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Design and Fabrication of Meat Shredder Machine Using VDI2221 Approach

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ABSTRACT

Shredded meat is more palatable to the taste of consumer and preparing shredded meat in a large scale requires the aid of meat shredder machine. This paper presents a detailed design procedure of a meat shredder machine developed by the VDI2221 approach. This paper also elaborates on the design of each part of the machine which includes selecting the components of the cutting and transmission system, kinematic arrangement of forces, material selection on the machine and proportion of parts to ensure the maximum strength and functionality of the machine. Further, the design of the various parts of the machine in 3D model and machine fabrication are discussed, along with the testing on the function and geometric aspects to ensure the efficiency of the machine. This study developed a meat shredder machine with 0.5Hp electric motor and capacity of 2kg per hour.

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1. INTRODUCTION

The consumption of meat along with other food is very important because it enriches both the nutritional content of the food and also acts as important delicacies. It is a nutritious food containing some quantities of essential amino acids, in the form of proteins and also contains group of vitamins. Animal meat is composed of muscles, bones, fats and connective tissues, and the main edible and nutritional part of the meat is the muscle or lean meat (Odior, 2012).

Meat shredder machine is a food processor or grater that is used to pull apart the cooked meat into the strips or thin slices. Nowadays, there are many machines available in the market with various functions, including slicing, grinding, or cutting up the larger pieces of meat into the smaller pieces. But for certain variety of meat cuisines, meat is more desirable to be pulled or shredded into smaller pieces as it brings more flavors and tastes (Bridge, 2008). Therefore, this study intends to develop a meat shredder machine.

The scope of this study is to develop a meat shredder machine that operates as both meat processor and meat flossing machine. The user target of the proposed meat shredder machine is for the home-scale industry, which is mostly disadvantaged due to the high price of the existing meat shredder machine in the current market. The development process is initiated from the shape designing of the meat shredder machine by considering its main function. Further, the design takes ergonomic factor into account, which allows for user comfort.

2. METHODOLOGY

This paper presents three main parts of development: design process flow, fabrication, and function and geometry testing. The VDI2221 guideline was considered in this study to develop the meat shredder machine design. VDI2221 guideline is a systematic approach in designing and developing technical systems and products. The main goal of the VDI2221 guideline is to serve a general methodology of product design, including the technical systems and the overall product design, so that the designing process can be completed more efficiently. The guideline is based on engineering systems and problem solving, and it emphasizes on the broad application within mechanical engineering, precision mechanics, software development and the planning of process engineering (Jänsch & Birkhofer, 2006).

