Optimization of Tool Design for Peeling and Cutting Pineapple Using the Stage Gate Process Method

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ABSTRAK

Nanas adalah makanan yang termasuk banyak diminati oleh penduduk di Indonesia, untuk memudahkan pekerjaan dan mempercepat produksi tidak terlepas dari mesin pengupas kulit dan inti nanas, industri rumah tangga dan supermarket pada saat mengupas untuk menghasilkan kulit nanas berukuran seragam untuk menghemat waktu dan tenaga. Maka, untuk mendapatkan nanas yang bersih dan aman untuk dikonsumsi kapan saja, kami merancang alat pengupas dan pemotong inti nanas portabel tingginya angka peminat nanas maka munculah gagasan membuat alat pemotong nanas secara otomatis. Alat pemotong nanas dengan 1 model mata pisau akan membuat sisa nanas tidak efektif atau masih banyak daging nanas yang terbuang menempel pada kulit nanas, maka dibuatlah alat penmotong nanas yang bisa di ganti ganti mata pisau nya. Berdasarkan hasil survey ukuran nanas, maka kemudian dibuat 3 mata pisau dengan klasifikasi ukuran mata pisau kecil, sedang, dan besar, berdasarkan hasil pengujian didapat daging nanas yang tidak terlalu banyak yang terbuang *Stage Gate Proces* akan membuat kemudahan dalam penuangan ide sampai dengan terealisasi nya produk, dengan tahapan kerangka kerja untuk merencanakan dan mengelola langkah-langkah yang terlibat dalam membawa produk baru ke pasar, mulai dari ide awal hingga distribusi.

Kata kunci: Mesin, Nanas, Inovasi, Mata pisau, Metode *Stage Gate Process*

ABSTRACT

Pineapple is a food that is in great demand by the population in Indonesia, to facilitate work and speed up production is inseparable from the pineapple skin and core peeling machine, the household industry and supermarkets when peeling to produce uniform-sized pineapple skin to save time and effort. So, to get a clean and safe pineapple for consumption at any time, we designed a portable pineapple peeler and core cutter. The high number of pineapple enthusiasts then came up with the idea of making a pineapple cutter automatically. Pineapple cutting tools with 1 blade model will make the rest of the pineapple ineffective or there is still a lot of wasted pineapple meat attached to the pineapple skin, so a pineapple cutting tool is made that can be replaced by changing the blade. Based on the results of the pineapple size survey, 3 blades were made with the classification of small, medium, and large blade sizes, based on the test results obtained pineapple meat that was not too much wasted Stage Gate Process will make it easy to pour ideas until the realization of the product, with the Stages of a framework for planning and managing the steps involved in bringing new products to market, from initial ideas to distribution

Keywords: Machine, Pineapple, Innovation, Blades, Stage Gate Process Method

INTRODUCTION

Indonesia is one of the countries with abundant wealth, one of which is the producer of various agricultural products from plantations, fisheries, and so on, one of which is pineapple. Along with the community's guidance on technological developments, various methods and forms of machines have replaced manual methods to achieve higher productivity and better quality. To assist a job and also to speed up the production process, and also to make it easier for pineapple peeling machines and cores to facilitate home industries and supermarkets during the peeling process so that work becomes faster and more efficient with more evenly distributed peeling sizes [1]. Pineapple is one of the types of tropical fruits widely consumed by the public, one of which is pineapple honi sunpride because it has sweet pineapple flesh that does not itch in the mouth when consumed. As Indonesians, you are certainly familiar with this pineapple. Pineapple is usually consumed during the day because of its fresh and sweet taste, not only as a side dish or dessert, but also as a processed ingredient such as jam and pineapple chips [2]. Generally, home industries and supermarkets still use manual tools such as kitchen knives for peeling the skin and pineapple cores, so peeling time takes a long time, 3-5 minutes per pineapple, and it is also prone to finger scratches by the knife. Therefore, we have an idea to create a tool aimed at making time and effort

efficient in doing a task, especially when peeling pineapple peels. The tool in question is "Optimization *of the design of tools* for peeling and cutting pineapple using *the Stage Gate Process* method" by optimizing the blade so that the cut pineapple is truly ready to eat.

Basically, pineapple is a compound fruit formed from a combination of 100 to 200 flowers, cylindrical in shape, with a fruit length of about 20.5 cm, a diameter of 14.5 cm, and a weight of about 2.2 kg.

Table 1 Subang Pineapple Size Classification

No.	Pineapple Weight	Pineapple Diameter	Category
1	±700 gr	85 mm	Small
2	±1500 gr	125 mm	Medium
3	±3000 gr	165 mm	Large

Smooth Cayenne *pineapple tends* to have a long fruit. The drawback is that the fruit is small in size and the eyes are somewhat deep, so a lot of flesh is wasted when peeled. The Subang Pineapple Variety Pineapple originates from Jalan Cagak District, Subang Regency. The pineapple, which is part of the *Smooth Cayenne* type, is round and oval, 23 cm long, 16.5 cm in diameter, ripe dark green, with large and shallowly notched fruit. The flesh is bright yellow, somewhat dense with a smooth texture. The taste is sweet (glucose content 345 mg/gram, starch 17.6 mg/gram), moderate water content, fragrant fruit aroma, and fruit weight 1.8 - 2.5 kg.



