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Optimization of rotation speed parameters and number of grinding wheels on the quality and production capacity of chicken feed pellets

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Abstract. This paper presents an experimental design approach for the optimization process parameters for the chicken feed pellets. To achieve this goal, the speed parameters and number of grinding wheels are selected and two levels of this parameter are considered. Design of expert (DOE) of tests was used for experimental design and analysis of results. The chicken feed ingredients mixture is formed into pellets using a grinding wheel pellet machine with a variation of 150, 200 and 250 rpm rotation and variations in the number of grinding wheels 4, 6, and 8 pieces. The highest pellet production capacity (26.2 Kg/hour) occurs at 200 rpm rotating speed and 4 pieces of grinding wheels. The highest engine efficiency (87.6%) occurs at 200 rpm rotating speed and 4 pieces of grinding wheels. The highest pellet durability (91.6%) occurs at 200 rpm rotating speed and 4 pieces of grinding wheels. Optimal machining parameters are recommended to produce a pellet production capacity response of 25.6 Kg/hour, 85.53% efficiency machine, and 91.473% durability pellets are 150-225 rpm rotation speed range and 4-5 pieces grinding wheels.

1. Introduction

The process of making animal feed involves the use of various raw materials to produce compound feeds. Compound feeds must be in accordance with certain specifications regarding nutritional composition based on the description specified for nutritional quality, hygienic and physical. These specifications require knowledge of the properties of different ingredients to optimize processing while controlling nutritional quality for a given form of feed. Therefore, cooperation is needed from various disciplines such as nutrition science, science, and feed technology for further progress in producing animal feed [1].

Feed processing provides an opportunity to increase broiler production. According to Nolan, the biggest cost in producing broilers from the total production costs is feed (60-70%) [2,3]. There are several strategies to improve feed processing techniques; however, the cost of each strategy must be carefully considered for performance improvements that can be achieved and negative effects on target animals [4]. For this reason, several strategies are needed to improve feed processing techniques; however, the cost of each strategy must be carefully considered for performance improvements that can be achieved and negative effects on target animals [4].

Pelleting is the most common thermal processing method in the production of poultry feed. The main aim of pelleting is to agglomerate smaller feed particles by the use of mechanical pressure, moisture and heat. A major step in the pelleting process is the conditioning of mash prior to pelleting, which is generally accomplished by adding steam to the mash feed [3,5].

Opening a new animal feed factory in the area is an effort to optimize the potential of large local raw materials, the number of educated workers in the field of animal husbandry, and can reduce unemployment. This effort can reduce the dependence of animal feed from large factories. So that the production of pellet animal feed with adaptive technology using local equipment and raw materials must continue to be improved [6, 7].

Making chicken feed in the form of pellets in large capacity requires a machine. Various kinds of chicken feed pellet machines have been circulating, but the price is still expensive, which makes it very difficult for chicken farmers to buy it. Thus, a new breakthrough is needed by making pellet machines using cheap and lightweight materials, small driving forces to produce pellet machines that can be provided by most farmers' communities [7, 8].

Feed processing refers to any treatment to which animal feed undergoes prior to ingestion [9]. Feed processing technology has witnessed substantial improvements, from a hand scoop shovel as the basic mixing tool [10] to various processing operations which are currently performed utilizing modern feed technology [11]. The widely used processing operations in feed manufacturing plants are receiving the raw materials, grinding or particle size reduction, proportioning or batching, mixing, heating or thermal treatment (or pellet shaping), packaging, warehousing, and loading. Each of these operations can influence feed quality and poultry performance. Feed processing refers to the treatment provided fodder for consumption [9].

Feed ingredients, especially cereal grains, are cleaned and ground before being mixed into the diet. Grinding or particle size reduction modifies the physical characteristics of the material to increase the surface area of the larger nutrient digestion, improve blending ability and homogeneity of mixed feeds [4, 12].

Hammer and roller mills are the most commonly used equipment to reduce the particle size of feed ingredients. At the factory hammer, particle size reduction is carried out by affecting the slow-moving material with a set of hammers moving high speed. Hammer mills generally produce spherical particles with polished surfaces [13]. Particle size distributions produced at hammer mills vary widely around the geometric mean, with most and many small-sized particles [13, 14]. In the roller mill, size reduction is carried out through the compression strength between pairs of rotating rolls, resulting in a more uniform particle size distribution with a lower proportion of fine material [13].

