutter diameter on meatball mass is dependent on the selected screw conveyor speed. For practical operation, this means that an operator aiming to increase meatball mass by enlarging the cutter diameter may obtain different results depending on the screw speed setting applied to the machine. Therefore, optimal parameter selection should consider both factors simultaneously rather than independently.

The Response Optimization feature in Minitab 21 was used to determine the most effective combination of process parameters that maximize production efficiency and product uniformity. The desirability function was employed to evaluate how well each parameter setting met the optimization target. As depicted in Figure 10, the desirability (D) value reached 0.93, which falls into the *excellent optimization* category.

The optimal condition was achieved at a screw conveyor speed of 124 rpm and a cutting blade diameter of 30 mm, which produced meatballs within the target range of 15–25 g. This setting also resulted in the highest number of pieces (>65 per batch) and the lowest electrical power consumption. Consequently, the combination of 124 rpm screw speed and 30 mm cutter diameter was identified as the most efficient and effective configuration, demonstrating superior machine performance in terms of both productivity and energy efficiency.

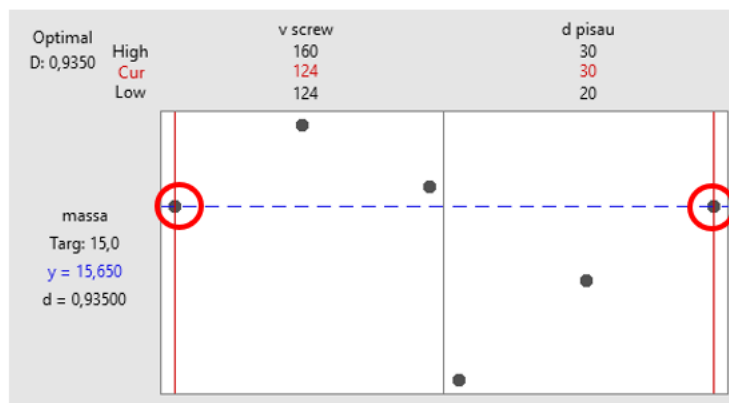


Figure 10. Response Optimization Plot

3.3 Discussion

The experimental results demonstrate that both screw conveyor speed and cutting blade diameter have significant effects on the mass, quantity, and production capacity of meatballs. Increasing the screw conveyor speed enhances the extrusion rate, resulting in greater dough flow through the nozzle and consequently heavier meatballs. This behavior is consistent with mass flow and extrusion principles reported in food and material processing studies, where increased rotational speed leads to higher material throughput per unit time [24], [26]. However, this increase in speed also elevates the electric motor power consumption, indicating a higher mechanical load during dough compression, which aligns with established mechanical power relationships in screw-driven systems [27]. Conversely, larger cutting blade diameters generate meatballs with higher mass but fewer total pieces, as the volume of dough per cut increases, a phenomenon widely observed in food-forming and extrusion operations [25]. These findings are consistent with previous studies by Sugiyanto and Muhtadi [5], Seprianto [8],

and Yogi [7], which collectively confirm that mechanical and geometric parameters in food-forming machines directly influence product mass and energy efficiency.

Statistical analysis using Two-Way ANOVA further validates these relationships, showing that both independent factors—screw speed and cutter diameter—have significant main effects ($p < 0.05$), while their interaction also exhibits a notable influence on meatball mass. The interaction plot revealed intersecting trend lines, confirming that the impact of screw speed depends on the level of cutter diameter and vice versa, as commonly reported in factorial experimental studies involving interacting mechanical parameters [28]. Furthermore, the response optimization results are in agreement with established Response Surface Methodology principles, where multi-parameter optimization is required to balance product quality and energy consumption [29]. The optimal setting at 124 rpm screw speed and 30 mm cutter diameter yielded meatballs within the target mass range of 15–25 g with the lowest energy requirement, achieving a desirability score of 0.93, which is categorized as excellent optimization. These outcomes reinforce that integrating mechanical design analysis with statistical optimization is an effective approach for developing efficient and reliable automated food-processing equipment suitable for small and medium enterprises [25], [30].

