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Research Article

Design and Construction of Manually Operated Vegetable Slicing Machine

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Abstract

This study evaluates the performance of a manually operated vegetable slicing machine intended for efficient, hygienic, and safe use in environments without electricity. Constructed with a mild steel frame and a stainless-steel rotating blade, the machine incorporates a hand-cranked pulley-belt system, a feeding chute, safety guards, and a collection tray. Experimental tests were conducted using three common vegetables—cucumber, carrot, and onion—to assess slicing time, output quantity, and slice uniformity. Each vegetable underwent three trials under controlled conditions. Results showed that cucumbers, due to their soft texture, required the least time (30 seconds) and yielded 25 slices at 4 mm thickness. Carrots, being denser, took 45 seconds and produced 30 thinner slices at 3 mm, while onions required 35 seconds for 28 slices at 4 mm. The belt and pulley transmission ensured smooth blade motion, and the crank mechanism provided adequate torque with minimal operator fatigue. Uniform slice thickness was consistently achieved across all tests. The design maintained high standards of hygiene through the use of stainless steel in food-contact parts and ensured user safety with protective features like blade guards and a hand pusher. The collection tray minimized waste and improved convenience. The machine demonstrated reliable and effective performance across a range of vegetable textures, making it suitable for both domestic and small-scale commercial applications, especially in off-grid areas. While performance met design expectations, suggested improvements include ergonomic enhancements to the crank and optimization of the pulley ratio for tougher produce. The study validates the machine's utility and efficiency.

Keywords: Manual Food Processing Equipment, Vegetable Slicing Machine, Postharvest Processing, Size Reduction Technology, Sustainable Agricultural Machinery

1. Introduction

Vegetable slicing is a fundamental process in food preparation across homes, restaurants, canteens, and industrial kitchens. Efficient slicing not only ensures uniform cooking but also enhances aesthetic appeal and reduces food preparation time. Traditionally, slicing is done manually using knives, which is time-consuming, inconsistent, and may pose safety risks, particularly for large-scale operations [1,2]. With increasing demands for precision and speed in food preparation, especially in developing nations with limited access to powered machinery, a manually operated vegetable slicing machine presents a viable solution. Mechanical slicing devices exist in a wide variety, from handheld tools to automated machines. However, many of these devices are either expensive, rely on electricity, or are unsuitable for rural or low-resource settings where access to power is unreliable. Manually operated devices offer a sustainable, low-cost, and easy-to-maintain alternative [3].

Developing such devices with ergonomic design, safety features, and efficiency in slicing various vegetables can significantly contribute to household and commercial food processing activities. The prevalent use of knives for slicing vegetables in homes and small-scale food businesses leads to several challenges. These include time inefficiency, irregular slicing thickness, user fatigue, and potential injuries. Electric vegetable slicers, while addressing some of these problems, are often expensive, require constant maintenance, and depend on electrical power, making them unsuitable for rural and off-grid communities. Additionally, existing manual slicers often lack versatility, durability, and user safety mechanisms. Therefore, there is a need to design and construct a low-cost, manually operated vegetable slicing machine that ensures consistent slicing, requires minimal human effort, is easy to maintain, and can operate without electricity. This machine must accommodate a variety of vegetables and incorporate safety features to prevent accidents during operation.

The primary objective of this study is to design and construct a manually operated vegetable slicing machine that:

• Provides consistent and uniform slicing.

- Is ergonomically designed to reduce user fatigue.
- Incorporates safety features to prevent injuries.
- Is affordable, durable, and suitable for both domestic and commercial use.
- Can be easily maintained and does not require electricity.

The study focuses on the mechanical design and construction of a vegetable slicing machine that can manually slice commonly used vegetables such as onions, tomatoes, cucumbers, carrots, and potatoes. The machine will be tested for efficiency, safety, and ease of use. While the focus is on manual operation, potential for future upgrades, such as motorization, will be considered in the design.

1.1. Importance of Vegetable Processing

Vegetable consumption is central to human nutrition and health, requiring proper processing methods such as slicing and dicing to enhance palatability and cooking efficiency [4]. According to WHO, processed vegetables contribute significantly to daily fiber intake and micronutrient availability [5]. Slicing facilitates faster cooking and uniform heat distribution [6].

