Prototype Development of Mechanize Cheese Grater

[*]Norazela Mohd Shah, Nursalbiah Nasir
School of Mechanical Engineering
College of Engineering
Universiti Teknologi MARA, 40450, Shah Alam, Selangor
**norazelaa@gmail.com*

ABSTRACT

The study presented in this topic is focused on the detail design of prototype cheese grater which meant to shred cheese into fine pieces. The main focus in this study is based on the real situation happening in small businesses entrepreneurs selling cheese fried bananas where mostly using manual grater. When having a lot to grating cheese, the sellers faced discomfort such as sluggish and sore shoulders, back pain and fatigue on hand because they have to stand while grating cheese. Although a cheese grater machine is available and widely used in the food processor industry, it is costly as the machine functions are over the specification for small businesses. The aims of this study are to design a prototype of a simple cheese grater to accommodate a small size of cheese as well as to reduce discomfort on the seller's body. There are few phases involved to perform this study; starting with survey and interview from the user, data analysis, determining product design specification, conceptual design selection, CAD modelling and fabrication and assembly process. Based on the data from survey, interviewand observation, the design of the cheese grater is designed by considering all the needs. Based on the survey, 100% of the respondents are still using manual grater and most of them want a machine that is easy to use, portable and lightweight. The prototype will incorporate an automated system to hold and grate the cheese in order to reduce hand and wrist discomfort. The detailed design of grater components such as body, jar, blade, motor, switch button and power source are fabricated and the result testing on grating prototype is run smoothlyand it helps for fried banana cheese to grating cheese faster. Blade acts as the cutting tools and critical parts of this study where FEA analysis is done. The factor of safety of the blade was being calculated to provide the safetyas well as the people using the device.

Keywords: *Grater machine, CAD modelling, FEA analysis, Cutting tools*

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Introduction

Cheese banana fritter is among favourite food in Malaysia and during Covid 19 pandemic, more local sellers opting to sell banana fritter as the resources are widely available as well as bigger profit margin. Cheese grater machines are widely used in the food processor industry with different operations and sizes. Nonetheless, in small scale business, sellers tend to minimize the capital cost such as buying equipment (example: electrical cooking top and automated machine). Thus, they grate the cheese manually as shown in Figure 1. As to authors knowledge, no small size operated grater machine/tool is found in the market. Although there are existing cheese graters in market [11] but the grating process required a lot of energy to operated and the output are based on the amount of energy applied as all small size grater operate manually. Due to this issue, motorized mechanism is proposed. The similar concept of working mechanism is the electric salt pepper grinder that uses battery as the source power and using DC motor to rotate the blade so the grinding process becomes faster [2]. Next, the manual garlic chopper uses a manual pull mechanism to operate the machine. It is also a portable product where users can easily use and bring anywhere [3].

Figure 1: Manual grating cheese

However, observation and survey conducted on a small business such as fried banana cheese sellers and showed there could be a posture/ergonomic problem in manual cheese grating task. Humans could feel uncomfortable to grate cheese continuously and in prolong time, thus affecting their health problems such as sluggishness, discomfort and pain at the neck, back and wrist area [1]. People need to bend their body to grate the cheese and use their both hands; one hand to grate and the other one to hold the cheese. Thus, the objective of the study is to develop a detailed design of the prototype, identify the suitable fabrication process and to fabricate the prototype. The design of the machine must follow the needs of the user where it requires a portable machine because the aim of the user is forfried banana sellers or hawkers who

have limited sources of power supply. CAD software is used to analyze the design of the machine before the fabrication process. The fabrication process is done according to the design in the software with the suitable material.

The material selection is very important in this study. Hence, one of the materials used in designing the prototype was Acrylonitrile butadiene styrene (ABS). ABS have strong dimensional stability and shape-ability, excellent impact resistance, and cost-effectiveness [4]. Therefore, ABS polymers have a huge market application:they are highly used in the manufacturing industry owing to its high property balance: these materials, in fact, offer a great compromise in mechanical, aesthetic, and processing characteristics [5]. The part used for ABS is for the jar which supports the main component of the blade where the grating process was done inside the jar. One of thematerials used for blades is stainless steel. Because of their great corrosion resistance and good mechanical qualities, stainless steels are commonly applied in the food industry. These characteristics are important since manufactured foods must meet stringent purity and quality requirements.