Figure 1. Classification of Small, Medium, and Large Pineapple Sizes

The process of peeling and cutting pineapple fruit is an important initial stage in the consumption and processing of the fruit. However, the methods commonly used manually today have various weaknesses that form the basis of the problems in this study. These problems can be detailed as follows:

1. The manual peeling and cutting process takes a long time.
2. Irregularity in the shape of peeling and cutting results.
3. Risk of injury when using conventional tools.
4. There is no effective, efficient, and time-saving tool available for peeling and cutting pineapples.

RESEARCH METHOD

The research stages are based on *a flow chart* as shown in Figure 2.

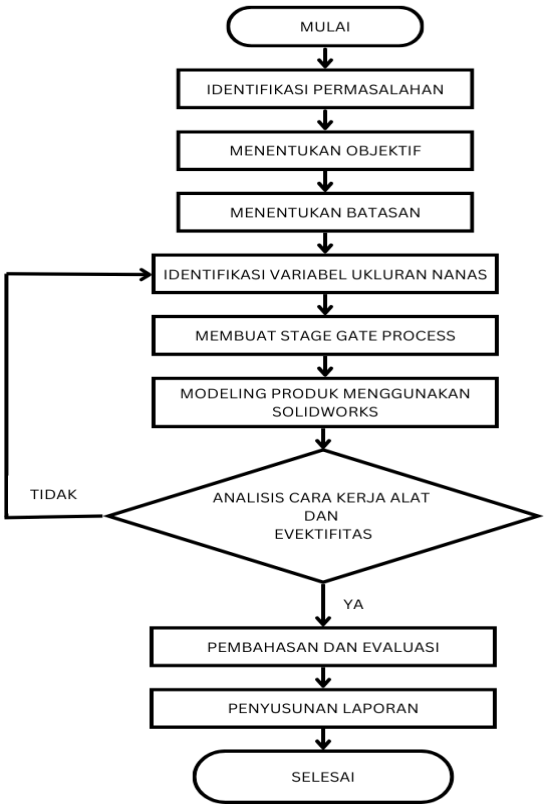


Figure 2. Research Flowchart

This research uses the *Stage Gate Process method, which is a systematic approach in product development consisting of several stages separated* by decision points (*gates*). Each *gate* functions to evaluate feasibility before proceeding to the next stage. This approach is suitable for optimizing the design process *of pineapple cutting and peeling tools, as it allows iterative evaluation based on data and user needs.*

The object of this research is tools for cutting and peeling pineapples, which have advantages over previous research, namely they can peel pineapple skins, cut pineapple stems, and cut pineapple flesh so that the pineapples are ready to be eaten and can be consumed directly. This research was conducted on pineapples, especially

subang pineapples, which are commonly found in local markets with varying size and shape characteristics.

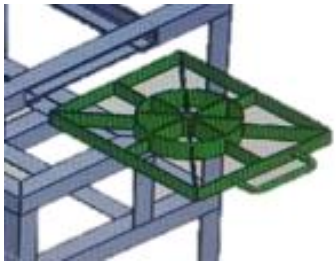


Figure 3. *Tools* for Cutting and Peel Pineapple Fruit

Research Stages

1. Tool Creation Up to Gate 4

To ensure research is focused and can be completed efficiently, clear boundaries are required. These boundaries help avoid expanding the scope and ensure the main objectives are achieved. The limitations in this study are as follows:

a. The type of pineapple used is honey pineapple (Subang)

This study specifically uses only the Subang honey pineapple as the main object in the design and testing of the device. Subang honey pineapple is one of the pineapple varieties that is easily obtained in West Java, especially in the Subang region, which is known as a pineapple production center. There are several aspects of the study that can be considered. Consistent Physical Characteristics of the honey pineapple have relatively uniform size, namely length ±18–25 cm, diameter: ±8–16 cm, skin tends to be thinner, and the eyes are shallower. The texture of the honey pineapple tends to be soft, sweet, and not too fibrous, making it suitable for manual pressure-based device testing. By using only one type of pineapple, the design and evaluation process of the device can be more focused and results more accurate, without being disturbed by variables from other pineapple types with different sizes, hardness, or fruit distribution distribution.

b. Stages *of the Gate Process Stage Used Until Gate* 4

In the product development methodology, this study uses the *Stage Gate Process method but only up to the 4th Gate.*

Table 2. Gate *Process Stage Method up to Gate* 4

Stages	Stage Name	Explanation
Stage 0	*Discover*	Initial observation of user needs and identification of problems in the field.
Gate 1	*Idea Screening*	Initial design idea selection is based on functionality and suitability.
Stage 1	*Scoping*	Technical, ergonomic, and economic feasibility analysis of the equipment.
Gate 2	*Second Screen*	Eliminate ideas that are not fit in dimension or function.
Stage 2	*Design*	Development of initial sketches and CAD models of the tool.
Gate 3	*Go to Development*	Feasibility assessment for prototyping.
Stage 3	*Development*	Prototype manufacturing with selected materials and initial assembly.
Gate 4	*Go to Testing*	Evaluate the decision to proceed to the user trial stage.

