

Evaluation of the Banana Slicing Machine Structure Design

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ABSTRACT

In the product planning procedure of a machine tool, mature designers consider various kinds of customers' requirements, while simultaneously conducting the necessary information processing, so as to finally determine the most suitable product specifications. In order to systematize this procedure, it is necessary and indispensable to clarify the decision-making process as well as knowledge of a mature designer in detail, and to analyse design information used in the product planning. In this study, a banana slicing machine development methodology, characteristics of design information related to the product specification have been analyzed using a simple survey analysis method. Actual design information used in this analysis is obtained from focused interviews and questionnaire investigations. Furthermore, the validity and effectiveness of the proposed method have been verified using the results of these investigations. Finite simulation also been carried out to analyze the structure and it was found the design is very robust which has a 4.4 safety factor. It was found the new machine design is able to contribute up to 12% cost reduction without any jeopardizing the performance of the banana chip production. The analysis also demonstrates the machine is able to produce 84 kg/hr which is significant increment compared to previous report.

Keywords: Banana chips, slicing, solidworks, George E. Dieter, life cycle assessment

1. INTRODUCTION

In general, banana chips in Malaysia are made by deep-frying of raw banana slices of 1.75 to 2.0 mm thick in a suitable cooking medium and salt added [1]. The production was quite acceptable during that time due to the high demand from the customer. Many people produce their own banana chips by homemade instead of buying them from any outlet. In the production of banana chips, the fresh banana needs to be sliced into a round or longitudinal shape before frying. Along with the development of technology, some countries have developed a variety of technologies to slice the banana, from the simple knife to the modern automated machine [2].

Previous work such reported by Krantidip *et al.* where his team develop slicing machine for fruit and vegetable. It was shown the machine able to slice banana for 68.68kg/hr [3]. Raniya *et al.* develop a banana chip making machine equipped with thermo control to control the frying oil automatically [4]. It was found that the machine able to produce 4 kg/hr. Ezeanya *et al.* develop an efficient and ergonomically sage slicing machine to small scale farmer [5]. It was reported the machine able to produce 44 kg/hr. Tillak *et al.* develop a banana slicer machine but not they were

no report on machine efficiency [6]. Generally, the using of machine able to produce the product output efficiently. This is agreed by Marcons *et al.* where they carried out the technology impact assessment on Banana Slicing Machine [7]. It was concluded that the using the machine is far more effective than manual process in terms of production number as well as product quality. However, none of previous work show a survey analysis prior of product development which is a very important step for product development. In this work a structured method for analyzing product specification and product planning for banana slicing machine is carefully carried out prior machine development. It is believed, this approach able to increase further the machine performance efficiency to produce banana slice [8].

2. MATERIAL AND METHODS

The project adapted the design process model by George E. Dieter. According this model, the design process consists of three phases and eight steps. The design process is beginning with conceptual design, followed by embodiment design, and finally the detail design. The steps in conceptual design include defining the problem, gathering information, developing concepts, and evaluating the concepts. The steps for embodiment design include product architecture, configuration design, and parametric design. The detailed design is the last step in this design process model [9].

The survey method through interview and questionnaire are conducted to gather all appropriate information. An interview session has been conducted to get the specific information related to the existing machine being used. There are two small and medium enterprises (SMEs) owners involved in this interview session. The interview focuses on the characteristics of their machine that they used to produce the banana chips. The questionnaire was used in this study. A survey form with the title "Design Specification of Banana Slicing Machine" has been distributed to the other owners of small-medium industries (SMEs) and the public. The questionnaire is divided into three sections. The first section is about respondent information, the second section is related to their general knowledge, and the last section is determining the requirement of customer. The same scale of score was used in all section where the score 1 is assigned for strongly not required and score 5 is for strongly required.

The structure of the banana slicing machine was designed using SolidWorks design software. It is used for planning, modelling, visual ideation, prototyping, feasibility analysis, and project management. SolidWorks simulation is an easy-to-use portfolio of structural analysis tools that apply Finite Element Analysis (FEA) to predict the real-world physical behaviour of the product by virtually testing of CAD models. The portfolio provides linear and non-linear static and dynamic analysis capabilities [10]. Life Cycle Assessment (LCA) is also used in conducting analysis through SolidWorks simulation. It is a method for evaluating the prospective environmental and prospective elements of a product by creating an inventory of relevant inputs and outputs, assessing the possible environmental consequences of those inputs and outputs, and interpreting the results of the inventory and impact stages in connection to the objectives of the study.