Good selection of stainless-steel grade can prevent corrosion from causing destruction on the entire manufacturing process. Stainless steels are a group of iron-based alloys that contain chromium, nickel, molybdenum, manganese, nitrogen, and other metals. Steel can be declared stainless if it contains "at least 10.5 percent chromium and no more than 1.2 percent carbon," according to European Standard [6], [7]. Hence the selection of material is important to determine the effectiveness of the machine. The properties of stainless steel were important to study because it is the crucial part in the machine.Stainless steel has high strength and durability, as well as its high and low temperature resistance, increased formability and ease of fabrication, minimal maintenance, long lasting, attractive appearance, and environmental friendliness and recyclable nature. There is no need to treat, coat, or paint stainless steel once it has been installed.The properties of stainless steel showed it was a good material to use for blades. Thus, the significance of this project is to give a beneficial and useful machine to fried banana cheese sellers and other people such as bakers toreduce their problem of grating shredder cheese.

Project methodology

Problem identification

In daily life, a few people face a problem which they do not know how to solve. In this project, it focuseson problems in the food processor industry. The problem is how to minimize the energy used for grating cheese. As mentioned in the problem statement, the process of grating cheese needs people to bend their body while standing and the process needs continuous grating. However, the process has a side effect on users where they willexperience health problems

such as back pain and shoulder pain. Besides, the problem when using a manual grateris that shredder cheese becomes a mess where it will spill out around the container while it requires higher processing time of grating. Furthermore, users have to use their hand to hold the cheese where it affects the hygieneof the process and the food. In addition, consumers are unable to finish the cheese completely for fear of the fingersbeing hit by a sharp grater. From this problem identification, the objective of the project can be determined to solve the problems.

Collecting the information

Conduct a survey

The questionnaire has been prepared with a few questions to identify design specifications based on customer experience and requirements. There were 10 respondents involved in the survey and most of them are users of cheese grater. The questionnaire was done in Google Form where it is an online survey. There was a bilingual language in English and Malay for easier people to answer. Hence, people were required to answer based on their own experience and suggestion. Throughthe survey, there is a lot of information that can be used in designing the machine. This survey was really importantwhere it can determine the real problem or situation faced by the user of manual grater.

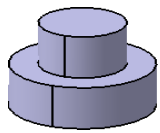
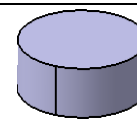
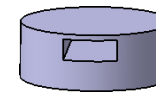
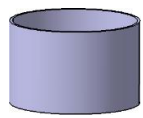
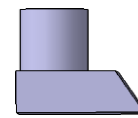
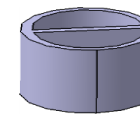
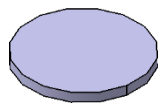
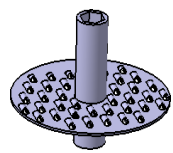
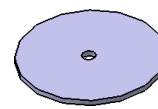
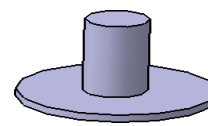
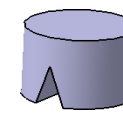
Feasibility study on existing product

Feasibility study was done to find the most suitable mechanism for the cheese grater machine. It is generally agreed that a lot of new technology in this world has been created and the aim is to improve the human lifestyle. For getting a good result of the new development of mechanized cheese grater, there are three machinesthat have been used as benchmarks as shown in Table 1. Based on the three machines, the machines offer a perfect balance between versatility, design, and practicality with effective and simple solutions available. There are a lot of mechanisms that can be used for generating the concept of the design cheese grater machine. Each of the products have their own features to operate and to attract people to buy and use.

Concept generation and selection

The concept generation is the process for choosing the most suitable mechanism and parts to be allocated in the cheese grater machine. The Morphological chart has been used to determine the suitable concept of the machine as shown in Table 1.

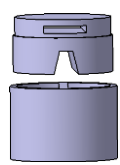
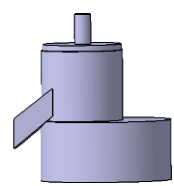
Table 1: Morphological chart

Parts	1	2	3
Upper body			
Jar			
Lower body			
Blade			-
Pusher	-		
Gear			-
Motor			-
Switch button			-

Power source			

Based on Table 1, three designs of machine were considered to be the prototype of cheese grater. The three designs have been shown in Table 2. The rate of 1 to 3 was given to each component involved in the design concepts based on feasibility, suitability to manufacture and functionality. Feasibility study was done comparing physical and function of the components in existing grater machine and other similar function products. Highest rating means the most feasible components. Based on the rating, design concept A showed the most rating values hence was chosen as the prototype design.