Two basic methods, namely, cycle (batch) can be used to reach proportions. In a cycle or batching system, each material is weighed into batches, while continuous systems involve concurrent and continuous material addition [15]. Proportional materials and proper mixing are needed to achieve a homogeneous mixture.

DOE has been used by several researchers to optimize various types of manufacturing processes. In this study, a model has been developed to predict the optimization of engine speed parameters and the number of grinding wheels in the process of making chicken feed pellets using a tapered form wheel pellet machine.

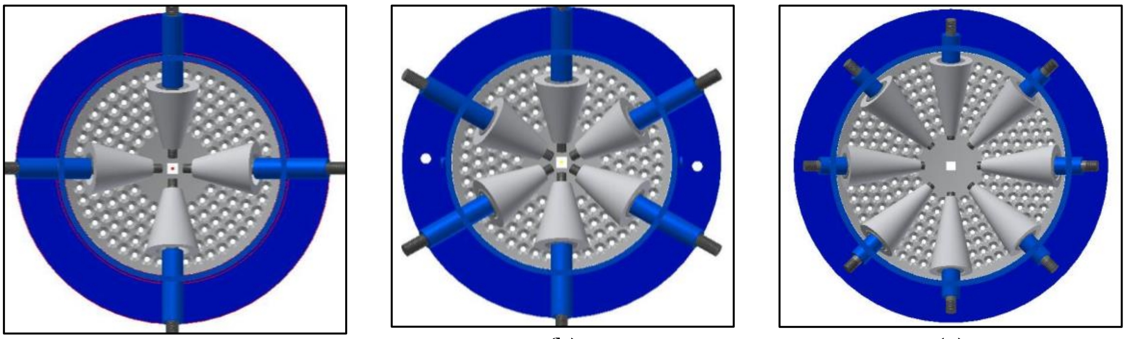
In this work using a comparison of the mixture of chicken feed ingredients constructed by the author, several experiments have been carried out on the effects of machining parameters such as rotational speed and a number of grinding wheels.

2. Experimental Procedures

2.1. Machine Specifications

Pellet machine wheels grinding system (Figure 1a) which is used to measure the effect of rotation speed and number of grinding wheels on the capacity of pellet, machine efficiency, and durability of the pellet. The specification of pellet machine wheels grinding system is: machine dimensions (600 x 470 x 1150 mm), a cylindrical tube (280 x 310 mm), disc printing (diameter 265 x 10 mm), wheel rollers (diameter 60 x 110 mm), dynamo motor (1HP, 1450 rpm), the speed rotation (100-400 rpm). The shape and the number of the grinding wheels is shown in Figure 2. The workings of this tool are a disc mold rotated by the motor and wheel roller rotates. The feed mixture was inserted into the hole-mold after crushed by the roller wheels. The pellets were formed after passing through the hole-mold.

Figure 1. The pellet machine with grinding wheels system.



(a) (b) (c)

Figure 2. The grinding wheels models, (a) four pieces, (b) sixth pieces, and (c) eight pieces.

2.2. Stage of Testing Method

Testing was conducted to obtain the composition of the feed mixture that is optimal. The first stage is to prepare 500 grams of feed materials are added to the adhesive (starch) 50 grams and then mixed with water 400 ml. The next stage, the feed pellets mixture are moulded on the machine roller wheel system. Testing parameters are rotational speed of 150 rpm, 200 rpm, and 250 rpm at a hole-mold diameter of 6 mm, and a number of grinding wheels 4 pieces, 6 pieces, and 8 pieces. Production capacity and pellet durability are calculated by equations (1) and (2).

$$\text{Production Capacity} = \frac{weight\ of\ pellet\ (Kg)}{Times\ (Hour)} \quad (1)$$

$$\text{Durability Pellet} = \frac{Weight\ of\ durablitiy\ \ pellet\ (Kg)}{Weight\ of\ broken\ \ pellet\ (Kg)}\ \text{x}\ 100\% \quad (2)$$

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2.3. Experimental design and statistical analysis.