3. RESULTS AND DISCUSSION

The data obtained in the customer survey is used to generate product design specifications (PDS). The score for each design requirement obtained from these customer surveys are shown in Figure 1. According to Figure 1, the score was given by the respondent according to the priority of the machine. The data obtained from the questionnaire was used as a foundation and as an important measure for the design criteria. The data is analyzed and the weightage value for each design criterion is calculated based on an appropriate rating according to the score value obtained

during the customer survey. The degree of importance for each design criterion is then ranked and sorted according to its weightage value. This weightage value is shown in Table 1.

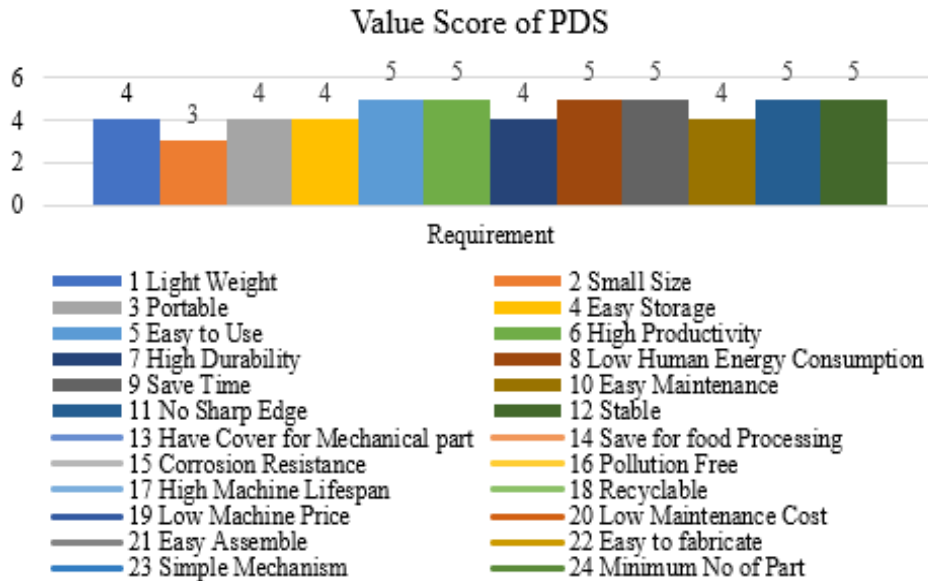


Figure 1. The score of Product Design Specification (PDS).

Table 1 Degree of Importance of Each Design Criterion

Customer Need	Score	Average	Weightage
Physical Characteristic		3.75	0.15
Light Weight	4		0.27
Small Size	3		0.20
Portable	4		0.27
Easy Storage	4		0.27
Total	15		1.00
Function		4.67	0.18
Easy to Use	5		0.18
High Productivity	5		0.18
High Durability	4		0.14
Low Human Energy Consumption	5		0.18
Save Time	5		0.18
Easy Maintenance	4		0.14
Total	28		1.00
Safety		5.00	0.19
No Sharp Edge	5		0.20
Stable	5		0.20
Have Cover for Mechanical part	5		0.20
Corrosion Resistance	5		0.20
Hygienic for food	5		0.20
Total	25		1.00
Sustainability		3.67	0.14
Pollution Free	4		0.36

High Machine Lifespan	4			0.36
Recyclable	3			0.27
Total	11			1.00
Cost		5.00	0.19	
Low Machine Price	5			0.50
Low Maintenance Cost	5			0.50
Total	10			1.00
Design Aspect		4.00	0.15	
Easy Assemble	4			0.25
Easy to fabricate	4			0.25
Simple Mechanism	4			0.25
Minimum No of Part	4			0.25
Total	16	26.09	1.00	1.00

As shown in Table 2, the most important criteria are safety and cost, which is 5, followed by function of the machine and design aspect which are 4.67 and 4.00, respectively. The least important are machine sustainability and its physical characteristics which score are 3.75 and 3.67, respectively. In the aspect of degree of importance, the product design specification (PDS) for the banana slicing machine is established as shown in Table 2.