Table 2: Conceptual design selection

	Concept		
	A	B	C
Parts			
Upper body	3	2	1
Jar	3	2	1
Lower body	1	2	3
Blade	2	2	1
Pusher	3	2	1
Gear	3	1	3
Motor	3	2	1
Switch button	3	2	1
Power source	3	2	1

Product architecture and material selection

The material selection as shown in Table 3 is based on the result of Table 2, where each material wasprovided with the reason of target market for hawkers and small businesses.

Table 3: Material selection

Parts	Concept selection	Material	Reason
Upper body	1	Plastic	Cheap and durable
Jar	1	ABS	Transparent and durable
Lower body	3	Plastic	Cheap and durable
Blade	1	Stainless steel	Durable
Motor	1	Dc motor	Cheap
Switch button	1	Push button switch	Easy operate
Power source	1	Battery	Cheap and rechargeable

Detail design and analysis (CAD)

All the detailed drawings of the machine have been designed and modelled using CATIA V5R20 software. The software shows the clear image of the design concept and the functioning principle of the cheese grater machine. All the parts were being assembled together to produce one complete model as shown in Figure 2.

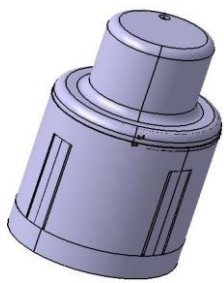


Figure 2: The design of the prototype

The analysis was done on the critical part where the distribution force was applied to the blade. In CATIA V5R20 software, the generative structural analysis was assigned with stainless steel as the material on the blade. These materials and properties can be seen in Figure 3. The middle rod of the blade was clamped, where the graterstays static when load is applied, with 100g weight or 1 N of force acting on the top surface of the grater.

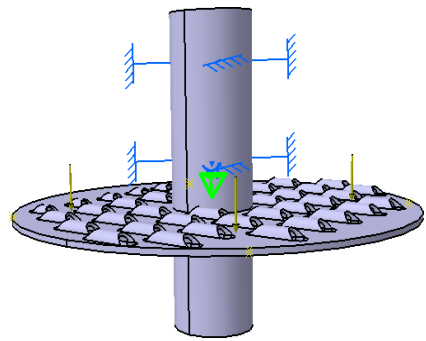


Figure 3: The critical part of prototype

Fabrication prototype

Fabrication processes were conducted to determine the functionalities and capabilities of the machine. The process to fabricate was started when all the detail drawing has been confirmed by the supervisor. For this prototype, there were 8 parts as shown in Figure 4. For commercials, each stage has a specified fabrication processsuch as extrusion moldings. However due to pandemics and no facility to do, so each part was purchased and thenmodified based on the design.

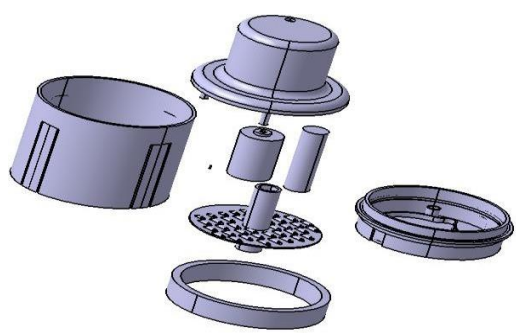


Figure 4: Detail design of prototype

Table 4 showed the bill of material for the cheese grater machine. The estimation cost is higher because itis based on the online shop price and it needs to buy one piece of each item based on the need of the prototype. However, for commercial price it must be cheaper than the estimation cost because it can be bought in bulk or in a cartoon.

Table 4: List of material

Parts	Material	Quantity	Procurement	Price (RM)
Blade	Stainless	1 sheet (150 x100) mm	Purchase*	12.00
	PVC	1 rod		10.90
Upper body	Plastic	1	Purchase	12.00
Lower body	Plastic	1	Purchase	-
Power source	3.7V rechargeable li-ion battery	1	Purchase	2.00
Motor	DC motor	1	Purchase	7.60
Jar	ABS	1 jar	Purchase*	15.00
Screw	Screw	1 packet	Purchase	2.00
PCB motherboard set	PCB motherboard set	1 set	Purchase	8.00
Cover	Silicon rubber	1 roll	Purchase	3.50
				73.00