2. *Stage Gate Process*

A systematic approach in product development consisting of several stages separated by decision points (*gates*). Each *gate* functions to evaluate feasibility before proceeding to the next stage. This approach is suitable for optimizing the design process *of pineapple cutting and peeling tools, as it allows iterative evaluation based on data and user needs.*

3. Blade Modeling Using *the Stage Gate Process*

The method used to systematically analyze product development by going through various stages called "*gates*" before proceeding to the next stage. This approach allows the development team

to objectively evaluate project progress and ensure that every decision is based on valid data.

a. Case 1

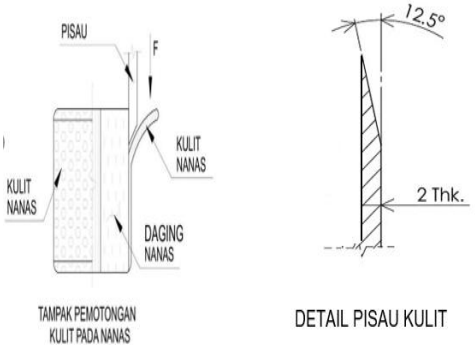


Figure 4. Pineapple Peel Blade Model

b. Case 2

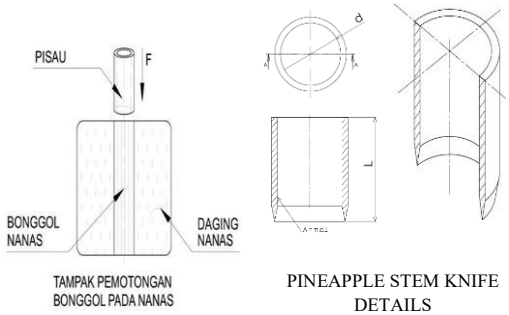


Figure 5. Pineapple Corb Blade Model

c. Case 3 Model 3

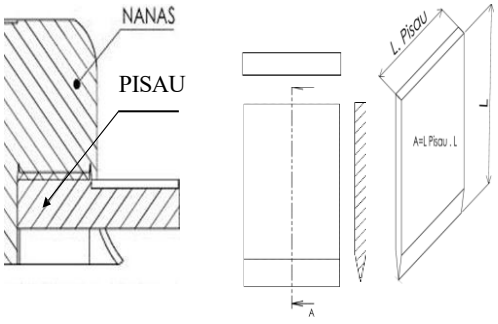


Figure 6. Pineapple Splitting Blade Model

4. Blade Design Using Solidworks

The design of the pineapple peel and pineapple stem cutting blade design is designed to provide efficiency and comfort in the cutting process. By prioritizing sharpness and material strength.

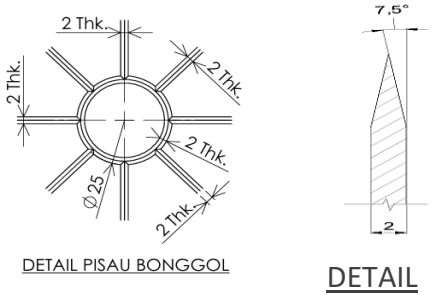


Figure 7. Design of Peeling Knife and Pineapple Corm

The design uses SolidWorks, which refers to identifying pineapple fruit sizes ranging from small, medium, to large. They are as follows:

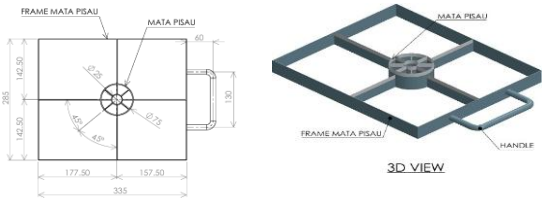


Figure 8. Pineapple Knife Size 85 mm

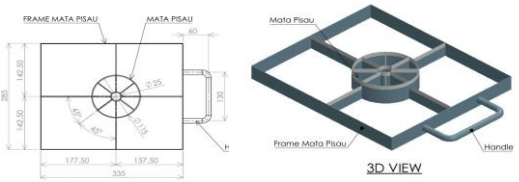


Figure 9. Pineapple Knife Size 125 mm

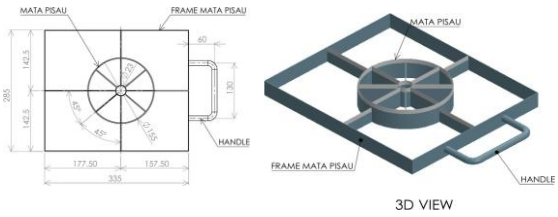


Figure 10. Pineapple Knife Size 165 mm

5. Machine Model

The 3-blade pineapple peeler with *a knockdown* system is a tool specially designed to peel pineapples efficiently and effectively. This tool has 3 blade models that function to separate the pineapple skin from the flesh. The *knockdown* system on this blade allows the blades to be easily disassembled and assembled to adjust the pineapple size according to its classification as well as facilitate storage and maintenance.