Table 2 Design Specification of the Banana Slicing Machine

Introduction	
Title	Banana Slicing Machine
Design Problem	Slicing Banana for Banana Chips Production
Purpose	To increase the rate of banana slicing compared to manual slicing method
Special Feature	Has speed controller for motor
Customer Requirement	
Functional Performance	Produce more than 50 kg in 1 hour Can be operated by only one person Easy to use
Life Cycle Target	More than ten (10) Years
Economic	Cost less than RM6000 No or little cost of maintenance
Maintenance	Easy for Cleaning Process
Reliability	No failure occurs during machine lifespan Heavy duty
Safety	Has safety cover for rotating mechanism No sharp edge Corrosion resistance Hygienic for food Stable
Physical Description	Dimension (L x W x H): 700 mm x 600 mm x 755 mm Weight: Less than 100 kg
Sustainability	Material use can be recycled Pollution Free

By referring to the PDS, the concept of the banana slicing machine was drawn by using SolidWorks Software version 2019 [11]. All the components that are drawn will be assembled to form the overall structure of the banana slicing machine. Figure 2 shows the full assembly 3D isometric of the banana slicing machine.

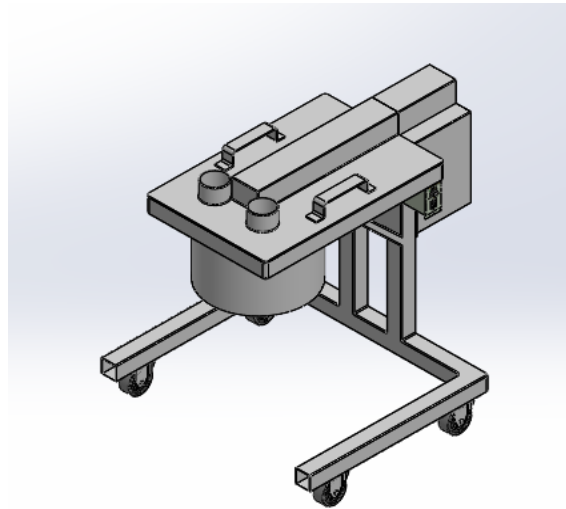


Figure 2. Banana slicing machine 3D isometric full assembly.

Before starting the slicing process, the machine will be placed so that the output cylinder position is on the top of the frying pan. This is to make sure that the banana slices fall directly into the boiling oil in the pan. Figure 3 shows the positioning of the machine with the frying pan during slicing process.

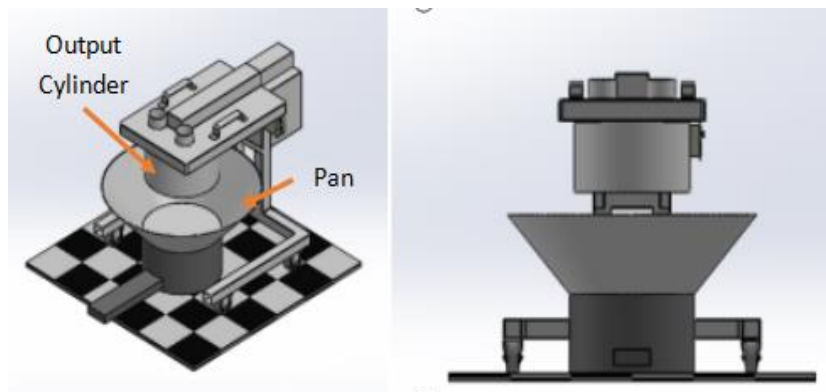


Figure 3. Positioning of the machine with the frying pan.

Once the switch is turned on, the raw banana with a diameter of 40 to 60 mm will be slotted into the feeder and the rotating disc will slice the banana into 1.0 mm thick banana slices. The slotting process will need a little human force to push the banana into the feeder. The slices will fall directly into the boiling oil in the pan. Figure 4 demonstrates slicing process and main parts of the components.

Three analyses have been done on the body frame of the machine. It was a stress analysis, displacement analysis, and factor of safety [11]. The magnitude of the maximum stress is 31.3 MPa which is less than the yield stress of the material of 205 MPa. Hence, the body frame will not yield when the machine is experiencing the maximum stress condition. Figure 5 shows the variation of stress in the frame as outcome of the stress analysis.