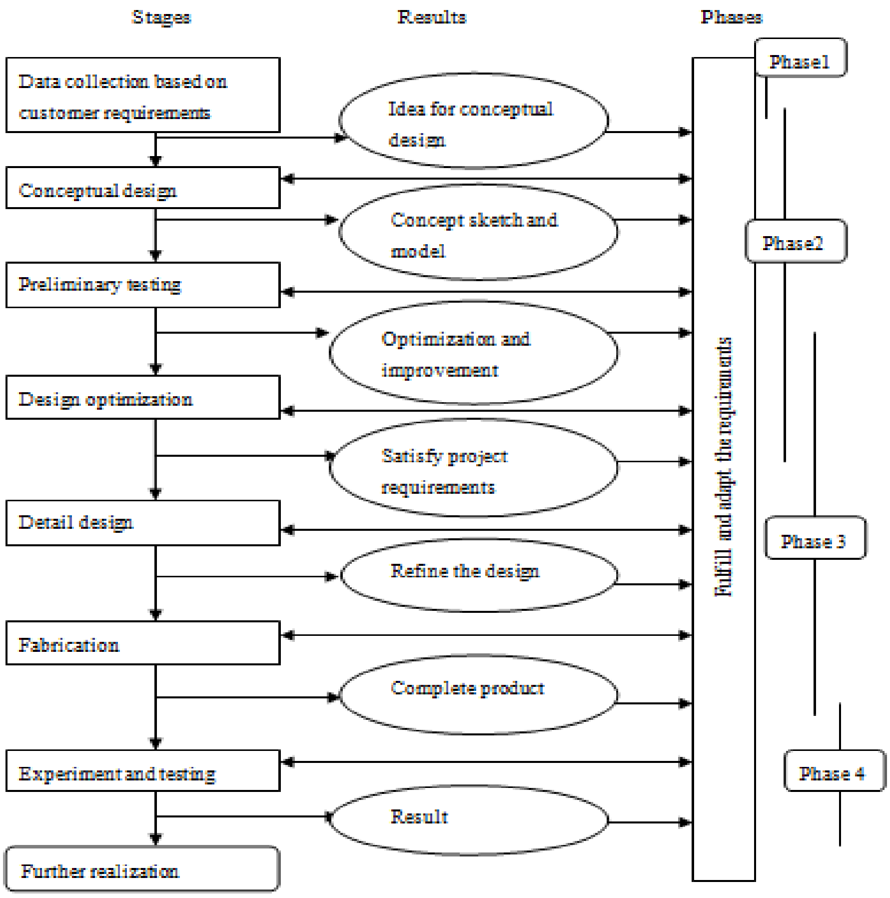

Figure 1. Design process flow.

2.1. Design process flow

The design process flow of VDI2221 guideline applied in this study follows that of proposed by the design society in the Germany, and it is shown in **Figure 1**. The activities are divided into a few stages which are data collection, design specification, conceptual design, design optimization and detailed design.

In the early stage of conceptual design of a new product, design specification provides information that contains the requirements to be satisfied, and the objectives can be also maximized here (Sreenivas et al., 2017). This process normally controls the design throughout the engineering design process. In designing process of engineering components or consumer products, observation and survey should be conducted to determine the customer needs and production requirements or any other technical characteristics (Kumar & Kumar, 2015)(Triawan et al., 2021). In addition, these steps are also important in order to obtain the design specification. Besides, to obtain the properties of the meat that is suitable to shred in this meat shredder machine, testing on the meat properties was performed.

After the process of design specification, several conceptual designs were sketched. These sketches of conceptual design were compared with the terms of the concept of DFMA, which are the design of manufacture and design of assembly. The selection of the most suitable design was done by using the decision matrix method. Design consideration was examined after the conceptual design process. Several factors considered in the design of the meat shredder machine including cost of production (Oktaviandri & Paramasivam, 2020), safety, and ease of operation (Onifade, 2016)(Waleola et al., 2017). The most suitable design was chosen by the decision matrix method. The selected design was then transferred to the 3D modelling and engineering drawing by using the software CATIA V5R21. Detailed design is the important stage where the design is refined, and specifications are reviewed further. Next, fabrication of the meat shredder machine was conducted.

2.2. Fabrication

In the fabrication stage, material selection and manufacturing process need to be taken into consideration. Material selection is important in this stage as the characteristics and properties of the material can affect the manufacturing process of the meat shredder machine (Shiri et al., 2017). The materials were selected based on the ASM material catalogue (Cobb, 2010). In addition, the materials were modified through manufacturing process to the required part. Selection of the manufacturing process means finding the best match between the set of process and the design requirements. In selecting manufacturing process, there are several attributes that need to consider, which are material to be used, number of parts required, size and shape of the product to be produced, dimensional tolerances required, geometrical complexity and the machine used. Fail to select the suitable manufacturing method such as machining process can produce incorrect required dimension and induce damage such as residual stress (Saptaji et al., 2019).

2.3. Functional and geometrical testing

Experiment and testing were implemented on the final product according to the aspects of the function and geometry. The result of the experiment and testing will be taken into further realization and improvement. Functional testing was conducted to verify the output of the machine to match the requirement. Geometrical testing was carried out to ensure the dimensions of each part of the machine developed to match with the design required.

3. RESULTS AND DISCUSSION

3.1. Design process

According to the requirements, there are two major requirements that need to take into account, which are customer requirements and production requirements, and those requirements are listed in **Table 1**.

In addition, to obtain the properties of meat required as design specification, the properties of meat was tested based on the four different conditions of the meat: fresh meat, half-cooked meat, fully cooked meat and fully cooked meat and stewed.

