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Engineering a Better Slice: Development of an Efficient Watermelon Slicing Tool

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ABSTRACT

The Watermelon Slicer project focuses on the design and development of a mechanical tool to efficiently and safely slice watermelons. The objective is to address the challenges associated with manually cutting large and irregularly shaped fruits, which often pose difficulties in terms of safety, consistency, and time consumption. The proposed device integrates ergonomic design with sharp cutting mechanisms to achieve uniform slices with minimal physical effort. Key factors considered in the design include user safety, ease of use, material durability, and cutting precision. Prototypes were tested under various operational conditions to assess performance in terms of cutting efficiency, slice uniformity, and user comfort. Results demonstrate that the slicer significantly reduces preparation time while enhancing safety compared to conventional methods. The study concludes that the watermelon slicer presents an effective, time-saving solution for both domestic and commercial applications. Future work will involve further refinements to improve the product's versatility for cutting a wider range of fruits and vegetables.

Keywords: Innovative design, Kitchen utensils, CNC Milling process.

1. INTRODUCTION

Cutting watermelons, due to their large size and tough outer rind, presents a unique challenge for both domestic users and food service professionals. Traditional methods of slicing watermelons with kitchen knives are not only time-consuming but also pose significant safety risks, especially when dealing with irregularly shaped fruits [1, 2, 3]. In addition, achieving uniform slices can be difficult, resulting in inconsistent portion sizes and wastage [4, 5]. The development of specialized tools for fruit preparation has gained increasing attention in recent years, as they offer opportunities to streamline food preparation, improve safety, and enhance user convenience [6, 7].

This study explores the design and development of a mechanical watermelon slicer aimed at addressing these challenges. The objective of this project is to create an ergonomic tool that simplifies the process of slicing watermelons, ensuring uniformity of slices, reducing preparation time, and minimizing safety risks associated with traditional cutting methods. By incorporating principles of mechanical engineering and ergonomics, the device is designed to be intuitive to use, requiring minimal physical effort while delivering precise, clean cuts.

Previous innovations in kitchen utensils have shown that tools specifically designed for certain fruits and vegetables can significantly improve the efficiency of food preparation. However, existing solutions for watermelon slicing often suffer from limitations in durability, effectiveness, and user safety [8]. Traditional fruit slicers are typically designed for specific fruit types or sizes,

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limiting their utility. Consumers often need to purchase multiple slicers to handle different fruits, resulting in cluttered kitchens and increased expenses. Traditional slicers are bulky and challenging to store, further worsening the problem for those with limited kitchen space. Hand may be injured while using the traditional fruit slicers by putting extra strength to cut some harder fruit as depicted in Figure 1.

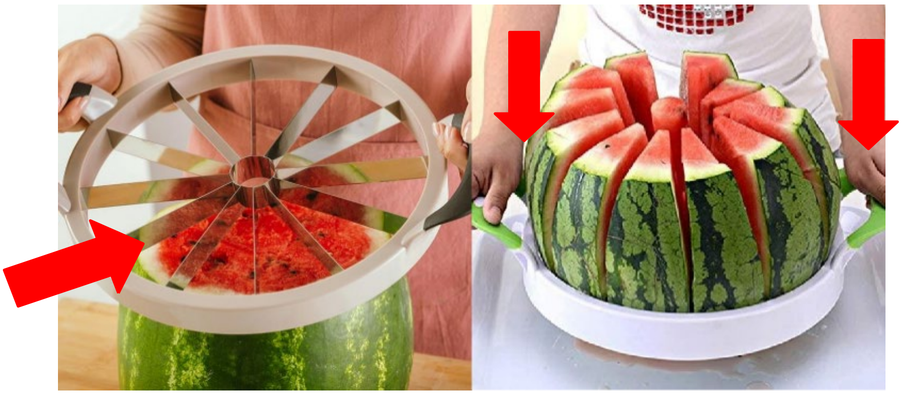

Figure 1: Traditional fruit slicers.

The development of a product incorporates various stages, from conceptual design to prototype testing [9]. One key aspect is the use of simulation [10, 11]. Computer-aided manufacturing (CAM) simulation plays a crucial role by allowing virtual testing of the manufacturing process, helping to identify issues such as tool collisions or inefficient cutting paths before production begins. This ensures the parts are accurately manufactured, reduces material waste, and optimizes production time [12]. By simulating the tool paths, designers can also ensure that all components fit together properly, leading to smoother assembly and improved functionality. The use of CAM simulation makes the development process more efficient, cost-effective, and helps produce a high-quality final product.