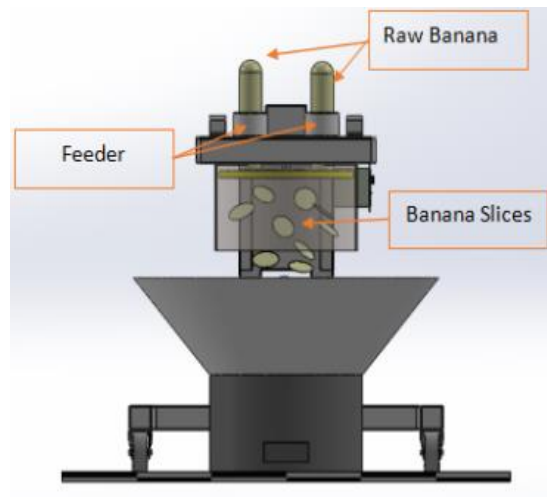


Figure 4. Slicing process.

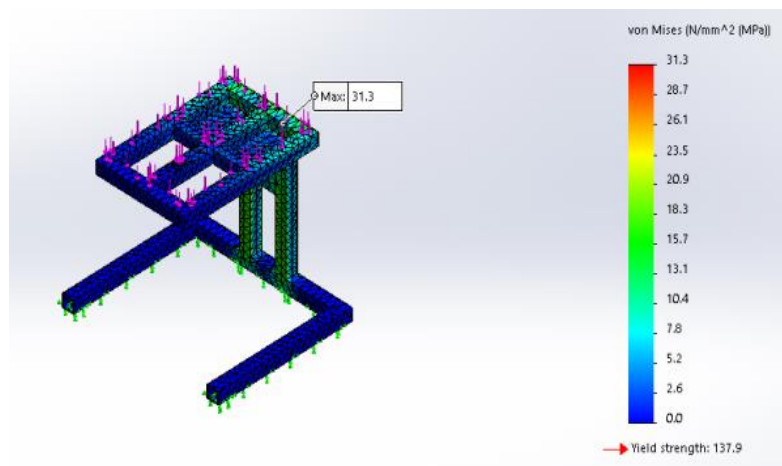


Figure 5. Outcome of stress analysis via simulation.

Then, the maximum displacement is located at the front vertices of the frame with a magnitude of 1.6 mm. This small displacement will not lead to any danger. Figure 6 shows the outcome of the displacement analysis.

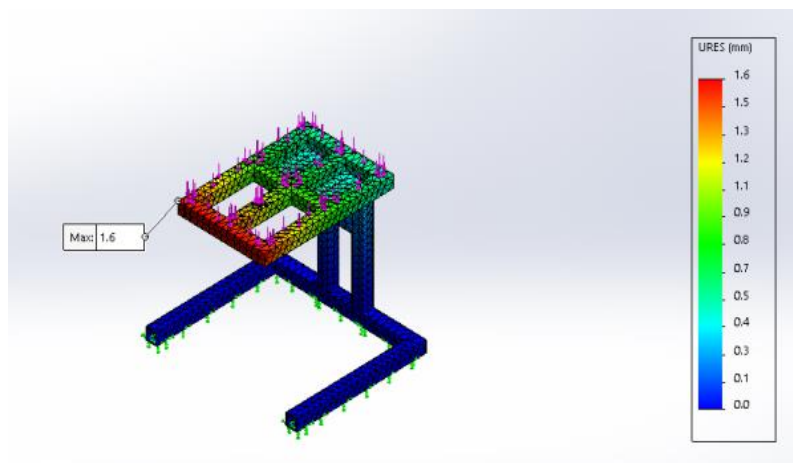


Figure 6. Analysis of displacement.

Lastly, Figure 7 shows the result of the simulation for factor of safety analysis of the body frame for banana slicing machine. The minimum safety factor for the frame is 4.4, which is above one. Thus, the structure of the frame is safe.

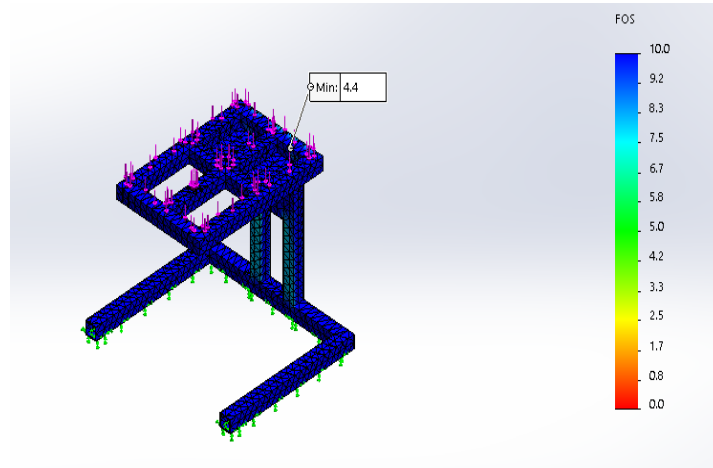


Figure 7. Analysis of safety factor given by simulation.