4. Conclusion

Based on the experimental and statistical analyses, it can be concluded that both screw conveyor speed and cutting blade diameter significantly influence the mass, number, and production capacity of meatballs produced by the machine. Higher screw speeds increase dough extrusion and meatball mass but also elevate motor power consumption, while larger cutting diameters yield heavier yet fewer meatballs. The interaction between these two parameters was statistically significant, indicating that their effects are interdependent. The optimal performance was achieved at a screw conveyor speed of 124 rpm and a cutting blade diameter of 30 mm, which produced meatballs within the target mass range of 15–25 g, more than 65 pieces per batch, and with the lowest power consumption. These results demonstrate that the developed meatball-forming machine operates efficiently and effectively, providing a valuable reference for optimizing food-processing equipment in small and medium-scale industries. However, this study has several limitations. The experiments were conducted using a single dough formulation and a fixed batch mass of 1 kg, while variations in dough composition, moisture content, and rheological properties may influence extrusion behaviour and cutting performance. In addition, the investigation focused on two main mechanical parameters, without considering other potentially influential factors such as cutter rotational speed, screw geometry, motor type, and long-term operational stability. Future research is therefore recommended to examine a wider range of dough formulations, expand machine parameters, and evaluate continuous operation performance, energy efficiency over extended use, and product quality attributes such as texture and sensory acceptance. Such studies would further enhance the applicability of the machine for diverse production conditions and broader industrial implementation.

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6. REFERENCES

- [1] S. Margritje and R. M. Tinangon, *Industri Pengolahan Daging*. Jakarta, Indonesia: Andi Publisher, 2019.
- [2] B. Asrah, D. Sima, H. S. Lubis, C. Tarisa, and N. Nurwani, "Optimalisasi strategi digital marketing untuk perkembangan usaha mikro kecil dan menengah (UMKM) di Desa Aras, Kecamatan Air Putih, Kabupaten Batubara," *MANEGGIO: Jurnal Ilmiah Magister Manajemen*, vol. 7, no. 2, 2024, doi: 10.30596/maneggio.v7i2.21299.
- [3] Y. Setiawan, "Mesin pencetak bakso sistem horizontal dengan motor DC skala rumahan," in *Seminar Nasional Penelitian dan Pengabdian Masyarakat, Indonesia, 2021*, doi: 10.33019/snppm.v5i0.2756.