This project aims to overcome these shortcomings by developing a robust and reliable tool that meets the needs of both domestic users and commercial kitchens. This project presents the design process, materials selection, and mechanical principles underlying the development of the watermelon slicer. Performance evaluations of the prototype are conducted to assess cutting efficiency, ease of use, and user safety. Finally, the potential for future enhancements and broader applications of the tool are discussed, highlighting its versatility in food preparation tasks beyond watermelon slicing.

2. MATERIAL AND METHODS

SolidWorks software was utilized for the design and creation of each component in this project, while SURFCAM software facilitated the simulation of the machining processes required for CNC milling. In the context of today's rapidly evolving industrial landscape, where efficiency and precision are paramount, these tools play a vital role in ensuring success across sectors such as manufacturing, construction, and fabrication.

Concept selection is a key step in product development, where different design ideas are evaluated to find the best option for further work. The process starts with generating several potential solutions. Then, a screening process eliminates impractical ideas, leaving a smaller set for detailed evaluation. These remaining concepts are assessed based on factors like performance, cost, and feasibility, often using tools like decision matrices to score and rank them. The concept that best fits the project's goals is chosen and then tested through prototyping or simulations. Feedback from testing may lead to improvements before finalizing the design. This approach ensures that the final product is practical, cost-effective, and meets user needs, reducing the chances of expensive changes later on.

2.1 Concept Design Selection

Three concept designs have been proposed for the watermelon slicer as shown in Figure 2. Concept A presents a one-handed watermelon slicer that features an ergonomic handle for a secure grip and multiple sharp blades arranged in a grid pattern. When the user pushes down on the handle, the blades simultaneously cut through the watermelon with minimal effort, to a lever-action mechanism that multiplies the applied force. Safety features like non-slip handles and blade guards enhance usability. This design allows for quick, efficient slicing and uniformly sized pieces, making it a convenient tool for preparing watermelon.

Concept A Concept B Concept C

Figure 2: Proposed concept designs for the watermelon slicer.

Concept B requires both hands to operate, featuring a handle designed so that the force is concentrated in the middle. Users grip either end of the handle and press down together, ensuring the pressure is evenly distributed. The central concentration of force allows the sharp blades to cut smoothly through the watermelon, creating even slices with minimal effort. This design maximizes efficiency and control while slicing the fruit.

Concept C operates with both hands, with the force applied at wide points on the handle, far apart from each other. Users grip the ends of the handle and press down, distributing pressure across a broader area. This design allows the sharp blades to slice through the watermelon evenly and smoothly, leveraging the wider force application for efficient cutting and uniform slices.

A decision matrix as shown in Table 1 is a structured tool used to evaluate and compare different alternatives based on multiple criteria, where each option is scored and weighted according to its performance across those criteria, allowing for a more objective and informed decision-making process.

Table 1: Decision Matrix.

No.	Design criteria	Weight factor	Concept 1		Concept 2		Concept 3	
			Rate	Score	Rate	Score	Rate	Score
1.	Component costs	3	2	6	2	6	3	9
2.	Assembly time	3	3	9	3	9	3	9
3.	Maintenance costs	4	2	8	3	12	3	12
4.	Occupied space	3	2	6	4	12	4	12
5.	Interface with other elements	4	3	12	3	12	4	16
6.	Will solve the problem fully	3	3	9	4	12	5	15
7.	Safety	3	2	6	3	9	5	15
8.	Accuracy	4	3	12	3	12	4	16
9.	Reliability	3	3	9	2	6	3	9
	Total			77		90		113

Scoring Key: 1-Much worse than baseline, 2-Worse than baseline, 3-No difference from baseline，4-Better than baseline，5-Much better than baseline.

The results from Table 1 indicate that Concept 3 is the superior design option, achieving the highest overall score of 113. It excels in several critical areas, including accuracy, reliability, safety, and problem-solving capability, all of which are weighted heavily in the evaluation. Concept 3 also shows strong performance in its interface with other elements, making it a better choice for integration into broader systems. In contrast, Concept 1 performs the worst, with an overall score of 77. While it is more cost-effective in terms of component costs and maintenance costs, it scores poorly in essential areas such as safety, accuracy, and reliability, making it less suitable for applications where these factors are critical. Concept 2 provides a middle-ground solution, with a total score of 90. It performs moderately across most criteria but lacks the standout advantages of Concept 3. Although it shares some strengths with Concept 1, such as lower costs, it fails to excel in high-priority areas like problem-solving ability and safety, which are crucial for robust design. Concept 3 is the best overall design, offering a balanced and high-performance solution, despite being more costly and time-consuming to assemble than the other concepts. Figure 3 depicts the orthographic and exploded view of the watermelon slicer.