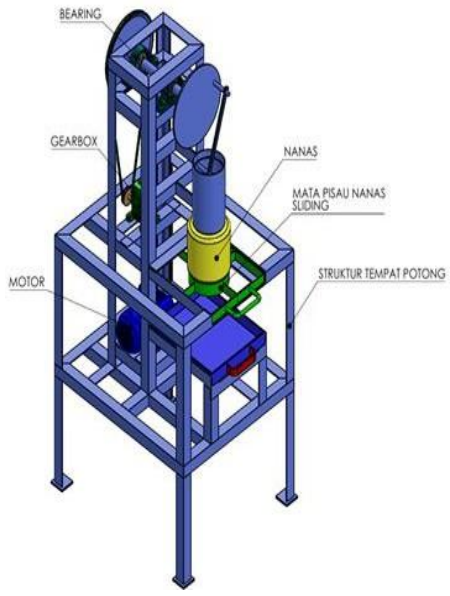


Figure 11. 3-Blade Pineapple Peeling Tool *with Knockdown System*

6. How the Pineapple Peel and Cutter Tool Work

The working mechanism of the pineapple peeling and cutting tool is designed to facilitate the process of peeling and cutting pineapples until they are ready to serve. In general, this tool works on a mechanical principle that pushes pineapples using a motor driven to the blade. Here are the general steps of how it works:

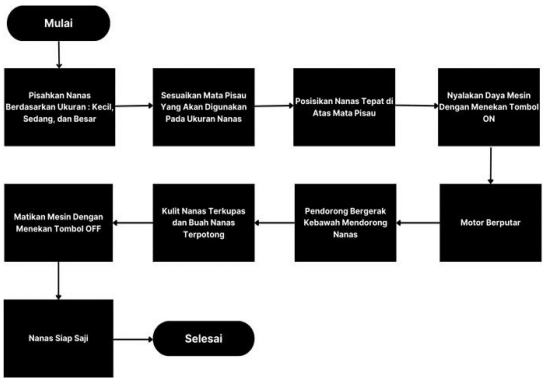


Figure 12. Usage Flow of Pineapple Peeling and Cutting Machine

RESULTS AND DISCUSSION

1. Pineapple Size Classification Results

Pineapple size classification is one of the initial stages in the design of a pineapple peeling and core peeling machine. Determining the correct pineapple size is key to ensuring the effectiveness and efficiency of the machine in carrying out its function so that the skin is peeled and the pineapple core is cut with results that meet the requirements. The pineapple size classification results were based on the diameter and weight of the pineapple fruit used in the experiment. Based on the data obtained, pineapples are divided into three size categories, namely:

- Small size, pineapple diameter ≤ 120 mm, pineapple weight ≤ 1.5 kg
- Medium size, pineapple diameter 120 – 160 mm, pineapple weight ≤ 1.5 kg
- Large Size, Pineapple Diameter > 160 mm, Pineapple Weight > 3 kg

This size classification data is very important because it affects machine design, especially in determining the dimensions of the blade for peeling and cutting pineapple fruit accordingly. The results of this classification are also used to determine the machine's efficiency level in processing various sizes of pineapples.

2. Optimization Stage Results Using the Method *Stage-Gate Process*

The optimization of the tool design for peeling and cutting pineapple fruit was carried out through the Stage-Gate *Process method*, which consists of eight stages. However, in this study, it is limited to the fourth *gate*. Each stage systematically contributes to the refinement of the product design.

a. *Stage* 0: *Idea Generation*

At this stage, ideas were collected from various sources, including:

- Household consumers complain about the lengthy peeling process and inconsistent deduction results.
- Fruit peelers in traditional markets who want tools that are safe, fast, and easy to clean.
- Fruit processing MSME actors who require time efficiency and uniform cutting results for mass production.
- Literature studies and observations of existing designs show that most tools have only one function, such as peeling the skin, without the ability to cut the pineapple fruit or separate the pineapple stem.

Common problems found are slow pineapple peeling processes, untidy cuts, and inefficient time management. The collected ideas are then

classified based on function, ease of use, and technical potential for development.