1.2. Existing Slicing Techniques

Conventional slicing with knives is widely used but presents several issues: variability in slice thickness, safety hazards, and time consumption [7,8]. To address this, researchers have developed various slicing devices. Mechanical slicers are categorized into manual, semi-automatic, and automatic slicers [9]. Manual slicers are often rotary-based or sliding mechanisms requiring physical force [10]. Automatic slicers, typically powered by electric motors, provide high throughput but are costly and inaccessible in rural settings [11].

1.3. Manual Slicers: Designs and Limitations

Manual slicers have evolved from simple mandolins to complex rotary and press-based systems. Mandolins provide adjustable blade heights for varying slice thickness but pose high risks of injury without safety guards [12]. Rotary slicers with crank handles offer better ergonomics but require regular maintenance and cleaning [13]. Some recent innovations in manual slicers include lever-operated blades and spring-loaded cutting mechanisms [14]. However, many of these models are either designed for single-vegetable types or fail to ensure uniformity in slicing, especially for irregular-shaped vegetables like tomatoes and onions [15].

1.4. Safety Considerations

Safety is a major concern in manual food processing equipment. Studies have shown that over 35% of domestic kitchen injuries are attributed to improper handling of sharp tools [16]. Effective designs must isolate the user's hand from direct blade contact through protective shields, feeding chambers, or controlled cutting strokes [17].

1.5. Ergonomic and Anthropometric Design

User fatigue is a key limitation in manual food processing tools. Ergonomic design reduces muscular stress, improves posture, and enhances ease of operation [18]. Tools developed using anthropometric data tend to be more user-friendly and efficient [19]. For example, a handle's length, grip diameter, and blade positioning influence slicing efficiency and safety [20].

1.6. Material Selection for Food Contact Equipment

Material selection is critical for hygiene and longevity. Stainless steel is widely preferred for blades due to its corrosion resistance and ease of cleaning [21]. Food-grade plastics and aluminum are used in frames and handles for weight reduction and cost effectiveness [22]. Durability, non-toxicity, and resistance to microbial growth are essential criteria [23].

2. Design Methodologies

Several engineering design approaches are used in developing food processing machines. CAD modeling and Finite Element Analysis (FEA) enable optimization of stress-bearing parts [24]. Prototyping and iterative testing help refine mechanical efficiency and user experience [25]. In low-cost settings, modular design simplifies maintenance and part replacement [26].

2.1. Case Studies on Slicing Mechanism Innovations

Researchers have developed slicing machines using scissor-action blades, reciprocating blades, and rotary disc systems. A study by Rani et al. developed a pedal-operated slicer for carrots and cucumbers, achieving high uniformity [27]. Chinedu et al. constructed a manually actuated slicing machine with dual blade orientations to handle hard and soft vegetables effectively [28]. Kumar et al. investigated a screw-type slicing press for onions, which demonstrated excellent cutting force distribution and slice consistency [29]. Similarly, hybrid designs combining crank and lever motions were shown to reduce fatigue and increase slice rate [30].

2.2. Conceptual Design

The conceptual design of a manually operated vegetable slicing machine focuses on simplicity, efficiency, and ease of operation, particularly in environments lacking electrical power. The machine comprises a stable rectangular frame made of mild steel, supporting the entire structure. At the core of the system is a slicing chamber where vegetables are inserted through a top feeding chute. A circular rotating blade, made of stainless steel for hygiene and durability, is mounted horizontally within the chamber. The rotation of this blade is manually powered via a crank mechanism connected to a pulley system. When the user turns the crank handle, the pulley rotates and transmits motion to a secondary pulley mounted on the blade shaft using a durable rubber belt drive. This belt-driven system ensures smooth and consistent rotation of the blade, providing uniform slices of vegetables such as cucumbers, carrots, and onions.

The pulley ratio is optimized to reduce operator effort while maintaining sufficient blade speed for effective slicing. Safety guards and a hand pusher are included to protect the user from the blade during operation. A collection tray positioned beneath the blade captures the sliced vegetables, minimizing waste and enhancing convenience. The design emphasizes ergonomics by positioning the crank handle at a comfortable height and ensuring stability during use. With its simple mechanical components, the manually operated vegetable slicing machine is cost-effective, easy to maintain, and suitable for domestic kitchens, small restaurants, and rural food processing units where electrical access is limited or unavailable.