To explore the effect of the operational factors on the response in the region of investigation, a DOE at two levels was performed. Rotation speed (rpm, A) and a number of grinding wheels (pcs., B) were selected as independent factors. The range of values and coded levels of the factors are given in Table 1. A polynomial equation (Eq. 3) was used to predict the response as a function of independent factors and their interactions. An interaction is the failure of the one factor to produce the same effect on the response at different levels of another factor [16]. In this work, there were four independent factors; therefore, the response for the quadratic polynomials becomes:

Table 1. Independent factors and their levels for DOE of chicken feed pellets process.

Independent Factors	Unit	Level		
		-1	0	1
Rotation speed (A)	(ºC)	150	200	250
grinding wheels (B)	(pcs.)	4	6	8

$$Y = \beta_0 + \sum \beta_i x_i + \sum \beta_i x_i^2 + \sum\sum \beta_{ii} x_i x_j \qquad (3)$$

where b_0, b_i, b_{ii}, b_{ij} are the constant, linear, square and interaction regression coefficient terms, respectively, and xi and xj are the independent factors (A and B).

Design-Expert 6 software was used for multiple regression analysis, analysis of variance (ANOVA), and analysis of ridge maximum of data in the response surface regression (RSREG) procedure. The goodness of the model was evaluated by the coefficient of determination R^2 and its statistical significance was checked by the F-test.

3. Result and Discussion

This study demonstrates the effect of rotation speed and number of grinding wheels for the optimization of the pellet feed chicken production. The design is used to obtain 11 design points within the whole range of two factors for experiments. The designs and the response are given in Table 2. Following the experiments, the response surface is approximated by DOE.

Table 2. Design layout and experimental results.

Std	Rotation Speed (rpm)	Number of Grinding Wheels (pcs.)	Coded A	Coded B	Production Capacity (Kg/hr.)	Machine Efficiency (%)	Durability Pellet (%)
1	150	4	-1	-1	26.0	87.3	91.6
2	200	4	0	-1	26.2	87.6	91.6
3	250	4	1	-1	25.8	86.6	91.4
4	150	6	-1	0	25.5	85.3	91.4
5	200	6	0	0	25.5	86.3	91.5
6	200	6	0	0	25.6	86.4	91.4
7	200	6	0	0	25.7	86.5	91.3
8	250	6	1	0	25.2	85.3	91.1
9	150	8	-1	1	24.5	83.9	90.9
10	200	8	0	1	24.8	84.7	90.8
11	250	8	1	1	24.7	84.0	90.4

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3.1. Production Capacity
Results for production capacity at rotation speed and number of grinding wheels show that it fits the quadratic model. The ANOVA for the production capacity data is given in Table 3. Having its Prob>F of much less than 0.01, the quadratic model is valid. As for the coefficients, the rotation speed and number of grinding wheels was considered a significant factor.

Table 3. ANOVA with CI = 95% for model and factors of the production capacity.

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	2.96	5	2.96	55.42	0.0002	significant
A	0.015	1	0.015	1.41	0.2890	
B	2.67	1	2.67	250.00	<0.0001	
A^2	0.016	1	0.016	14.84	0.0120	
B^2	0.025	1	0.025	2.37	0.1839	
AB	0.040	1	0.040	3.75	0.1106	
Residual	0.053	5	0.011			
Cor Total	3.01	10				

The obtained empirical equation of the production capacity in the form of an actual factor is as stated in equation (1),

$$\text{production capacity} = 25.60 - 0.050A - 0.67B - 0.25A^2 - 0.10B^2 + 0.100AB \tag{4}$$

Where A is rotation speed (rpm) and B is a number of grinding wheels (pcs.).

For convenience, the equation can be displayed as response surface contour as well as three-dimensional surfaces, as shown in Figure 3.