Results:

A need for pineapple cutting and peeling tools was found to facilitate work processes, reduce waste, and improve safety and efficiency.

b. *Gate* 1: *Idea Screening*

Idea screening was conducted based on criteria of market needs, initial technical feasibility, and product development potential. Ideas were selected through group discussions, mini surveys of potential users, and initial feasibility assessments.

Results:

The idea to create a pineapple cutting and peeling tool was approved to proceed because it was considered relevant, useful, and not yet widely available in the market in multifunctional form. At this stage, a screening process was carried out on all the ideas that had been collected. The main criteria in this process included technical and production feasibility, efficiency in cutting results, ease of use, and user safety aspects. The final chosen idea was a multifunctional tool design consisting of three main blades: a skin peeling blade, a center corm removal blade, and a pineapple flesh cutting blade. This design was considered the most feasible because it combines several important functions in one tool, is simple in mechanism, and can provide uniform cutting results.

c. *Stage* 1: *Scoping*

At this stage, a quick analysis of market needs, competitors, and initial technical specifications is conducted. Market research is conducted through interviews, brief surveys, and benchmarking of existing tools.

Results:

The target users consist of culinary MSMEs, households, and catering businesses. The required features include safety of use, work efficiency, neat cut results, and ease of cleaning.

d. *Gate* 2: *Second Screen*

The second evaluation was conducted based on market and technical study results. Idea validation was done through *rapid prototyping* from simple materials to assess the initial form's potential.

Results:

The idea was declared feasible to proceed to *business case* development because it meets user needs and is technically feasible.

e. *Stage* 2: *Build The Business Case*

This stage focuses on initial design creation, technical planning, cost calculation, and initial market planning. The initial design is done using CAD software, and prototypes are made on a small scale. Concept testing is conducted through small-scale testing to validate movement efficiency and with the advantages of "3 functions in 1 tool," time efficiency, and hygienic.

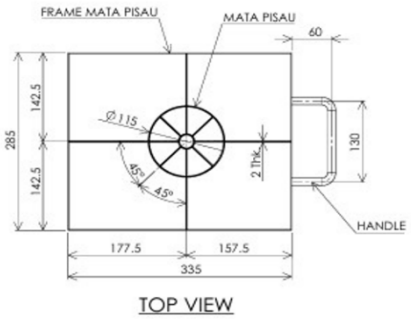


Figure 13. Digital 3D Sketch and Prototype

Results:

The initial prototype was successfully made. Cost analysis showed that the device could be produced at an affordable selling price. Initial marketing planning included demonstration and promotion strategies for MSMEs.

f. *Gate* 3: *Go To Development*

Evaluation of product development readiness. A thorough review was conducted on the design, prototype, and production cost plan.

Results:

Approved for development because the *business case* is mature, the initial prototype works well, and there is a clear market opportunity.

g. *Stage* 3: *Development*

This stage focuses on full technical development. The prototype is finalized using *stainless steel material*. Testing is conducted in the engineering laboratory.



Figure 14. Product Development

Results:

A final prototype capable of peeling and cutting pineapples was obtained. Two iterations were performed to optimize grip comfort and knife sharpness. The tool's function was proven to be safe and efficient.

h. *Gate* 4: *Go To Testing*

This stage assesses the readiness of the device to enter field testing and user validation.

Results:

The team stated that the product is ready to be tested on consumers. A final evaluation was conducted on the limited production plan, initial distribution scenarios, and equipment readiness from both technical and visual aspects.

i. *Stage* 4: *Testing and Validation*

The product is tested directly by the target users (MSMEs and households). The aspects tested include comfort, working speed, cutting results, as well as ease of cleaning and storage.

Results:

Most respondents felt satisfied. The product was considered to shorten cutting time, produce neat cut shapes, and be easy to use for casual users. Minor feedback was accepted and used as final improvement material.

3. Solidwork Image Evaluation Results with 3 Blade Sizes

From the design using SolidWork, a flexible blade design was obtained, meaning the blade is not fixed but can be replaced or detached, called *knockdown* , according to the size of the pineapple to be cut. Here are the components that can be removed (*knockdown*).

This will make the pineapple peel cutting process easier and more ready to serve. This tool will also increase efficiency, from one tool that should only use 1 knife size to one tool that can use 3 knife sizes.

The blade for cutting pineapple skin and cores is designed to provide sharp and clean cutting. The blade shape is shaped as shown in Figure 14, so it can precisely follow the pineapple contour. Its size varies depending on the capacity and size of the identified pineapple; for 3 blades, adjusting to the pineapple identified during the cutting process.

