Jurnal Kejuruteraan 36(4) 2024: 1643–1656
https://doi.org/10.17576/jkukm-2024-36(4)-28

Performance Analysis on the Safety and Automation System of a Modified Cutting Machine: Repurposing Initiatives

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Received 18 December 2023, Received in revised form 28 April 2024
Accepted 28 May 2024, Available online 30 July 2024

ABSTRACT

A circular economy is an alternative to the traditional linear economy. The concept reduces waste by recovering resources at the end of a product's life cycle and repurposing them to reduce environmental impact. The repurposing of machines is a model of production and consumption that involves re-pairing, refurbishing, and recycling to reduce waste. This project aims to improvise and repurpose existing mangosteen peeling machines into another suitable manufacturing process. The designed potato-cutting machine uses the existing conveyor system of a customised mangosteen peeling machine. The cutting mechanism incorporates safety and automation systems using through-beam infrared and capacitive proximity sensors. For the safety system, detecting objects within a range of 2.0 cm to the conveyor region indicates that the machine is unsafe to operate. The system will stop the machine and send audio and visual warnings to notify the users. Based on the trial runs the machine cuts the potato with approximately 1-tenth of the time needed in manual labour. The most significant benefit, however, is the overall savings in production costs, which are more than 85%. This is achieved as the machine re-purposes more than 50% of the components from the existing mangosteen peeling machine, such as sensors, control panel boxes, and PLC system. Consequently, this has helped minimise the overall cost of new equipment while encouraging a circular economy approach to engineering practices.

Keywords: Circular economy; sensor; safety system; automation system; cutting mechanism

INTRODUCTION

Repurposing is one of the circular economy guides when a product is used for a purpose other than the one for which it was designed. This research aims to modify the existing mangosteen peeling machine to be reused, repaired or repurposed. These are the principles of the circular economy, a notion championed by the European Parliament (European Commission, 2020). The circular economy is a manufacturing and consumption paradigm that emphasises sharing, leasing, reusing, repairing, refurbishing, and recycling existing materials and products for as long as possible (Pozo Arcos et al. 2018). The goal is to escape the linear model that has dominated society since the Industrial Revolution (Macarthur n.d.). Therefore, the circular economy is significant because it aims to reduce waste by recovering resources at the end of the product's life cycle and channelling them into production, dramatically lowering environmental impact. Thus, the circular economy offers a more sustainable model of production and consumption, in which raw materials are retained in production cycles longer and can be reused multiple times, associated with significantly less waste.

This research focuses on redesigning the cutting mechanism and the machine's safety and automation system using suitable sensors. Figure 1 shows the original condition of the machine that was repurposed at the end-of-life cycle. Several pieces of equipment or part of the original product were repurposed for use similar to the original purpose. The main goal of this research was to create a prototype potato-cutting machine for the small-medium food industry. The machine should be able to lower the manual labour needed in food preparation, increase handling capacity, and enhance safety features to prevent user accidents.

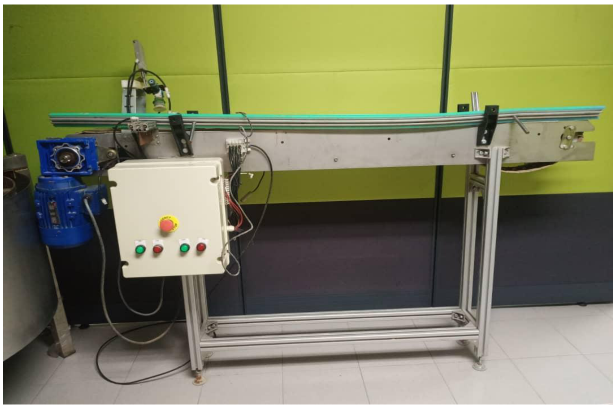


FIGURE 1. The condition of the machine before improvement

AUTOMATED CUTTING PROCESS

Slicing fruits or vegetables for canning, shredding sweet potatoes for drying, slicing onion, chopping, grinding grain for livestock feed, and milling flour are examples of size reduction operations. Reducing the size of raw food materials is an important way to achieve a definite size range. The process is time-consuming and physically demanding. For example, a study on the plantain slicing process showed that a semi-automated slicer by Obeng (Obeng 2005) took 5 to 7 seconds to slice an average-sized plantain pulp into chips of 2-3 mm thickness, while a motorised machine by Obayopo et al. (Obayopo et al. 2014) were able to slice 30 plantain pulps in 267 seconds to 5±0.5 mm thickness with an average efficiency of 93%. On the other hand, Ojariafe and Inegbedion (Ojariafe & Inegbedion 2023) have successfully fabricated a plantain slicing machine capable of slicing at an average of 5 seconds with a 1.5 safety factor. These are examples of plantain slicing innovation presented in (Olutomilola 2021), which discusses the advantages and disadvantages of different machines and slicing processes.