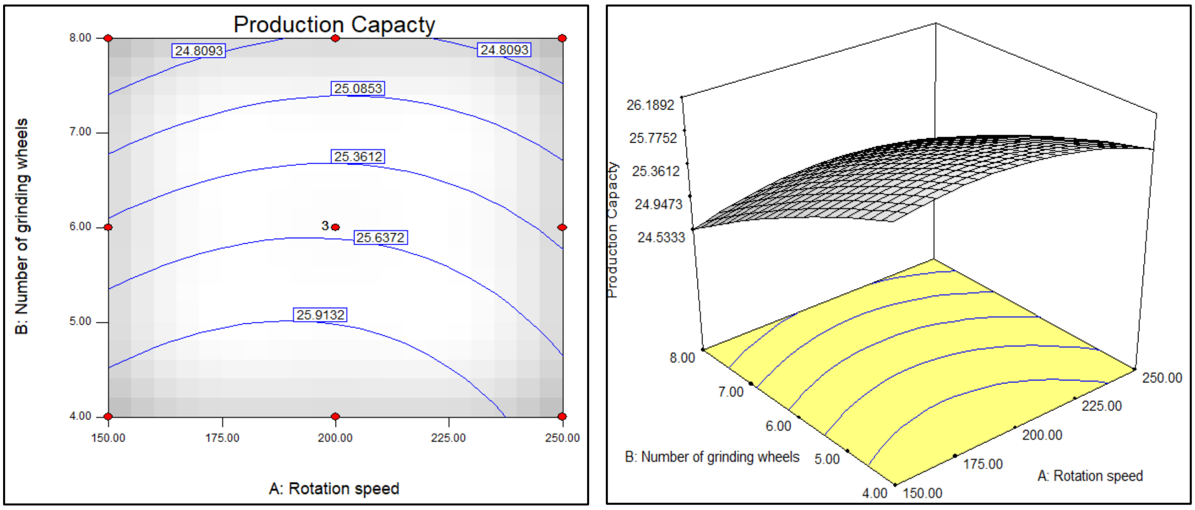

Figure 3. Response surface graph of (a) contours and (b) 3D Surface for production capacity.

Figure 3 shows the pellet production capacity of the test results of pellet machines with rotational speed variations (150, 200, and 250 rpm) and the number of grinding wheels (4, 6, and 8 pieces). The higher the rotational speed, the greater the production capacity, but at a rotating speed from 200 rpm to

250 rpm there is a decrease in production capacity. Figure 3 also shows the addition of the number of grinding wheels causes the production capacity to decrease. The average production capacity in this study was 25.4 Kg/hour. This pellet production capacity is better than the results of previous tests [7, 17]

3.2. Machine Efficiency

Results for machine efficiency at various rotation speed and number of grinding wheels show that it fits the linear model. The ANOVA for the machine efficiency data is given in Table 4. Having its Prob>F of much less than 0.01, the linear model is valid. As for the coefficients, both of the rotation speed and number of grinding wheels was considered as a significant factor. Machine efficiency was insensitive to the change in rotation speed and number of grinding wheels.

Table 4. ANOVA with CI = 95% for model and factors of the machine efficiency.

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	10.20	2	5.10	13.49	0.0027	significant
A	0.060	1	0.060	0.16	0.7008	
B	10.14	1	10.14	10.14	0.0008	
Residual	3.03	8	0.38			
Cor Total	834.85	10				

The obtained empirical equation of machine efficiency in the form of an actual factor is as stated in equation (2),

$$Machine\ Efficiency = 85.54 - 0.10A - 1.30B \quad (5)$$

Where A is rotation speed (rpm) and B is a number of grinding wheels (pcs.). For convenience, the equation can be displayed as response surface contour as well as three-dimensional surfaces, as shown in Figure 4.