- [4] C. B. Nugroho, N. Yuniarsih, and S. Widiawan, "Pengaruh kecepatan putar poros terhadap massa dan volume bakso yang dihasilkan pada vertical meatballs machine," *Jurnal Integrasi*, vol. 7, no. 2, pp. 119–122, 2015.
- [5] D. Sugiyanto and M. Muhtadi, "Pengaruh putaran screw terhadap keluarnya adonan dari nosel mesin pencetak bakso," *Jurnal Teknik Mesin*, vol. 6, no. 1, pp. 45–52, 2018.
- [6] N. S. Saputra, M. Muchlisinalahuddin, and A. Armila, "Rancang bangun mesin pencetak bakso," *Jurnal Teknik Mesin*, vol. 15, no. 2, pp. 115–120, 2022.
- [7] Yogi, "Analisis pengaruh putaran screw terhadap keluarnya adonan dari mesin pencetak bakso," *Jurnal Teknologi Produksi*, vol. 10, no. 1, pp. 33–40, 2022.
- [8] D. Seprianto, "Analisis pengaruh diameter pisau pemotong terhadap kapasitas produksi mesin pencetak bakso," *Jurnal Teknologi Rekayasa Mesin*, vol. 4, no. 1, pp. 45–52, 2021.
- [9] A. Arsana, N. Widiantara, and I. A. Darmayanti, "Designing and performance testing of meatball forming machine," *Advances in Social Science, Education and Humanities Research*, vol. 390, pp. 22–27, 2020, doi: 10.2991/icracos-19.2020.49.
- [10] M. V. Adiansyah, "Perawatan mesin press kaleng (cans crushing machine) dengan penggerak motor bensin," *Jurnal Teknik Mesin*, vol. 9, no. 1, pp. 36–42, 2023.
- [11] S. S. Agung, "Penyebab kerusakan motor listrik penggerak pompa hidrolik crane saat proses bongkar muat di MV Sinar Sejati," *Karya Tulis Teknik Elektro*, pp. 8–45, 2022.
- [12] K. Alfiansyah, R. Setiawan, and B. Suhendra, "Proses pembuatan roda gigi miring pada mesin kertas," *Jurnal Kajian Teknik Mesin*, vol. 8, no. 2, pp. 121–130, 2023, doi: 10.52447/jktm.v8i2.6984.
- [13] D. D. Aryadi, "Kajian ragam rasio pulley terhadap daya listrik yang dihasilkan generator pada prototipe turbin cross-flow," M.S. thesis, Dept. of Mechanical Engineering, Universitas Mercu Buana, Jakarta, Indonesia, 2023.
- [14] M. E. Murdianto, A. Wahyudianto, and Suriyanto, "Modifikasi dan perhitungan rangka pada mesin sablon gelas," *MeKaniK: Jurnal Teknik Mesin*, vol. 16, no. 2, pp. 50–56, 2022.
- [15] Y. D. Novitasari and T. Akhir, "Perhitungan ulang transmisi sabuk dan puli serta pemilihan alternator pada kinetic flywheel conversion I (KFC I)," in *KFC I Proceedings*, pp. 57–71, 2018.
- [16] N. Ridha, "Proses penelitian, masalah, variabel, dan paradigma penelitian," *Jurnal Hikmah*, vol. 14, no. 1, pp. 62–70, 2017.
- [17] D. C. Montgomery, *Design and Analysis of Experiments*, 9th ed. Hoboken, NJ, USA: Wiley, 2017.
- [18] Muhib, "Analisis kinerja screw conveyor terhadap kapasitas pemindahan material," *Jurnal Rekayasa Mesin*, vol. 1, no. 1, pp. 1–8, 2006.
- [19] Sandra and Meiselo, "Analisis pengaruh kecepatan putar screw terhadap daya listrik pada mesin pengaduk adonan," *Jurnal Teknologi Mesin dan Energi*, vol. 8, no. 2, pp. 101–108, 2020.
- [20] T. Ulaan, A. Hidayat, and A. Firmansyah, "Analisis kebutuhan daya motor pada mesin ekstruder," *Jurnal Teknik Mesin Terapan*, vol. 12, no. 1, pp. 55–62, 2022.
- [21] R. S. Khurmi and J. K. Gupta, *A Textbook of Machine Design*, 14th ed. New Delhi, India: Eurasia Publishing House, 2005.
- [22] E. Waluyo, H. Kurniawan, and M. S. Wibowo, "Statistical analysis using p-value for experimental design validation," *Jurnal Sains Teknologi Industri*, vol. 6, no. 1, pp. 1–10, 2024.
- [23] J. Frost, *Regression Analysis: An Intuitive Guide for Using and Interpreting Linear Models*. Traverse City, MI, USA: Statistics By Jim Publishing, 2019.
- [24] J. R. Welty, C. E. Wicks, R. E. Wilson, and G. Rorrer, *Fundamentals of Momentum, Heat, and Mass Transfer*, 6th ed. Hoboken, NJ, USA: Wiley, 2015.
- [25] R. L. Earle and E. M. Earle, *Unit Operations in Food Processing*, 2nd ed. Oxford, U.K.: Pergamon Press, 2004.
- [26] J. F. Steffe, *Rheological Methods in Food Process Engineering*, 2nd ed. East Lansing, MI, USA: Freeman Press, 1996.
- [27] S. Kalpakjian and S. Schmid, *Manufacturing Processes for Engineering Materials*, 6th ed. Boston, MA, USA: Pearson, 2014.
- [28] G. E. P. Box, W. G. Hunter, and J. S. Hunter, *Statistics for Experimenters: Design, Innovation, and Discovery*, 2nd ed. Hoboken, NJ, USA: Wiley, 2005.
- [29] R. H. Myers, D. C. Montgomery, and C. M. Anderson-Cook, *Response Surface Methodology: Process and Product Optimization Using Designed Experiments*, 4th ed. Hoboken, NJ, USA: Wiley, 2016.
- [30] ISO 22000:2018, *Food Safety Management Systems—Requirements for Any Organization in the Food Chain*. Geneva, Switzerland: International Organization for Standardization, 2018.