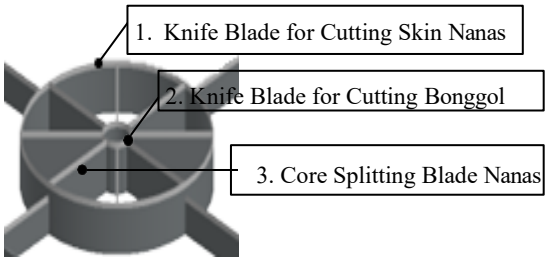


Figure 15. 3-Blade Model

Geometries Pisau:

- Blade Diameter: After identifying the pineapple size, the size is divided into 3 (Small 85 mm, Medium 125 mm, and Large 165 mm), with a sharp tip to follow the pineapple contour.
- Blade Thickness: The blade thickness is 2 mm to provide a stable cutting force.
- Blade Shape: The tip of the blade is made sharp so that the cutting motion does not damage the inside of the fruit. The blade shape should also allow for a clean cut on the stem.

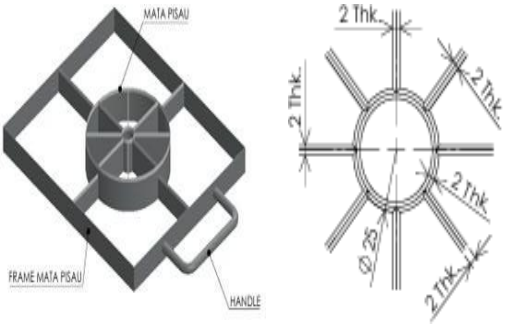


Figure 16. Blade Geometry

Cutting Angle:

Pineapple peel cutting knives usually have a cutting angle of 12.5°. A sharper angle will make cutting harder and rougher-textured skin easier, but still allows for sufficient durability.

Blade Thickness:

Blade thickness with a size of 2 mm to provide a balance between strength and sharpness. The thinner blade thickness allows for finer cuts, while the larger thickness provides resistance to pressure when cutting hard pineapple cores.

4. Design Analysis *of Tools* for Cutting and Peel Pineapples Using Failure Mode and Effects Analysis (FMEA)

Table 3. *Failure Mode and Effects Analysis* (FMEA)

FMEA Berdasarkan Aspek Riset Optimasi Desain											
ID Komponen	**Aspek Riset**	**Potensi Kegagalan**	**Efek Kegagalan**	**Penyebab**	**Metode Deteksi**	**Severity (S)**	**Occurrence (O)**	**Detection (D)**	**RPN (S×O×D)**	**Alasan Nilai**	**Tindakan Pencegahan**
Pisau single blade	Desain + Analisis	Sudut tidak optimal	Potongan gagal	Material lunak	Inspeksi visual	3	7	4	84	Perlu memilih jenis pisau yang tepat	Validasi bentuk melalui simulasi SolidWorks
Pisau pengupas kulit	Desain + Pengujian	Ketajaman kurang optimal	Sisa kulit tertinggal	Desain kurang optimal	Uji fungsional	3	5	6	90	Sudut kurang optimal	Pilih material tajam & optimalkan sudut tajam
Pisau pemotong bonggol nanas	Desain + Analisis	Tidak cukup kuat untuk bonggol keras	Gagal memotong	Material terlalu lunak	Uji potong bonggol keras	5	2	7	70	Material dengan spesifikasi food - grade	Gunakan baja tahan karat yang diperkuat
Pisau pemotong daging nanas	Desain + Analisis	Hasil potong tidak rata	Distribusi irisan tidak konsisten	Posisi & panjang pisau tidak tepat	Simulasi potong 3D	4	2	7	56	Pisau sudah sesuai dengan hasil yang diinginkan	Uji simulasi irisan → optimalkan panjang dan sudut

FMEA (*Failure Mode and Effect Analysis*) is used to identify potential failures in design components, assess their effects and causes, and provide preventive actions. Scores are given for *Severity* (S), *Occurrence* (O), and *Detection* (D), each on a scale of 1–10, and are calculated as RPN (*Risk Priority Number* = S x O x D). In FMEA (*Failure Mode and Effects Analysis*), there is no absolute number that serves as an "official boundary" to state that a device is good/feasible, because context and industry type influence risk assessment. However, in general:

RPN Score Interpretation Standards

RPN = *Severity* (S) × *Occurrence* (O) × *Detection* (D)

Each scale: 1–10 → maximum RPN = 1000

- RPN < 100

Low risk, generally accepted without action. Components or tools can be considered fairly good/feasible.

- RPN 100 –200

Medium risk, requires further monitoring or design evaluation. Can still be considered feasible, but minor adjustments may be needed.

- RPN > 200

High risk, immediate corrective action is needed. The equipment is considered unfeasible and requires *redesign*, retesting, or improvement of detection methods.

In FMEA (*Failure Mode and Effects Analysis*) conducted in the research on *the design of tools* for peeling and cutting pineapples, the risk obtained was low, generally accepted without action, as shown in Table 2. The components or tools can be considered quite good/feasible to use.