2.3. Engineering Design

The design of the manually operated vegetable slicing machine consists of four major components: the handle, crank, pulley, and belt drive. The entire mechanism operates by converting the manual rotary input into linear or rotary motion required to rotate the slicing blade.

2.4. Power Transmission Mechanism

The motion begins with a handle, which is manually rotated. The handle is connected to a crank system that transmits torque to a pulley through a shaft. The pulley is connected to another pulley mounted on the blade shaft via a belt drive. The power transmitted (P) by the handle can be estimated using:

$$P = \frac{2\pi NT}{60}, \tag{1}$$

where P is the Power in Watts (W), N is the speed of rotation in revolutions per minute (rpm), T is the torque in Newton-meters (Nm) [31].

2.5. Torque Calculation

The torque (T) applied by the user on the handle of radius rr is:

$$T = F \times r\,, \tag{2}$$

where F is the applied tangential force (N), or is the radius of the handle (m) [32].

2.6. Belt Drive Design

For power transmission via a belt drive, the velocity ratio (VR) is:

$$VR = \frac{N_2}{N_1} = \frac{D_1}{D_2}, \tag{3}$$

where N_1 is the Speed of the driver pulley (rpm), N_2 is the speed of the driven pulley (rpm), D_1 is the diameter of the driver pulley (m), D_2 is the diameter of the driven pulley (m) [33].

The belt length for an open belt drive is given by:

$$L = \pi(R + r) + \frac{(R-r)^2}{4C} + 2C, \tag{4}$$

where R and r are Radii of the large and small pulleys respectively (m), C is the center distance between the pulleys (m) [34].

2.7. Shaft Design

The shaft that connects the handle to the pulley transmits torque and must resist shear stress. The torsional shear stress (τ) is calculated as:

$$\tau = \frac{16T}{\pi d^3}, \tag{5}$$

where T is the torque transmitted (Nm), d is the diameter of the shaft (m) [35].

2.8. Blade Rotation and Cutting Force

The rotational speed achieved at the slicing blade determines the cutting rate. The required force to cut vegetables depends on the shear strength of the vegetable material. The cutting force (FC) is approximated as:

$$Fc = \tau_s \times A, \tag{6}$$

where τ_s is the shear strength of the vegetable (Pa), A is the area of the cross-section being cut (m^2) [36].

2.9. Pulley and Belt Material Selection

The pulleys are made of aluminum or cast iron for durability, while the belt is selected based on flexibility and grip, typically using rubber or reinforced synthetic material.

2.10. Ergonomic Considerations

The crank radius is optimized between 100 mm to 200 mm for comfortable operation by the average user, ensuring that the handle does not require excessive force for rotation.

3. Construction

The construction of the manually operated vegetable slicing machine was carried out systematically to ensure functionality, safety, and durability. The process began with the fabrication of a stable rectangular frame using mild steel. Mild steel bars were cut to size, aligned, and joined together through arc welding to form the structural base and support for the entire system. This frame provided rigidity and stability during the slicing operation. Following the completion of the frame, a slicing chamber was installed at the center of the structure. This chamber served as the operational area where the slicing process occurred. A top feeding chute, fabricated from stainless steel sheet metal, was mounted on the chamber to facilitate the easy insertion of vegetables such as cucumbers, carrots, and onions.

A circular rotating blade made of stainless steel was then mounted horizontally inside the slicing chamber. Stainless steel was chosen due to its corrosion resistance and hygienic properties suitable for food processing. The blade was securely attached to a horizontal shaft, which was supported on both ends with bearings for smooth rotation. To manually power the blade, a crank mechanism was constructed. A crank handle was fabricated and connected to a primary pulley mounted on the crank shaft. A secondary pulley was fixed onto the blade shaft. Both pulleys were connected using a durable rubber belt, forming a belt drive system. The pulley sizes were carefully selected to optimize the speed ratio, thereby reducing user effort while ensuring efficient blade rotation.

Once the power transmission system was established, safety features were incorporated. A protective guard was fabricated and installed around the blade chamber to prevent accidental contact during operation. Additionally, a hand pusher was constructed and provided to help the user feed vegetables into the chute safely without coming into contact with the rotating blade. Finally, a collection tray was fabricated from stainless steel and positioned directly beneath the blade to capture sliced vegetables. The tray helped in minimizing waste and ensured easy retrieval of the output. All components were then assembled, aligned, and tested to ensure that the machine operated smoothly and safely. The result was a manually operated vegetable slicing machine that was efficient, hygienic, and safe for domestic or small-scale commercial use.