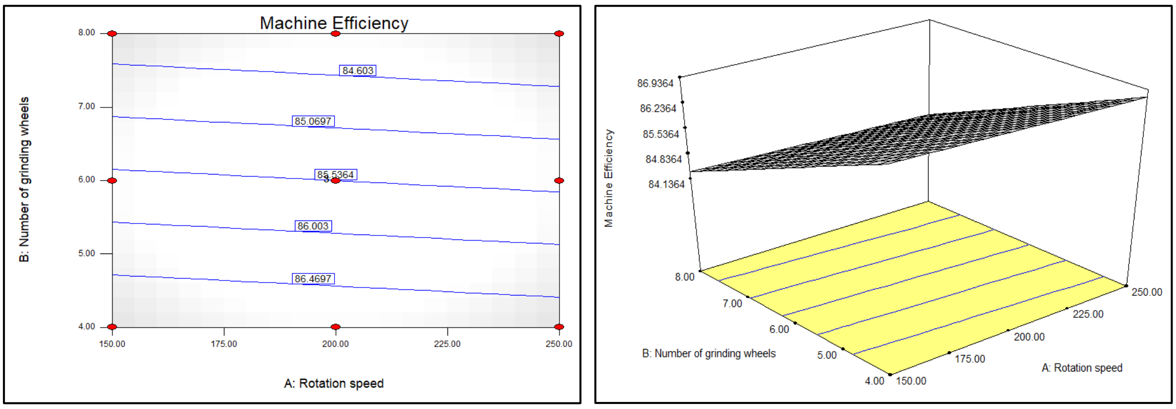

Figure 4. Response surface graph of (a) contours and (b) 3D Surface for machine efficiency.

Figure 4 shows the pellet production capacity of the test results of pellet machines with rotational speed variations (150, 200, and 250 rpm) and the number of grinding wheels (4, 6, and 8 pieces). The higher the rotational speed and the more grinding wheels the smaller the engine efficiency capacity.

3.3. Durability Pellet

Results for durability pellet at various rotation speed and number of grinding wheels show that it fits the quadratic model. The ANOVA for the durability pellet data is given in Table 5. Having its Prob>F of much less than 0.01, the quadratic model is valid. As for the coefficients, both of the rotation speed and number of grinding wheels was considered as a significant factor. Durability pellet was insensitive to the change in rotation speed and number of grinding wheels.

Table 5. ANOVA with CI = 95% for model and factors of durability pellet.

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	1.54	5	0.31	16.78	0.0038	significant
A	0.17	1	0.17	9.10	0.0295	
B	1.04	1	1.04	56.90	0.0006	
A^2	0.086	1	0.086	4.70	0.0825	
B^2	0.14	1	0.14	7.59	0.0401	
AB	0.022	1	0.022	1.23	0.3181	
Residual	0.092	5	0.018			
Cor Total	1.63	10				

The obtained empirical equation of durability pellet in the form of an actual factor is as stated in equation (3),

$$\text{Durability pellet} = 91.47 - 0.17A - 0.42B - 0.18A^2 - 0.23B^2 - 0.75AB \quad (6)$$

Where A is rotation speed (rpm) and B is a number of grinding wheels (pcs.).

For convenience, the equation can be displayed as response surface contour as well as three-dimensional surfaces, as shown in Figure 5.

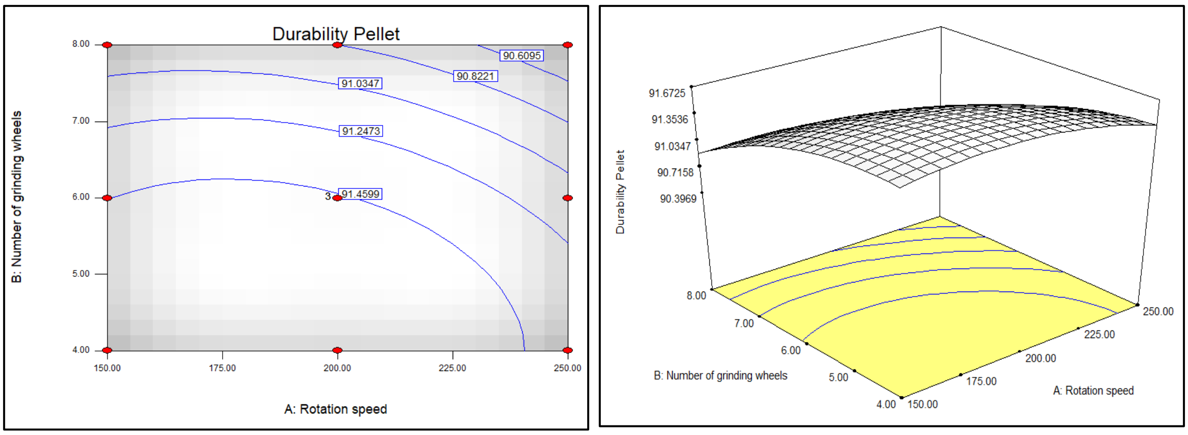

Figure 5. Response surface graph of (a) contours and (b) 3D Surface for durability pellet.