After the meat properties test, it was found that fresh meat could not be shredded as desired, due to the texture of the fresh meat that cannot be ripped apart to become thin slices. Similarly, the half-cooked meat did not show a desirable end result from the shredding process. Meanwhile, fully cooked meat was found to be shredded quite well. Amongst the meat types, the fully cooked meat with stewed for 30 minutes was found to give the best result of shredded texture. As shown in **Figure 2**, this meat type is the most successful and suitable to use in the shredding process since the texture of this meat is more tender compared to others. Therefore, fully cooked meat with stewed is the recommended choice to use in the shredding process. By referring to the customer requirements and production requirements, there are three designs sketched for the conceptual design of the meat shredder machine (**Figures 3** to **5**).

Table 1. Customer and production requirements for product.

Customer Requirements	Production Requirements
Easy to clean	Easy to manufacture
Easy to operate	Easy to assemble
Lightweight	Serviceability
Cost	Reliability
Quiet when operating	Safety
Aesthetic	Cost

Figure 2. Fully cooked meat with stewed after shredded.

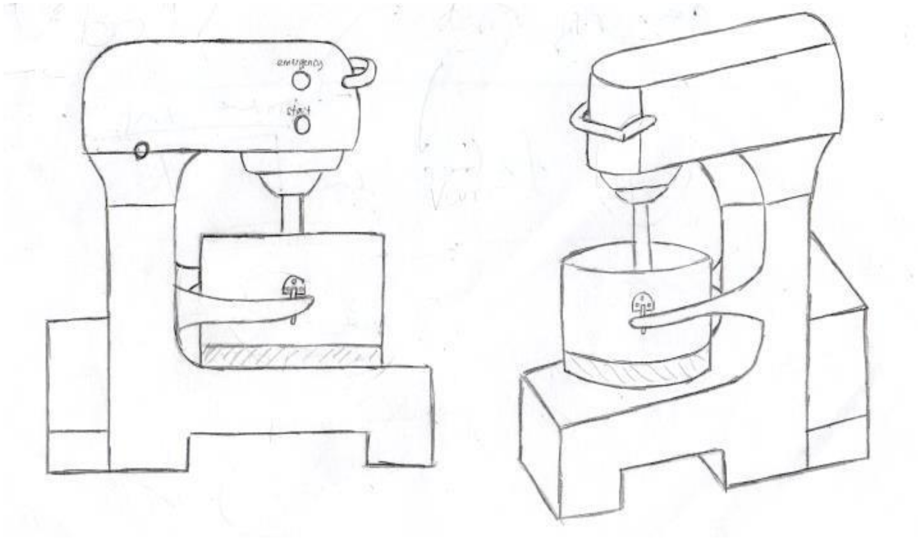

Figure 3. Sketch of Design #1.

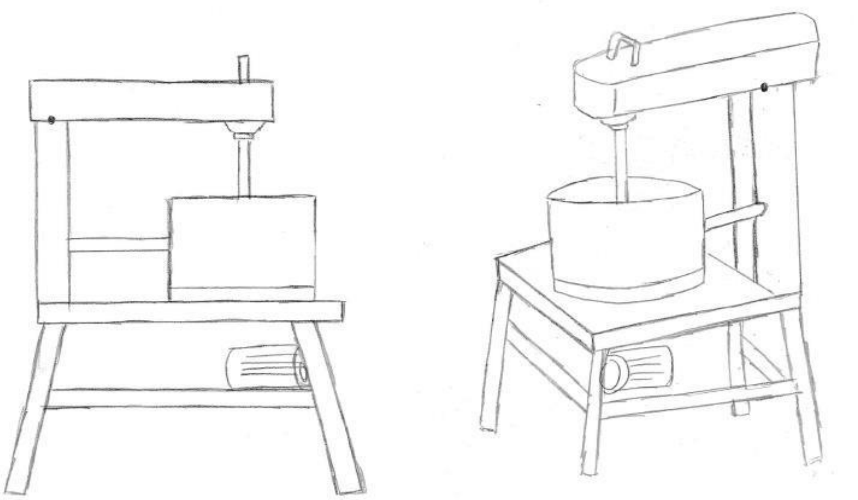

Figure 4. Sketch of Design #2.