Table 4. Results of Tool Design Development for Cutting and Peel Pineapple Fruit

Stages	Activities	Development Results
***Stage* 0: *Discovery* (Penemuan Ide)**	Identification of problems in the process of peeling and cutting pineapple manually. Discovery of new product ideas for pineapple peeling and cutting tools.	The idea of pineapple peeling and cutting tools was discovered to improve efficiency.
Gate* 1: *Idea Screen	Evaluate ideas based on market feasibility and technical aspects.	The idea of the device was accepted to proceed because the market for this product was promising. Further development plans based on analysis of tool advantages. The decision to proceed to *Stage* 1.
Stage* 1: *Scoping	Preparing user needs analysis and product specifications. Preparation of plans for prototype development.	A clearer definition of the tool: an efficient and easy-to-use pineapple peeler and cutter. Research results show there is

		significant demand in the MSME market and home consumers. The product development plan shows that the product has good advantages.
Gate* 2: *Second Screen	Further evaluation related to feasibility and technical challenges. Market feasibility testing is based on further research data.	The idea of a pineapple peeling tool was accepted and proceeded to the development stage. The decision to proceed to *Stage* 2 with more thorough business preparation.
Stage* 2: *Build the Business Case	Develop a more detailed business plan, including technical analysis. Initial prototype creation and internal testing.	A clear business plan with financial projections and marketing strategies. The initial prototype design was developed and tested internally, showing good results. Preparation to proceed to *Gate* 3 and obtain approval for further development.
Gate* 3:** ***Go to Development	Readiness check to proceed to further product development. Final evaluation of all analyses and business plans.	Approval to proceed to the development stage after meeting all technical and market criteria. Products are ready to enter into *Stage* 3: *Development*.
Stage* 3: *Development	Deeper product design development and more thorough prototyping. Laboratory testing and analysis.	The prototype with the advantage of 1 *tool* has three functions: peeling the skin, cutting the core, and cutting the pineapple flesh. Some design improvements were made based on test results (for example, on blade geometry such as the ratio of cutting edge angles). The product is ready for field testing after minor revisions have been made.
Gate* 4:** ***Go to Testing	Product readiness evaluation for the field trial stage. Product feasibility inspection is based on development results.	The product is ready for field testing with real customers. Minor technical issues have been fixed, and the product is ready for market testing. Decision to proceed to the stage *Stage* 4: *Testing and Validation.*
Stage* 4: *Testing and Validation	Product testing with Solidworks simulation is related to the product's strengths Production process testing and market validation.	The product test results with SolidWorks simulation related to the product's strength are good. The product goes through the final testing stage before being marketed.

5. Comparison of Cutting Angle Effectiveness

With a fixed cutting force of 539.65 N and an average cutting time of 2.5 seconds for each blade and angle combination. To determine the most optimal cutting angle (7.5°, 10.5°, 12.5°) for all blade sizes (85 mm, 125 mm, 165 mm).

Table 5. Comparison of Cutting Angle Effectiveness

NO	Blade Diameter (mm)	Cutting Angle (°)	Cutting Style (N)	Cutting Time (second)	Neat Slices (%)	Fruit Damage (%)
1	85	7.5	539.65	2.5	70	30
2	85	10.5	539.65	2.0	85	15
3	85	12.5	539.65	1.8	90	10
4	125	7.5	539.65	2.8	68	32
5	125	10.5	539.65	2.3	82	18
6	125	12.5	539.65	2.1	87	12
7	165	7.5	539.65	3.2	65	35
8	165	10.5	539.65	2.7	80	20
9	165	12.5	539.65	2.4	85	15

From Table 3, the average *tool angle* is obtained to achieve the optimal pineapple cut result.

Table 6. Performance Data for Each Cutting Angle

Cutting Angle (°)	Average Neat Slice (%)	Average Fruit Damage (%)
7.5	(70+68+65)/3 = 67.7%	(30+32+35)/3 = 32.3%
10.5	(85+82+80)/3 = 82.3%	(15+18+20)/3 = 17.7%
12.5	(90+87+85)/3 = 87.3%	(10+12+15)/3 = 12.3%

From Table 4, a comparison graph of knife cutting angle effectiveness based on neat slices and fruit damage is obtained as follows:

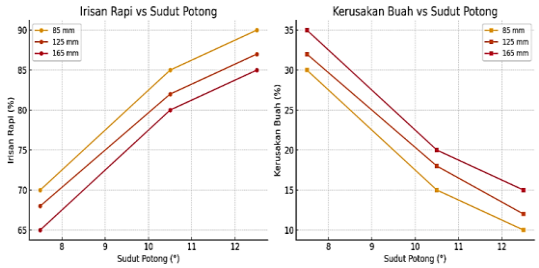


Figure 17. Comparison Graph of Knife Cutting Angle Effectiveness Based on Neat Slices and Fruit Damage

Performance Data from Each Angle:

Effectiveness evaluation of three variations of cutting angle (7.5°, 10.5°, and 12.5°) on the blades of pineapple cutting and peeling tools. Each angle was tested on blades with diameters of 85 mm, 125 mm, and 165 mm with fixed parameters of a cutting force of 539.65 N and an average cutting time of 5 seconds.