In the context of sustainability analysis, design for the environment refers to the process of designing a product in order to reduce its environmental impact. There are two criteria involved in the designing process of a banana slicing machine. They are designed for minimal material and energy consumption and have a Life Cycle Assessment (LCA). Life Cycle Assessment (LCA) is a method for evaluating the prospective environmental and prospective elements of a product by creating an inventory of relevant inputs and outputs, assessing the possible environmental consequences of those inputs and outputs, and interpreting the results of the inventory and impact stages in connection to the study's objectives. The banana slicing machine used very minimal material. The proof is that the mass of the machine is not heavy as it does not exceed 100 kg. It is also designed with the minimum of mechanical movement. Only one electric motor is used in this machine, which requires only one source of electric energy. Besides, this machine is also designed to be operated only by one person. From that, human energy can be reduced. A LCA consists of four main analyses, which are carbon footprint, amount of energy used, air acidification, and water eutrophication for 10 years. Figure 8 shows the pie chart of the life cycle assessment.

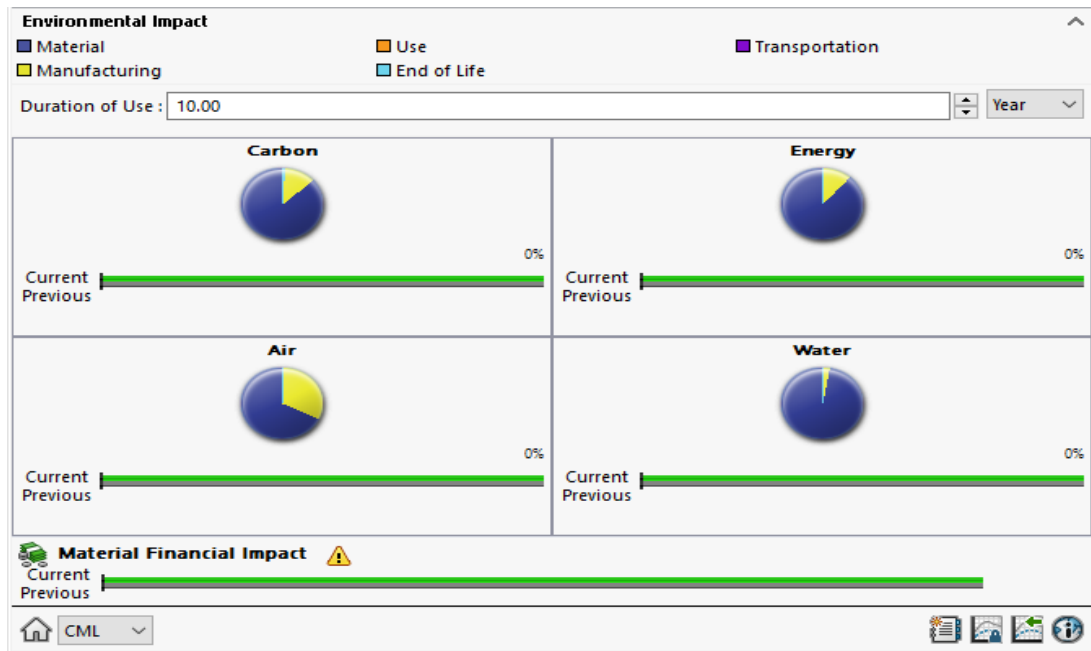


Figure 8. Outcome of the Life Cycle Assessment.

Figure 9 shows the carbon footprint result. It is the value of carbon dioxide released by the industry or people who operate the product. For this machine, the highest carbon use is on the material, which is 2900 kg of CO₂, and the lowest is on the transportation, which is 0.052 kg of CO₂.