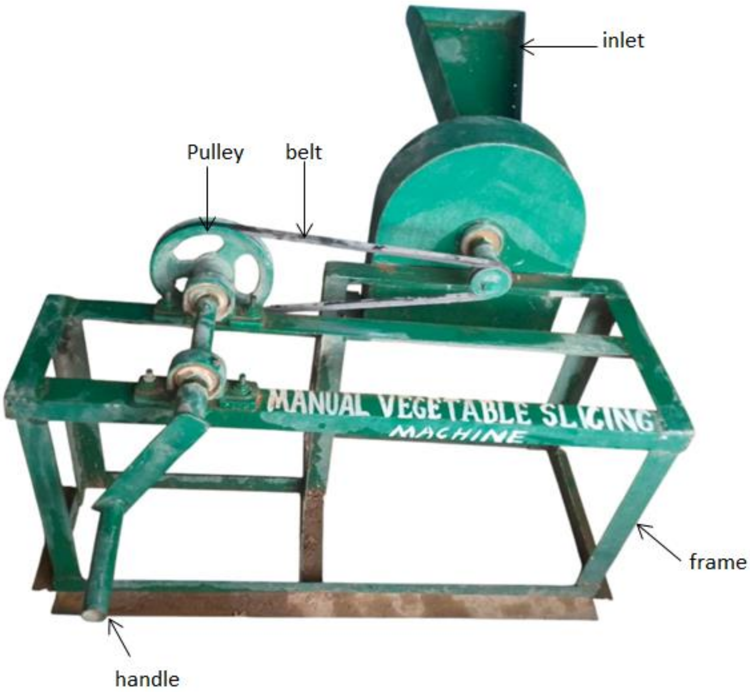

Figure 1: Manually Operated Vegetable Slicing Machine After Construction

3.1. Experiment Test Procedure

The manually operated vegetable slicing machine was subjected to a controlled test to evaluate its performance with three commonly sliced vegetables: cucumber, carrot, and onion. The test involved measuring:

- The average time taken to slice each vegetable completely.
- The average number of slices produced.
- The average slice thickness obtained.

Each vegetable type was tested in three independent trials. The vegetables were inserted into the top chute and pushed with the hand pusher while the crank mechanism was manually rotated at a consistent speed. Slices were collected in the tray and measured manually using a digital vernier caliper. The test result is shown in the Table 1.

Vegetable	Average Time to Slice (s)	Average Number of Slices	Average Slice Thickness (mm)
Cucumber	30	25	4
Carrot	45	30	3
Onion	35	28	4