Note: * purchase but modified according design

Functional testing

After all the fabrications were done, the testing toward the prototype was conducted. The testing was required to test the critical part and other parts will damage or have other problems that are related with the wholeprocess of grating. Firstly, the cheese was cut into small cubes and inserted in the jar. Before inserting the small cubic cheese, the blade must be inserted inside the jar as shown in Figure 5. Then assemble the body with the jar. After finishing setting up the prototype, touch the switch to start the machine. Observe the movement of the wholeprocess and the size of the shredder cheese whether the texture of the shredder was acceptable or not. The observation also takes the

important data of the time taken for the prototype to grate the cheese based on the required amount of cubic cheese which is 39 grams. Then, it is being tested with manual operation of grating. Forthe manual, it uses hand tool grating as shown in Figure 6 and the time taken to grate cheese was recorded with 39 grams shredder cheese. The time taken is recorded for the comparison between manual grating and semi-automaticgrating.

Figure 5: Condition inside prototype

Figure 6: Condition to grate for manual grating

Result and discussion

Collecting information activity

The method,A questionnaire was created in an online platform through Google Form to collect information regarding the problems or issues to grate a cheese for small businesses. The first question was asking the people whether they use a cheese grater and what type of cheese grater used. 100 % of the respondent's stated usingmanual grater. It showed that most of therespondents need this new development of a cheese grater machine that can help them to ease the work.

The next question was asking about how many times they use cheese

grater in a day. 40% of the respondents used cheese grater above 10 times per day and 20% of the respondents use between 4 to 10 times per day, proving that most of them use the cheese grater frequently. Third question was on difficulties during grating cheese. Most of them agreed that they were having trouble to grate cheese in large quantities. They also reported that the task time was high, the grated cheese was always in contact with fingers or hands thus could cause hygiene issue. In addition, normal grating could cause injuries to the hand as the grater slot is directly in contact with hand. Fourth question asked the respondents about the health issue. There were four choices of answers whether they experienced any pain or discomfort when grating in large quantities of cheese. The result indicated that 90% of respondents experienced muscle strains at forearm and fingers during grating cheese. Second issue was the sore shoulder and neck. This showed that the majority of people have a health problem when dealing with the manual grating process. Next, all the respondents were asked to choose and state the features that they would want in the cheese grater machine. The highest criteria was the machine must be easy to use and followed by lightweight and portable as shown in Figure 7.

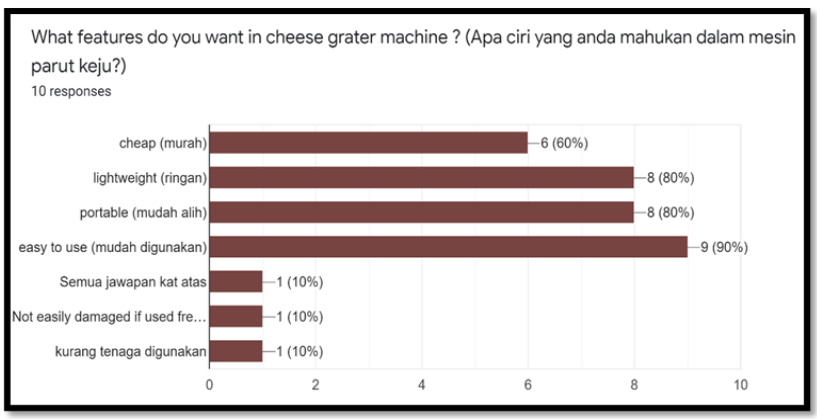
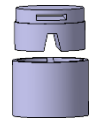
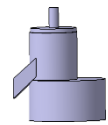


Figure 7: The result of survey

Concept generation activity

Pugh chart is the method for identifying the most suitable design concept of the cheese grater machine. From this method the concept was analyzed through the different criteria to get which one is better, poor and same as the datum that is being compared.

Table 5: Pugh chart

Sketch				

Criteria	Weight	Datum	Concept 1	Concept 2	Concept 3
Durable	2	0	-	+	+
Safety	3	0	-	0	+
Complexity	1	0	0	+	0
Easy to use	3	0	-	0	+
Reasonable	2	0	0	-	+
Performance	3	0	-	+	0
Size	2	0	0	-	+
Power Consumption	2	0	-	+	0
Weight	2	0	0	+	0
Maintenance	2	0	-	+	0
Storage	2	0	-	+	0
Noise	3	0	0	-	0
Processing Time	3	0	-	+	0
Reliability	3	0	-	0	+
Efficiency	3	0	0	+	+
+		0	0	20	18
0			13	9	21
-		0	-9	-7	0
Netscore		0	-9	13	18