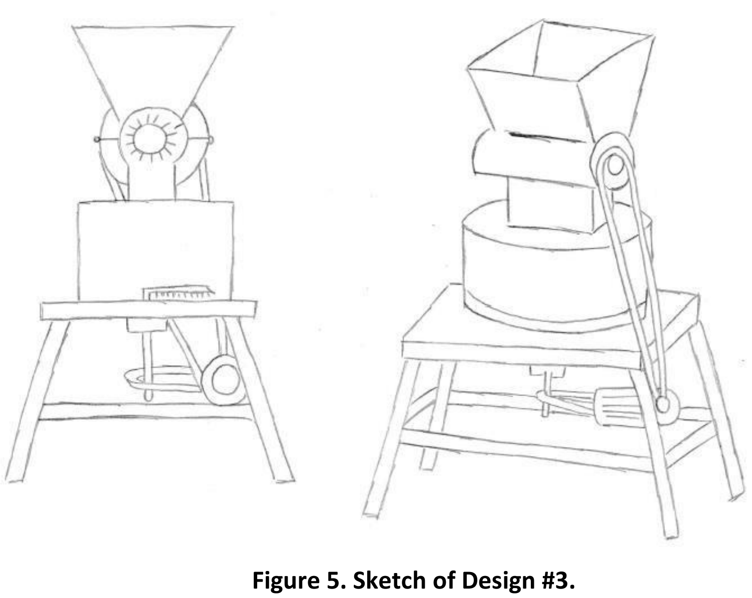

Figure 5. Sketch of Design #3.

In order to select the best design for the meat shredder machine, the decision matrix method was considered in this design selection as illustrated in **Table 2**. Decision matrix is a useful method to select or make a decision. To obtain the weightage and score that tabulated in **Table 2**, a product design survey was conducted based on the criteria of the customer requirements and production requirements. The score which was rated by the respondents in the criteria that listed in the survey form followed the Likert scale. After rating all the options, the option with the highest score was selected as the best decision. From Table **2**, design #1 is the best design since it has the highest score compared to the other designs. Then, the selected conceptual design was brought further to be 3D model designed using Dassault System CATIA V5R21. **Figure 6** shows the CAD drawing of the machine.

Table 2. Design selection

Criteria	**Options**						
	Weightage	**Design #1**		**Design #2**		**Design #3**	
		Score	**Total**	**Score**	**Total**	**Score**	**Total**
Easy to operate	5	6	30	6	30	6	30
Easy to clean	6	7	42	7	42	4	24
Lightweight	4	5	20	5	20	5	20
Serviceability	4	5	20	5	20	4	16
Aesthetic	8	8	64	6	48	5	40
Durability	5	6	30	6	30	6	30
Safety	5	7	35	6	30	6	30
Cost	10	5	50	5	50	3	30
Total			**291**		**270**		**220**