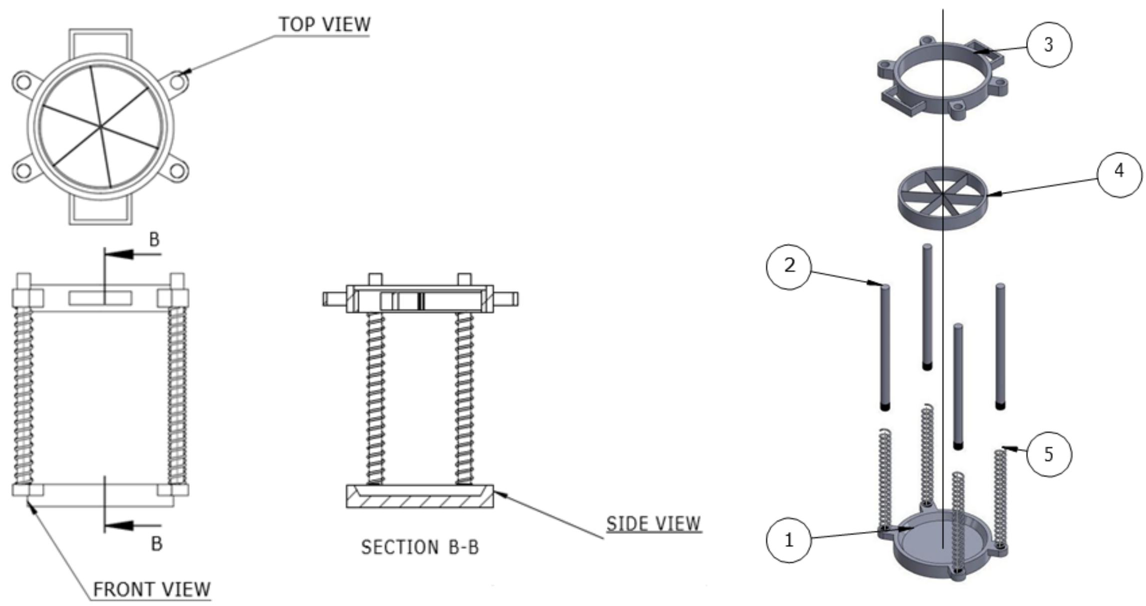

Figure 3: Orthographic and exploded view of watermelon slicer.

2.2 Manufacturing Process

The fabrication process involves several key stages, each crucial to the development of a high-quality final product. It begins with design and prototyping, where engineers and designers collaborate to create detailed plans and prototypes. This stage is essential for visualizing the product and testing its functionality and aesthetics. Engineers ensure the design is feasible and meets all technical requirements, while designers focus on the product's usability and visual appeal. Once the design and prototyping phase is complete, the manufacturing process takes over. This stage employs various techniques such as machining, molding, or additive manufacturing to produce the individual components of the product. Machining involves precise cutting and shaping of materials, molding uses specific forms to shape materials, and additive manufacturing builds components layer by layer. Each technique is selected based on the material and design requirements, ensuring that the components are produced to exact specifications. Following manufacturing, the assembly process begins. In this stage, the individual components are meticulously combined to form the final product. This involves fitting parts together correctly, securing them in place, and ensuring that the product functions as intended. The assembly process is critical, as any misalignment or incorrect assembly can affect the product's performance and durability. Throughout each stage, design and prototyping, manufacturing, and assembly, quality control measures are implemented to ensure the product meets stringent quality standards and customer expectations. Rigorous testing and inspections are conducted to identify and rectify any issues, ensuring the final product is both functional and reliable. By meticulously following these stages, the fabrication process ensures that the end product is of the highest quality, meeting both design specifications and user needs.

2.3 Cutting Force equation

Cutting force (F) is calculated using the formula:

$$F = \sigma \times A \tag{1}$$

Where σ is the shear strength of the watermelon flesh (0.5-1.0 MPa), and A is the cross-sectional area of the blade edge in contact with the watermelon.

3. RESULTS AND DISCUSSION

SURFCAM software was employed to design the staircase locator and prepare it for the Computer-Aided Manufacturing (CAM) process on a CNC milling machine. The software facilitated the creation of precise toolpaths and machining strategies tailored to the component's design. Additionally, SURFCAM generated the necessary Numerical Control (NC) code, which was then imported into the CNC milling machine, enabling the machine to accurately execute the required milling operations for producing the staircase locator as shown in Figure 4. This integration ensured precision, efficiency, and consistency in the manufacturing process.