Table 1: Test Results

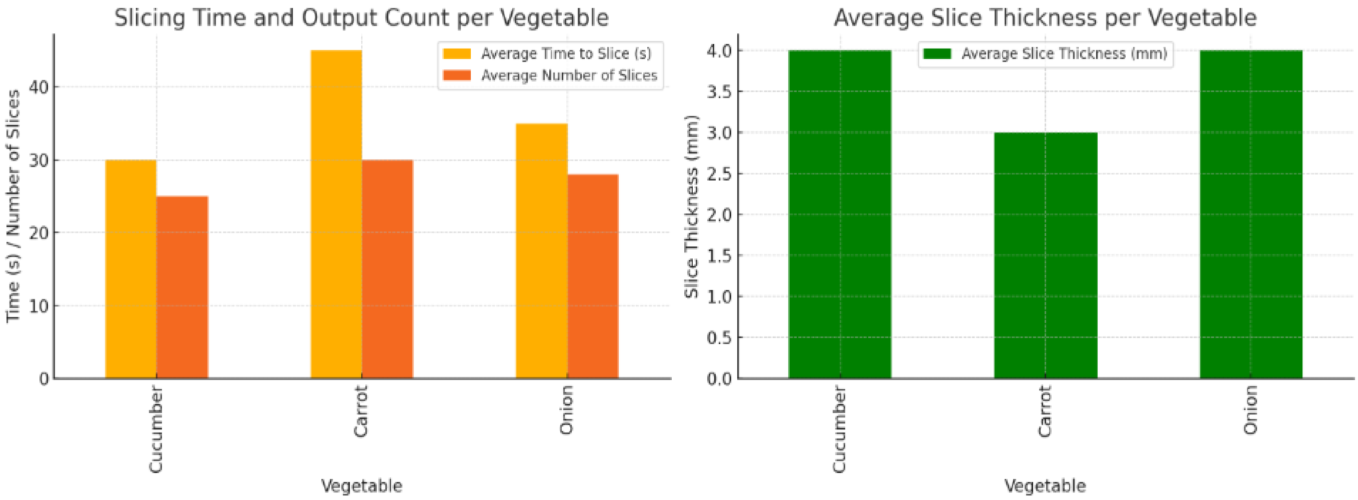

Figure 2: The Graph of the Experimental Test

4. Discussion of Results

The experimental test results of the manually operated vegetable slicing machine revealed promising performance in terms of slicing efficiency, consistency, and user effort. Among the three tested vegetables cucumber, carrot, and onion distinct differences were observed due to variations in hardness, diameter, and internal structure.

4.1. Cucumber

Cucumbers were the easiest to slice, requiring the least amount of time (30 seconds) and yielding 25 slices on average. Their soft and watery texture facilitated smooth cutting with minimal resistance on the crank handle. The blade's sharpness, combined with the optimized pulley ratio, ensured effective slicing with reduced physical strain. The average slice thickness of 4 mm was consistent and within acceptable culinary standards for salads and garnishes. Cucumber's tubular shape and uniform diameter made it ideal for the slicing chamber, which also contributed to the high level of consistency observed.

4.2. Carrot

Carrots posed the highest resistance during the slicing test, taking 45 seconds on average to complete. This was attributed to their denser and harder structure. Despite the increased resistance, the slicing machine performed well, producing an average of 30 slices per carrot, albeit slightly thinner at 3 mm. The thinner slices were likely due to the increased pressure required to pass the carrot through the blade, causing more material to be removed per crank rotation. This observation demonstrates the blade's strength and edge retention even under higher mechanical loads. However, the extra effort needed during operation suggests that further improvements in leverage or handle ergonomics could enhance user comfort during extended use.

4.3. Onion

Onions, being moderately soft but having layered internal structure, required an average of 35 seconds for complete slicing. A total of 28 slices per onion were obtained, with a slice thickness of 4 mm. The unique layered structure of onions contributed to slight variations in slice edge integrity, although overall slice uniformity remained acceptable. The smooth blade rotation ensured minimal disruption to the onion's concentric structure. This indicates the machine's ability to handle vegetables with irregular internal characteristics while maintaining slicing quality.

4.4. Performance Analysis

The performance analysis of the slicing machine shows that the belt and pulley transmission system maintained a consistent blade speed across different materials. The safety features, including the guard and hand pusher, were effective in protecting the user without interfering with the operational workflow. Slice collection in the tray was efficient, with minimal waste or misdirected pieces. From a design perspective, the machine's slicing consistency across different vegetables shows that the chosen pulley ratio, blade diameter, and crank arm length were well optimized. The material selection, particularly the use of stainless steel for the blade and feeding chute, contributed to the overall hygiene and corrosion resistance required for food processing applications. In conclusion, while the slicing time increased with vegetable hardness, the machine demonstrated reliable and safe operation. Minor design enhancements, such as improved grip on the crank handle or reinforced frame stability during heavy-duty slicing, could further elevate its usability [36].

5. Conclusion

The experimental testing of the manually operated vegetable slicing machine demonstrated its capability to perform uniform, efficient, and hygienic slicing of various vegetables, including cucumbers, carrots, and onions. The machine showed consistent performance, with average slicing times ranging from 30 to 45 seconds and producing slice thicknesses between 3 mm and 4 mm. The pulley and belt drive mechanism effectively transmitted manual power to the slicing blade with minimal physical strain on the operator. Stainless steel components ensured hygienic operation and durability. Although slicing harder vegetables like carrots required more effort, the machine-maintained performance without compromising slice quality or user safety. Safety guards and a hand pusher provided reliable protection during operation. The integrated collection tray ensured neat accumulation of sliced output, minimizing waste. Based on these results, the machine is suitable for domestic and small-scale commercial applications, particularly where electric power is unavailable. Future improvements may include ergonomic enhancements for ease of use during extended operation. Overall, the machine meets its design objectives in terms of mechanical performance, food safety, and user convenience.

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