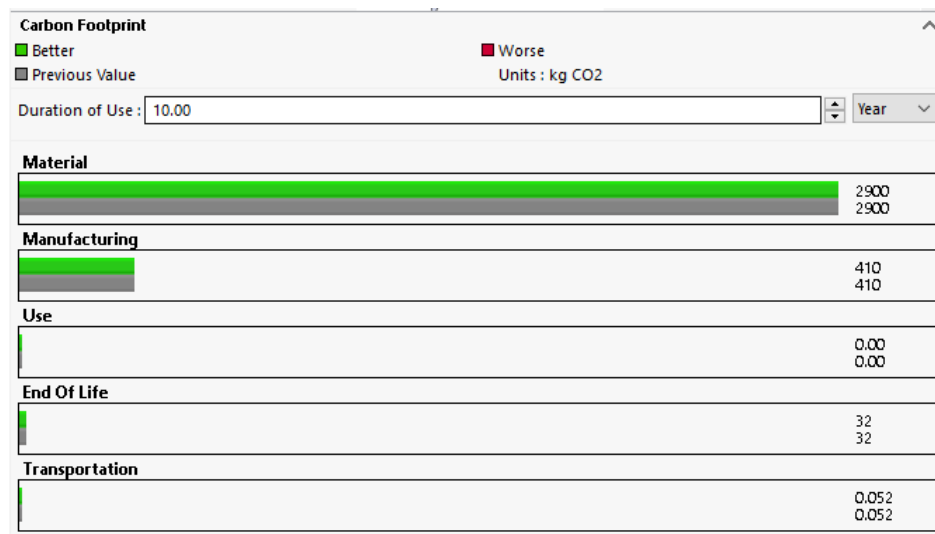


Figure 9. The result of carbon footprint.

The value of energy used is evaluated by the amount of energy used associated with the machine lifespan. Figure 10 shows the result of the energy consumption.

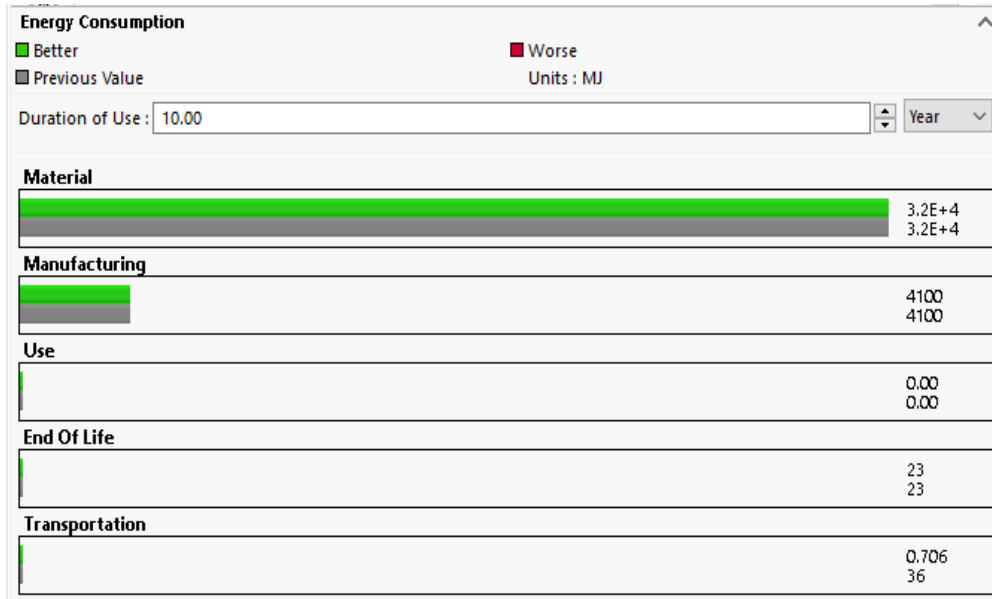


Figure 10. Result for energy consumption.

Figure 11 shows the effect of the air acidification for the banana slicing machine in 10 years of use. It is caused by nitric oxide, sulphur oxide, and other acid substances in the air.

Figure 12 shows the result of the water eutrophication on the machine. It occurs when an excessive amount of polluted material evaporates into the water. Water quality can be harmed by extreme eutrophication.