Figure 5 shows the pellet durability of the test results of pellet machines with rotational speed variations (150, 200, and 250 rpm) and the number of grinding wheels (4, 6, and 8 pieces). The higher the rotational speed, the greater the percentage of pellet durability, but at a rotational speed from 200 rpm to 250 rpm there is a decrease in the percentage of pellet durability. Figure 3 also shows the addition of the number of grinding wheels causes the percentage of pellet durability to decrease. The average pellet durability in this study was 91.2%. The durability of this pellet is better than the results of previous tests [7, 17]

3.4. Optimization

Now that the empirical model for all casting responses as a function of stirring speed and stirring time has been obtained, the selection of the optimal casting parameter setting can be performed. One can adjust the expected range of each casting response and the range of stirrer speed and stirring time in line with expectations for all foundry responses can be determined. For example, that in order to obtain optimal mechanical properties, minimum grain size, and optimum shape factor, the stirring parameters should be carried out at 150-225 rpm rotation speed range and 4-5 pieces grinding wheels. To achieve this criterion, the rotation speed range and number of grinding wheels must be within the yellow plot of the overlay (Figure 6) of all production pellets responses.

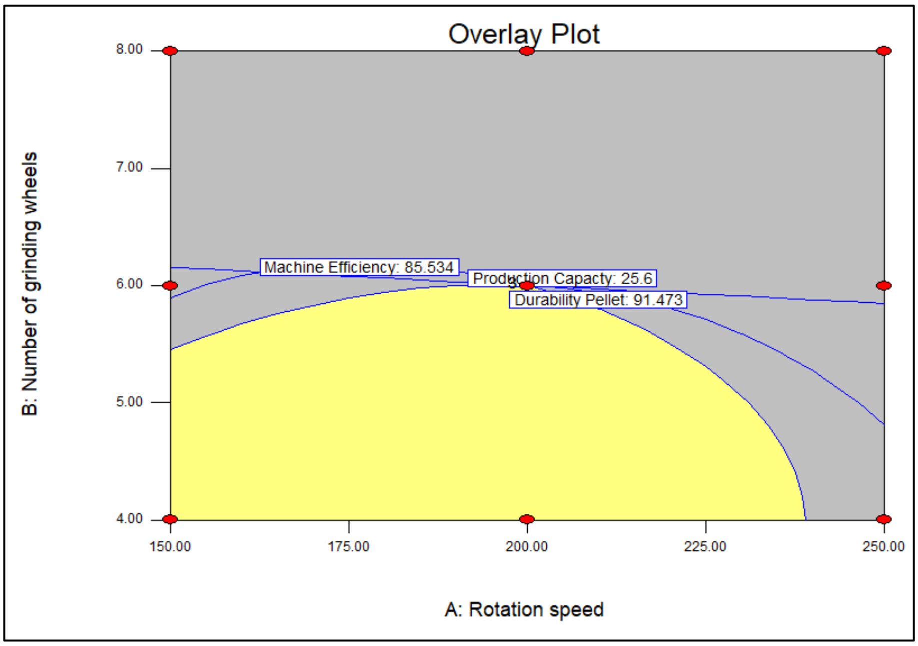

Figure 6. Overlay plot of the input factors for the predetermined response criteria of pellet production of 25.6 Kg/hour, 85.53 % efficiency machine, and 91.473 % durability pellets.

4. Conclusion

Research on making chicken feed pellets using a roller wheel pellet machine with rotational speed variations and the number of grinding wheels has been studied. The results obtained can be synergized as follows: The highest pellet production capacity (26.2 Kg/hour) occurs at 200 rpm rotating speed and 4 pieces of grinding wheels. The highest engine efficiency (87.6%) occurs at 200 rpm rotating speed and 4 pieces of grinding wheels. The highest pellet durability (91.6%) occurs at 200 rpm rotating speed and 4 pieces of grinding wheels. Optimal machining parameters are recommended to produce a pellet production capacity response of 25.6 Kg/hour, 85.53% efficiency machine, and 91.473% durability pellets are 150-225 rpm rotation speed range and 4-5 pieces grinding wheels.

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