It is important that the size reduction machine can be developed together with other added qualities, such as increased efficiencies and throughput capacities while maintaining handler safety. Given the circular economy, the application of the Industrial Revolution 4.0 (IR4.0) utilising the Internet of Things (IoT) has been recognised as a vital enabler of the circular economy approach (Voulgaridis et al. 2022). IoT is one of the most revolutionary technologies in current wireless communications, where the software, sensors, and technology involved purposely connect data over the internet (Falkenreck & Wagner 2017; Gnoni et al. 2020; Tao et al. 2021).

Therefore, this project focuses on designing a potato-cutting machine with safety and automation systems incorporated. A through-beam infrared sensor was used to sense the appearance of obstacles, such as body parts, to ensure that employee safety is guaranteed, and a capacitive proximity sensor was used to detect non-metallic materials (Mgbemena et al. 2022; Oladapo et al. 2016), which serve as the potato placement tags, that initiate the cutting process automatically upon detection. This was programmed using a programmable logic controller (PLC) as the central controller. The PLC is commonly used in manufacturing to organise various complex tasks, including security monitoring, energy management, and computer and automated production line control (Sheng-Jen Hsieh et al. 2003). This project uses the PLC controller to power machinery and control manufacturing processes such as the cutting process, automation process, and control speed of the conveyor.

REPURPOSE INITIATIVE: POTATO CUTTING MACHINE

Mangosteen flesh and skins are used primarily as an antioxidant and antibacterial agent in pharmaceutical products (Watanabe et al. 2018). The integrated mangosteen cutting machine was originally designed to split the mangosteen peel and seeds without damaging the seeds. The cutting system involved three (3) pneumatic cylinders in a conveyor system. The two pneumatic cylinders with a pressure of 1.0 MPa were installed on the left and right sides of the conveyor. Both pneumatic cylinders are equipped with a set of cutters. Another pneumatic cylinder of 0.7 MPa, equipped with a suction cup, is installed above the conveyor. A suction cup holds the mangosteen while the cutting process is being run. The pneumatic cylinders on both the right and left sides moved simultaneously toward the middle of the conveyor to cut the mangosteen skin. The mangosteen is then transferred to another machine to separate the mangosteen skin and its flesh. The original cutting mechanism is shown in Figure 2.

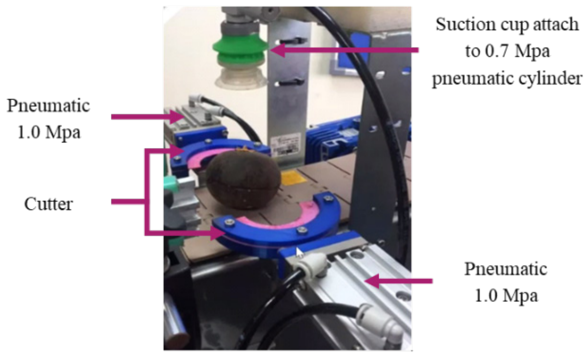


FIGURE 2. The mangosteen cutting machine

The mangosteen peeling machine was then repurposed for a new product: potatoes. At the end of the cutting process, the potatoes are formed into a long rectangular form. The cutting process was maintained at the same location as the previous machine, with several pieces of equipment being reused in the new machine. In this study, a new jig was designed to complement the new purpose of the machine, which is a potato-cutting machine, complete with the safety and automation system installed.

METHODOLOGY

Machine development can be separated into several stages, from concept generation to the testing phase, with the design process flow shown in Figure 3. In the early design stages, brainstorming, idea sketching, and idea analysis were all part of the process. Solidwork® 2018 was utilised to analyse the positioning and time gap that needs to be maintained throughout the assembly. After the final design stage was completed, material selection and details for the cutter, such as the blades' size and the cutter's frame, were determined. After completing the fabrication and installation phase, the machine was tested regarding workability and efficiency. Figure 4 shows the assembly in Solidwork® with the components labelled accordingly.

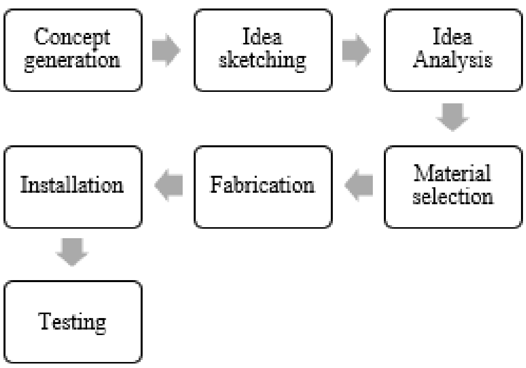


FIGURE 3. Design process flow

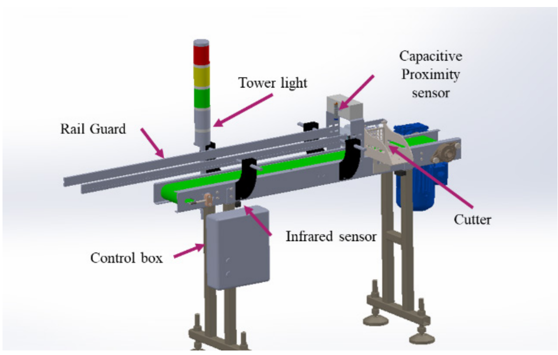


FIGURE 4. Detail drawing of the machine

REPURPOSED MACHINE DESIGN AND DEVELOPMENT

The main components of the machine labelled in Figure 4 are the infrared and capacitive proximity sensors, cutter, control box, tower light, and rail guard. Table 1 describes each labelled machine component.