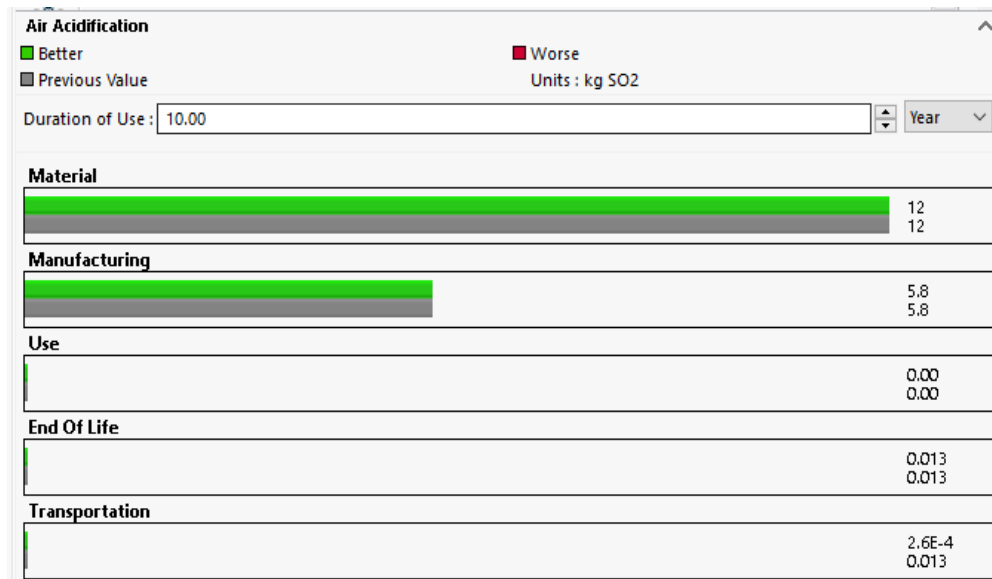


Figure 11. Effect of air acidification.

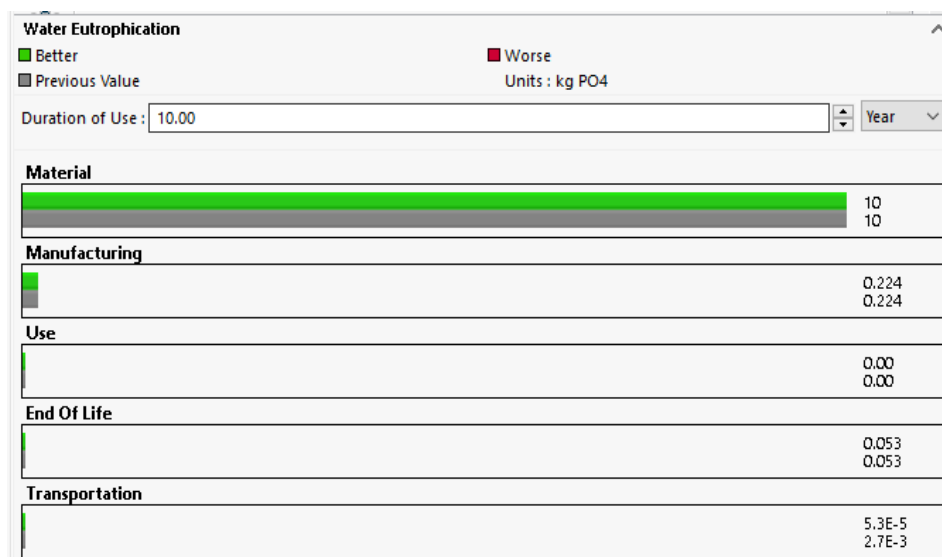


Figure 12. Result of water eutrophication.

Based on analysis and calculation the specification for the design of the machine as shown in the Table 3.

Table 3 Specifications of Banana Slicing Machine

Product Specification	Description
Motor Specification	Power: 0.37 kW, Voltage: 220 V, Speed: 1400 rpm Frequency: 50 Hz, Phase: Single
Weight	57.16 kg
Dimension	700 mm x 600 mm x 755 mm
Productivity	84 kg/h
Power Consumption	314.15 Watt
Price	RM 4227.30

4. CONCLUSION

After completing this project, it can be concluded that this project achieved the objective successfully. As a result, a banana slicing machine has been designed. The design met the requirements of the SME, which was that the machine be designed such that the banana would be directly sliced into the pan. Using theoretical calculations and experimental results from the existing machine, this machine is able to produce 140 kg of banana slices in a day, which is more than 100 kg a day. Lastly, with the analysis on cost, this machine was able to be sold at a price range of below RM6000. Therefore, with this affordable design of machine, it will help the banana chip industry in Malaysia grow successfully.

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