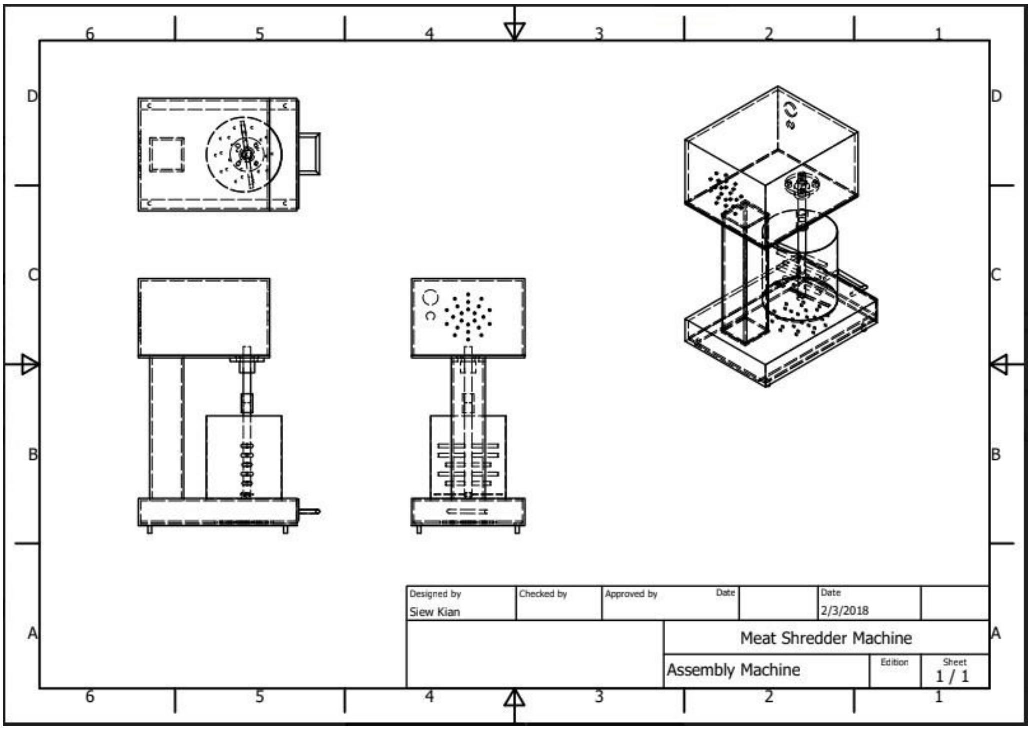

Figure 6. Assembly drawing of meat shredder machine.

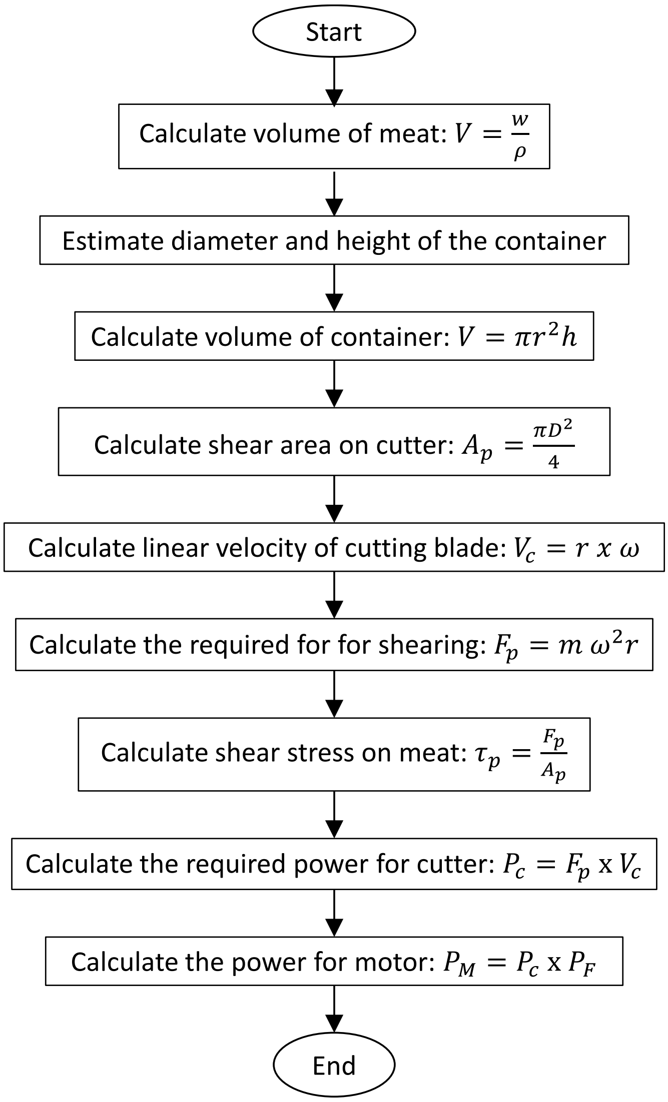

Figure 7. Calculation flow chart.

3.2. Design parameters calculation and component selection

At this stage, calculation of several design parameters was conducted to determine the critical and actual parameter needed for selection of the components required (Amiebenomo et al., 2013). Flow chart shown in **Figure 7** displays mathematical equations employed in this study. This flow chart was designed to ensure the sequential flow of calculation and to smoothen the process of selecting components.

3.3. Fabrication

This study selected stainless steel 304 as the main material for meat shredder components. According to the ASM catalogue, stainless steel 304 is suitable as the material to fabricate parts that will be in contact with food such as cutter and container.

This is because stainless steel 304 contains minimum carbon content (0.08%) which is harmless when contacted with food. Stainless steel is also high in strength, excellent corrosion resistance and has a high melting point which can withstand high heat as shown in **Table 3**. For the other parts of the machine, the material selected is mild steel. The reason mild steel was chosen is mild steel has great durability and weldability.

Table 3. Mechanical and physical properties of stainless steel 304

Properties	Value	Unit
Hardness	80	HBN
Tensile strength	600	MPa
Yield strength	262	MPa
Melting point	1399 – 1421	°C
Density	7900	Kg/cm^3
Modulus of elasticity	200	GPa

Figure 8. Meat shredder machine.