Based on Table 5, the score obtained showed that concept 3 was the best and suitable for small businesses as it fulfills minimum criteria required by respondents and manufacturability purpose. The performance of this concept has been benchmarked from the datum product which is being compared with industrial cheese grater. Concept 3 is durable, safe, easy to use because users can use just one touch switch button and reasonable price because the target market is for hawkers. Hence, the cost for raw material is not too pricey because the parts material is plastic and stainless steel. The

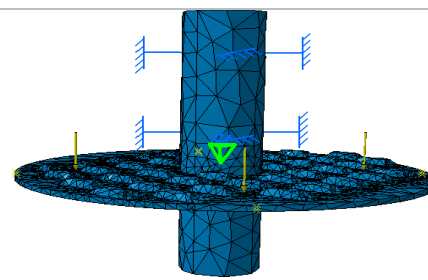
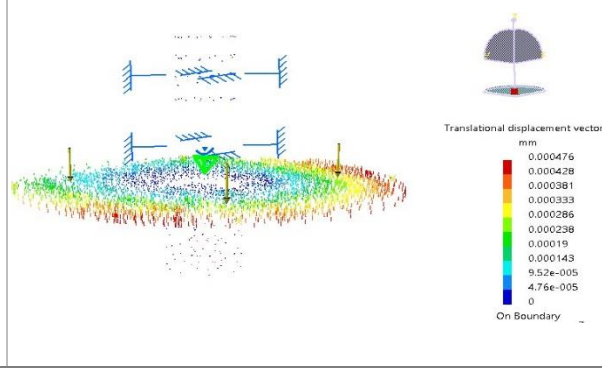
maintenance of the concept 3 is easy to do because the user can easily take out the blade and other parts for washing. This concept has good reliability and efficiency

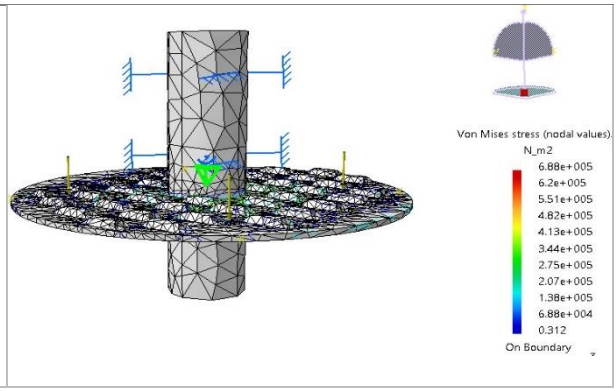
Designing and analysis (CAD) activity

The analysis results present the deformation, Von Mises Stress and translational displacement occurred on the blade with 100g of load acting on the surface of grater. The deformation and translational displacement that occurred on the blade was shown in Table 6. The value of deformation on the blade was to analyse whether the blade will buckle with the amount of the load applied. The Von Mises Stress result on the blade was also shownin Table 6.

The value of Von Mises Stress is to determine the value of maximum stress of the blade.

Table 6: The result of analysis in CAD

1. Deformation of blade	
2. Translational displacement ofblade	

3. Von Mises Stress of blade	

Based on the analysis result, the value of displacement when the load applied was 0.000476 mm. The value shows the blade can withstand the amount of maximum force which is 1 N and has a minimum displacement.Besides, the value of Von Mises Stress is 0.688 MPa where the blade has a higher factor of safety. The value of the factor of safety can be determined by using the equation as shown in Equation 1. The value of the factor of safety shows the blade is safe to use and suitable to apply to the prototype. Furthermore, the load applied onto theblade is low which is not for heavy duty.

Factor of safety = Yield strength of material /max Von Mises Stress value (1)
= (205 MPa) / (0.688 MPa)
= 297.97

Based on the value obtained, the value of Von Mises Stress is lower than the yield stress value. The valueis in accordance with the study on multi-angle kitchen waste grater where the minimum result stress obtained fromthe Ansys is 0.4547 MPa [8]. The low stress value shows that this grating mechanism can obtain the optimum working performance and will not have failure when cheese is applied. Moreover, the force acting on the blade is small with maximum force acting is only estimated as 1 N. This is because the texture of cheese was very soft where the moisture content is the most important determinant of firmness [9]. Hence the force required to push the cheese down the blade is small. Thus, the result of stress is reliable for this prototype and the factor of safetyis acceptable.