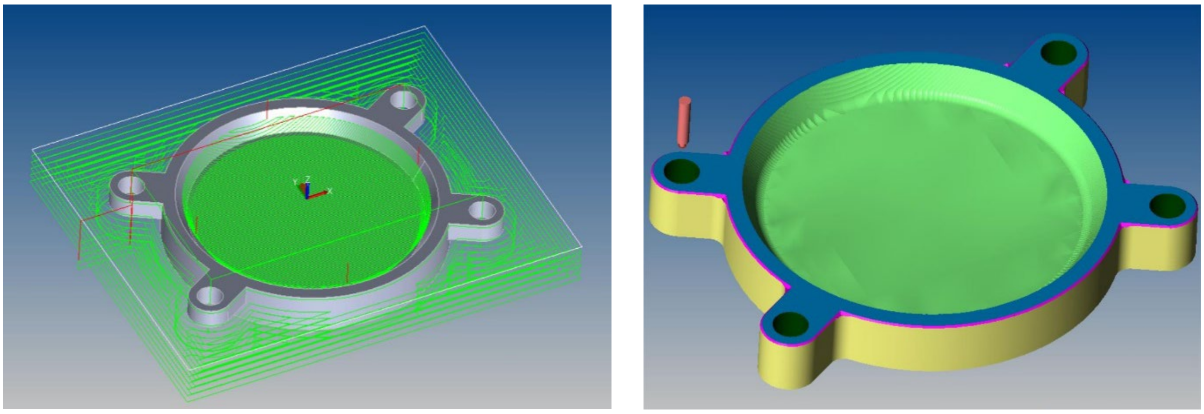

Figure 4: Computer-Aided Manufacturing (CAM) processes.

The tooling list as shown in Figure 5 contains information about the tools used in a machining process. These tools include drills, ball end mills, and a custom tool. The tools are used for various operations like drilling, milling, and creating specific shapes. The choice of tools depends on the workpiece material, desired finish, and the machining operation being performed. Proper tool maintenance and selection can help maximize tool life and reduce costs.

The operations list as shown in Figure 6 represents a well-structured approach to machining a part with varying complexities. It balances between roughing, drilling, and finishing, with appropriate tool selection and parameters for each task. However, further process optimization in terms of tool path efficiency and machining time reduction could enhance productivity, particularly for large-scale or repetitive production environments. The use of custom settings, precision tools, and diverse machining strategies indicates a strong focus on achieving both high efficiency and quality.

The feed rates, plunge rates, and spindle speeds vary significantly between operations, reflecting the different requirements for each tool and material interaction. For instance, the 2 Axis Pocket operation (Tool #20) runs at a high plunge rate of 203.718 mm/min, while the 3 Axis Chamfer Mill (Tool #5) operates at 413.803 mm/min with a spindle speed of 1273 RPM. This variation suggests an effort to balance tool wear, precision, and time efficiency. Higher feed and plunge rates may be used to reduce machining time but could impact the tool's lifespan or finish quality if not carefully managed. Conversely, lower speeds in hole processes (e.g., 93.37 mm/min plunge rate for Tool #2) allow for more controlled and accurate drilling.

Cycle times are an essential factor in assessing process efficiency. The total machining time across all operations is 5 hours, 32 minutes, and 40 seconds. The longest single operation, a 2 Axis Pocket, takes nearly 3 hours (2:59:59), which could indicate a large or complex pocket geometry requiring extensive tool movement. On the other hand, shorter operations like the 3 Axis Chamfer Mill (4:47) suggest tasks focused on fine finishing or edge preparation. This variation indicates a mix of bulk material removal and precision finishing tasks within the overall process.

surfcam	TOOLING LIST
Date:	Mon Jun 17 2024
Time:	23:12:23
Output Filename:	MP-Stage_3-_chp4Setup_One.INC

Description:	Custom 0:25:0
Tool Number:	20
Length Register:	20
Diameter Register:	20
Diameter:	25.0000
Corner Radius:	0.0000
Flute Length:	55.0000
Total Length:	130.0000
Number of Flutes:	4
Program Point:	Tip

Description:	2.00mm Center Drill - HSS
Tool Number:	1
Length Register:	1
Diameter:	2.0000
Tip Angle:	118.0000
Flute Length:	2.0000
Total Length:	40.0000
Number of Flutes:	2
Program Point:	Tip