There are various processes that are involved in manufacturing the meat shredder machine, including cutting, drilling, rolling, and bending. Two types of cutting processes involved to cut the materials in this study are shearing and laser cutting. While the assembly method used in this machine is by welding method. **Figure 8** shows the fully assembled meat shredder machine.

3.4. Functional testing

The developed model of the meat shredder machine was subjected to the performance test or functional testing. The functionality of the meat shredder machine was measured by recording the time taken for different quantity of the meat being shredded. This machine has a maximum capacity of 2 kg/hour. The functional test was conducted to measure its suitability and functionality. The functional testing was carried out with two performance tests, by observing the required time to shred the meat and the time to dry the shredded meat.

Table 4. Time taken to shred the meat with speed of 140rpm.

Speed of cutter (rpm)	Quantity of meat (kg)	Time taken (sec)
	0.4	112
	0.8	230
140	1.2	330
	1.6	456
	2.0	554

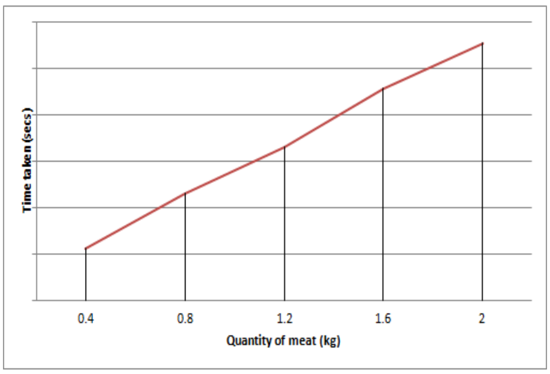

Figure 9. Graphical representation of quantity of meat (kg) v/s time taken (sec).

Table 4 shows the time taken with respect to quantity of meat needed to shred. From **Figure 9**, the graph shows that the required time to shred the meat increases with the increasing quantity of the meat.

Table 5. Time taken to dry the meat at a constant speed of 140rpm.

Speed of cutter (rpm)	Quantity of meat (kg)	Time taken (sec)
	0.4	24
	0.8	58
85	1.2	72
	1.6	112
	2.0	132

Next, the time required to dry the shredded meat was measured. **Table 5** shows the time recorded with respect to the quantity of shredded meat to dry. **Figure 10** shows that the time required to dry the shredded meat increases following the quantity of the shredded meat. **Figures 11** and **12** display the final output of the shredded meat and the dried shredded meat, respectively, using the machine developed in this study.

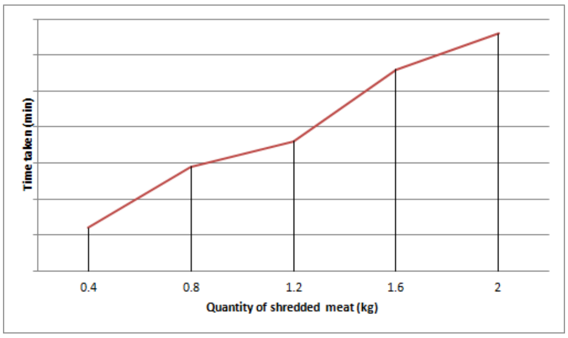

Figure 10. Graphical representation of quantity of shredded meat (kg) v/s time taken (min).

Figure 11. Final output of shredded meat.

Figure 12. Final output of the dried shredded meat.

3.5. Geometrical testing

Figure 13. Geometry testing on the length of motor cover.

Figure 14. Geometry testing on diameter of container.

The tests on the machine's geometries are shown on **Figures 13** and **14**. From the figures it was observed that the dimensions of the developed machine matched the required dimension on the drawings. There is some small difference of the dimension between the developed machine and the drawings due to the tolerances upon fabrication.

4. CONCLUSION

This paper concludes that VDI2221 guideline employed in this study is suitable to be implemented in designing an efficient meat shredder machine. Also, the developed meat shredder machine has met the requirements of the consumers and production. Finally, we can conclude that this meat shredder machine is a better option to use by home industry. The machine is designed by taking considerations of various demands in the home industry. Since this machine is made for home industry application, thus less work is required to operate this machine.

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