Functional testing

Physical appearance of prototype

Based on the testing process, the prototype worked in good condition where the prototype can grate the required cheese continuously and efficiently. The blade was rotated smoothly with minimum noise. The user needs to hold the prototype tightly between the jar and body to prevent it from opening. Overall, the physical appearance of the prototype was working well and smooth. Figure 8 showed the physical appearance of the prototype when the switch was off while Figure 9 showed in switch on condition.

Figure 8: The physical appearance when switch off

Figure 9: The physical appearance when switch on

Comparison of time taken

During the functional testing, the time taken for each cycle was recorded by using handphone timer. Each cycle needs to produce 35 grams of shredded cheese. The both process of manual and machine were compared to determine the efficiency of the prototype. Figure 10 showed comparison of time taken to grate cheese by manual grater and the prototype in five trials. The manual process maximum time taken was 85 seconds in trial 5 while using the prototype, the time taken showed maximum time was 60 seconds in trial 3 while the lowest was 50 seconds (trial 5). Despite the fluctuation pattern of time, it is proven

that by using a prototype time taken to perform the task is shorter than manual grater hence increases in productivity. The difference is time could be due to the source of power and force applied on the blade. Hence, using the prototype against manual could have effects in improved accuracy, increased production speeds, enhanced safety, increased efficiency and most of all cost savings [10].

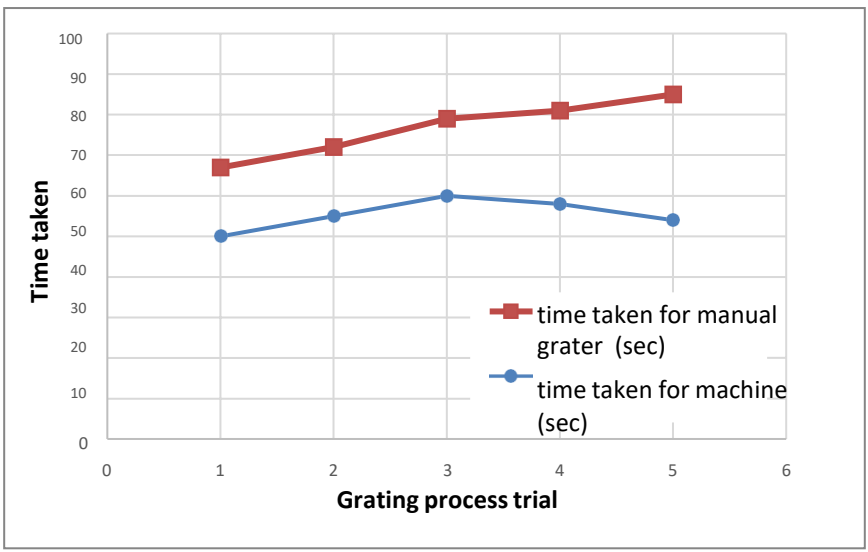


Figure 10: The graph of time taken to grate 35 g

Shredded cheese appearance

The appearance of shredded cheese was compared to determine the fineness of the grated cheese. The manual grating produces long and inconsistent thickness of shredded cheese as shown in Figure 11 while using prototype, the shredded cheese was a bit short with consistent thickness as shown in Figure 12. The result of appearance was affected by several factors which was the amount of force applied on the grate. For manual grating, the force will be inconsistent when it comes to grate in large quantities and users will experience fatigue. Besides,the size of cheese was also affecting the result of shredded cheese appearance. The texture of cheese was very soft and it cannot handle heavy duty activity, so when the manual grating was done with high force applied, the cheese would break easily. Hence, the user will face difficulty to grate cheese consistently. For machine grating, the source of power was consistent and it will produce consistent shredded cheese.

Figure 11: Shredded cheese using manual grating

Figure 12: Shredded cheese using prototype

Conclusion

In conclusion, the prototype development of mechanized cheese grater was successfully fabricated and analysed based on the planning process from starting until the end. The result has given understanding of a gratingblade mechanism and the process fabrication of the prototype even though having limitations of machine and material. This is in accordance with the main objective which is to develop detailed design using CAD, identify the suitable process and to fabricate the prototype. The prototype was running smoothly and it showed the productcan give impact to help fried banana cheese sellers for grating cheese faster than using manual grate. However, there are a few recommendations that can be improved in future such as making a funnel shape at the bottom part.This funnel is shaped to avoid the output of shredded cheese from being messy. Next, add the part in the machineto cut the block cheese into small cubes before entering the grating process. Thus, cutting part to decrease the time processing to grating cheese. Furthermore, the prototype can be

commercialized in the market as there are no othermachines that have the same features with the prototype.

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