Description:	10.0mm HSS Drill
Tool Number:	2
Length Register:	2
Diameter:	10.0000
Tip Angle:	118.0000
Flute Length:	25.0000
Total Length:	170.0000
Number of Flutes:	2
Program Point:	Tip

Description:	30.0mm HSS Drill
Tool Number:	3
Length Register:	3
Diameter:	30.0000
Tip Angle:	118.0000
Flute Length:	75.0000
Total Length:	390.0000
Number of Flutes:	2
Program Point:	Tip

Description:	20mm - 4 flute - HSS Ballmill
Tool Number:	4
Length Register:	4
Diameter Register:	4
Diameter:	20.0000
Corner Radius:	10.0000
Flute Length:	38.0000
Total Length:	104.0000
Number of Flutes:	4
Program Point:	Tip

Description:	Custom 0:0:0
Tool Number:	5
Length Register:	5
Diameter Register:	5
Diameter:	0.0000
Corner Radius:	0.0000
Flute Length:	3.5000
Total Length:	54.0000
Number of Flutes:	10
Program Point:	Tip

Figure 5: Tooling used in the CNC process.

surfcam	OPERATIONS LIST
Date:	Mon Jun 17 2024
Time:	23:12:23
Output Filename:	MP-Stage_3-_chp4Setup_One.INC

Tool Number	Operation	Plunge Rate	Feed Rate	Spindle Speed	Min X	Min Y	Min Z	Max X	Max Y	Max Z	Cycle Time
20	2 Axis Pocket	203.718	407.44 MMPM	637 RPM	-265.0000	-200.0000	-50.0000	250.0000	200.0000	25.0000	2:9:59
1	2 Axis Hole Process	-	222.82 MMPM	3183 RPM	-173.2051	-100.0000	-4.1164	173.2051	100.0000	26.0000	0:0:12
2	2 Axis Hole Process	-	101.86 MMPM	637 RPM	-173.2051	-100.0000	-60.0000	173.2051	100.0000	26.0000	0:2:35
3	2 Axis Hole Process	-	93.37 MMPM	212 RPM	-173.2051	-100.0000	-60.0000	173.2051	100.0000	26.0000	0:2:48
4	3 Axis Planar	89.127	178.25 MMPM	318 RPM	-141.2749	-140.0000	-25.0000	141.2749	0.0000	26.0000	1:37:33
4	3 Axis Planar	89.127	178.25 MMPM	318 RPM	-141.2749	-0.0000	-25.0000	141.2749	140.0000	26.0000	1:37:33
5	2 Axis Chamfer Mill	413.803	827.61 MMPM	1273 RPM	-199.2480	-166.0429	-2.4571	199.2480	166.0429	51.0000	0:1:47
Overall					-265.0000	-200.0000	-60.0000	250.0000	200.0000	51.0000	5:32:30

Figure 6: Operation list.

3.1 Cost Analysis

This section analyzes the costs associated with the development, production, and sales of the innovative watermelon slicer. The cost analysis will be broken down into direct and indirect costs, selling prices, profits, and return on investment (ROI).

3.1.1 Direct and Indirect Costs

Table 2 outlines the direct and indirect costs for the project, including machinery investment and maintenance, material and packaging costs, production and quality control expenses, labor costs, and overheads such as utilities, rent, and taxes, providing a comprehensive overview of both one-time and recurring expenses.

Table 2: Direct and Indirect Costs.

Section	Criteria	Cost
Machines	Initial Investment for Machinery:	MYR 100,000
	Maintenance Costs:	MYR 5,000 per year
	Depreciation:	MYR 10,000 per year (assuming a 10-year useful life)
Material	Raw Materials (per unit):	MYR 20
	Packaging (per unit):	MYR 2
Process	Production Cost (per unit):	MYR 15
	Quality Control (per unit):	MYR 3
Labour	Labour Cost (per unit):	MYR 10
	Total Labour Cost (monthly):	MYR 50,000 (assuming 5000 units produced per month)
Overhead	Utilities (monthly):	MYR 5,000
	Rent (monthly):	MYR 10,000
	Miscellaneous (monthly):	MYR 2,000 Taxes
	Corporate Tax Rate:	24%
	Annual Tax Amount:	To be calculated based on profits

3.1.2 Profits

To determine monthly profit, it is necessary to calculate the total cost per unit and then subtract it from the selling price. The calculation in Table 3 will reveal the profit generated from each unit sold. Multiplying the per-unit profit by the total number of units sold in a month will provide the total monthly profit as calculated in Table 4.