The 7.5° angle technically has the highest sharpness among the three configurations. Its main advantage lies in its ability to cut quickly and easily penetrate the fruit skin. However, this sharpness actually causes greater pressure on the cutting area, especially when used on large-diameter knives. This results in a high rate of fruit damage, reaching an average of 32.3%. Therefore, although effective for quick cuts, the 7.5° angle is not recommended in industrial knife designs, especially for large-scale cutting.

A cutting angle of 10.5°, a 10.5° angle configuration shows more stable results. The resulting slices are at a good level of precision with fruit damage still within tolerance limits. The average neat slice is 82.3% and damage is only 17.7%. This angle is also flexible for use on various blade sizes. From the perspective of design ergonomics and process efficiency, this angle can be positioned as an ideal compromise between cutting speed and yield stability.

A 12.5° cutting angle, a 12.5° angle shows superior performance in all tested aspects. With an average neat slice reaching 87.3% and the lowest fruit damage of 12.3%, this angle delivers optimal results for both small and large blades. This advantage comes from a duller cutting angle, which reduces excessive penetration force and allows for more even pressure on the fruit surface. Thus, the 12.5° angle is highly recommended as the main design configuration in pineapple cutting tools.

6. Tool Strength Simulation

Simulations using SolidWorks Simulation software were conducted to test the maximum stress (*von Mises stress*) on the blade under a load of 133.5 N for the cutting force on the pineapple peel, 80.10 N for the force received by the pineapple core, and the total force received by *the tool* was 539.65 N (higher than the actual cutting force for safety factors). With this simulation, it can be proven that *the tool* designed based on the parameters needed to cut and peel pineapple fruit can withstand the accepted force.

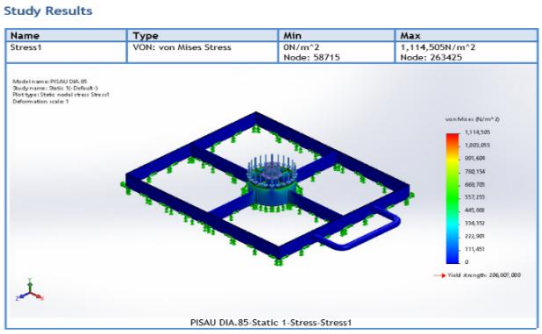


Figure 18. Simulation *Tools* Using Solidworks Simulations for D = 85 mm with a 12.5° Angle

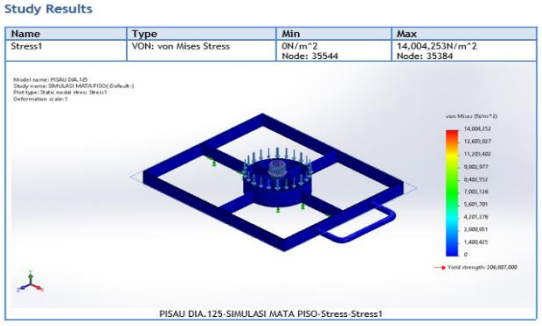


Figure 19. Simulation *Tools* Using Solidworks Simulations for D = 125 mm with an Angle of 12.5°

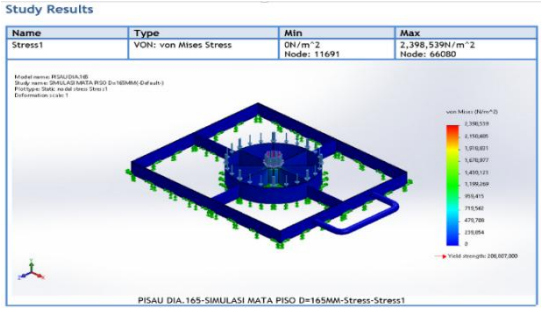


Figure 20. Simulation *Tools* Using Solidworks Simulations for D = 165 mm with a 12.5° Angle

Simulations show that the blades are safe for long-term use and do not experience plastic deformation under normal use.

CONCLUSION

Optimization of pineapple cutting and peeling tool design through the *Stage-Gate* Process *approach* has proven to provide significant improvements in time efficiency, usage safety, and cutting product quality. Each stage of the process, from needs identification, CAD modeling using Solidworks, cutting force simulation, to result validation, is carried out systematically and data-driven. The final design integrating the *knockdown* system and the three main types of blades (skin peeler, corm cutter, and meat cutter) was successfully optimized. A cutting angle of 12.5° on *the single blade type* produced the best performance, with an average of 87.3% neat slices and a minimum fruit damage of 12.3%. The entire cutting process can be completed within 5 seconds, exceeding the performance of the previous design. Evaluation using the FMEA method effectively identifies potential risks from the early design stage. The *Stage-Gate* Process approach *as a framework for engineering product innovation has proven capable of minimizing risks, improving design reliability, and serving as a strong foundation for further development.*

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