Table 3: Total Cost per Unit.

Item	Cost
Selling Price (per unit):	MYR 80
Raw Materials:	MYR 20
Packaging:	MYR 2
Production Cost:	MYR 15
Quality Control:	MYR 3
Labour Cost:	MYR 10
Total Cost per Unit:	MYR 50

Table 4: Monthly Revenue and Profit Calculation.

Item	Cost
Units Produced and Sold Monthly:	MYR 5,000
Monthly Revenue:	5,000 units * MYR 80 = MYR 400,000
Total Monthly Costs:	
Total Cost per Unit:	MYR 50 * 5,000 = MYR 250,000
Utilities:	MYR 5,000
Rent:	MYR 10,000
Miscellaneous:	MYR 2,000
Total Monthly Costs:	MYR 267,000
Monthly Profit Before Tax:	MYR 400,000 - MYR 267,000 = MYR 133,000
Monthly Profit After Tax:	MYR 133,000 * (1 - 0.24) = MYR 101,080

3.1.3 Return on Investment (ROI)

The initial investment (Table 5) is a crucial factor to consider when evaluating the financial feasibility of a project. It represents the amount of capital that needs to be invested upfront to generate future returns.

Table 5: Initial Investment.

Item	Profit
Machinery:	MYR 100,000 Annual Profit Calculation
Monthly Profit After Tax:	MYR 101,080
Annual Profit After Tax:	MYR 101,080 * 12 = MYR 1,212,960

Return on Investment (ROI) is calculated using the formula:

ROI Formula: (Annual Profit / Initial Investment) × 100% (2)

ROI: (MYR 1,212,960 / MYR 100,000) × 100% = 1212.96%

The ROI is significantly positive, indicating a highly profitable investment. It summarizes that the innovative watermelon slicer project exhibits strong financial viability with substantial profits and a high return on investment. The detailed cost analysis highlights the effectiveness of the production and sales strategy in generating a positive financial outcome.

3.2 Impact of the product

The watermelon slicer has the potential to create a significant impact in both domestic and commercial food preparation environments. By addressing key issues such as safety, efficiency, and precision, the device offers a practical solution for handling large fruits like watermelons, which are notoriously difficult to cut with traditional kitchen tools. Its ability to reduce preparation time while minimizing physical effort directly benefits users in various settings, from household kitchens to professional food service operations. In domestic use, the slicer improves user convenience by simplifying the fruit-cutting process, making it accessible to individuals with limited strength or knife-handling skills. This is particularly beneficial for households where watermelons and other large fruits are frequently consumed. The device enhances safety by eliminating the need for sharp knives, thus reducing the risk of accidents, especially for inexperienced users or children.

For commercial kitchens, where time efficiency is critical, the slicer provides a streamlined solution for preparing large volumes of fruit. By delivering uniform slices consistently, helps ensure portion control, reduce food waste, and improve presentation in catering, restaurants, and other food-related businesses. The slicer's ergonomic design also minimizes worker fatigue, which can be a significant factor in high-paced environments where repetitive tasks are common. Additionally, the broader potential impact of the watermelon slicer extends to promoting healthier eating habits by making fruit preparation easier and more appealing. The device encourages the consumption of fresh fruit by removing one of the common barriers, difficulty in preparation. Thus supporting public health initiatives focused on increasing fruit intake.

4. CONCLUSION

The watermelon slicer project successfully demonstrates the potential of a specialized tool to significantly improve the process of slicing large fruits like watermelons. Through a combination of ergonomic design and precision cutting mechanisms, the device addresses key challenges associated with manual cutting, including safety risks, inconsistency in slice uniformity, and time consumption. The performance evaluations of the prototypes highlight that the slicer not only reduces preparation time but also enhances user safety and comfort, making it a practical solution for both domestic and commercial applications. The results confirm that the tool effectively meets its primary objectives by simplifying the slicing process and providing consistent, high-quality results with minimal physical effort. This project demonstrates robust financial viability, characterized by significant profitability and a substantial return on investment. However, opportunities for further development remain, particularly in refining the design for increased versatility to handle a broader range of fruits and vegetables. Future iterations could focus on improving material durability, expanding the scope of its application, and optimizing the cutting efficiency for various produce sizes and textures. Overall, the watermelon slicer presents a valuable innovation in kitchen tool design, offering a safer, more efficient alternative to traditional cutting methods.

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