TABLE 1. Description of machine component

No	Components	Description
1	Blade/Cutter	A 0.5 mm thick rectangular-shaped cutter was made from stainless steel. It was mounted on the conveyor system parallel to the jig.
2	Control Box	The control box contains the PLC control system, which is used as the central controller to control the movement of the conveyor system.
3	Tower Light	The tower light provides a system to alert others when the machine is in use or to warn users of proximity caution.
4	Capacitive proximity sensor	The capacitive proximity sensor is placed in a holder attached to the conveyor chassis. It is placed at the centre to easily detect the marked position on the conveyor used to start the potato-cutting process
5	Through-beam infrared Sensor	A through-beam infrared sensor is placed on the conveyor machine close to the operator's position. The light emitter is housed in one sensor, while the receiver is housed in another. Therefore, each sensor is placed in line but opposite one another on the conveyor stand. During operation, if someone comes near the conveyor, the conveyor will stop immediately for safety reasons.
6	Rail guard	To ensure potatoes stay on the conveyor during transport.

CUTTER

For the cutting mechanism (Figure 5), a rectangular cutter blade was mounted on the conveyor system, and a jig was mounted on a pneumatic cylinder parallel to the cutter blade 15 mm away. A locking mechanism was used to install the cutter and the jig to avoid slippage while enabling easier attachment and removal operations. This would also enable the cutter and jig to be removed from the machine for washing after usage.

The design concept of the jigs is based on their function in the cutting mechanism. It focuses on locating and guiding cutting tools to enable the material-cutting process. The cutter was in static condition on one side of the conveyor. The jig design must not obstruct the cutter blade during the cutting process. Apart from that, the loading and unloading of the material should be optimised to shorten the process time. The jig must be easy to operate to increase process efficiency. The concept of jig design was taken from a conventional hand-pressing potato-cutting mechanism.

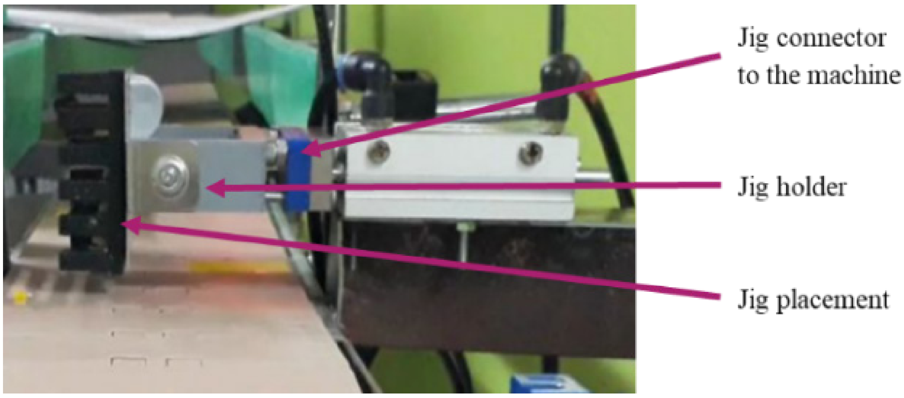


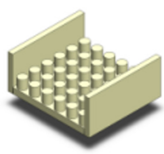
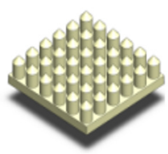
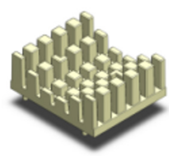
FIGURE 5. The cutting mechanism

An 8 mm rectangular cutter made of high-quality stainless steel was chosen. If a larger cutter is used, more force will be needed to push the potatoes effectively. The desirable texture of the potatoes is one that is firm and low in moisture. The support for the cutting mechanism was made of mild steel. The earlier cutter/system employed was a two-way cutter to remove the mangosteen skin. The cutter was already damaged (refer to Table 5). The cutter was replaced with a one-way rectangular cutter with a stainless-steel blade.

JIG

The final concept for the jig was selected using the Pugh analysis method. This method selects the optimal design based on the design criteria outlined. Previous researchers also used the Pugh analysis method to choose the best jig design (Awang et al. 2014; Norasikin Hussin et al. 2018). The design criteria were chosen based on the handling of material during loading and unloading, the element of the jig that supports and holds the material during operation, and the safety and lightweight design features. This is detailed in Table 2. According to the Pugh Chart in Table 2, the chosen design was Design 3. The overall jig dimension is shown in Figure 6.

TABLE 2. The Pugh Chart for the jig design

Design criteria	Weightage	Design 1	Design 2	Design 3
				
Ease of unloading material	3	+	-	+
Safe	2	+	-	+
Locate element	3	-	+	+
Holding element	3	+	+	+
Supporting element	3	+	-	+
Simple design	2	+	+	-
Easy disposal of residue	3	+	+	+
Light in weight	1	+	+	+
	TOTAL	14	4	15
	RANK	2	3	1

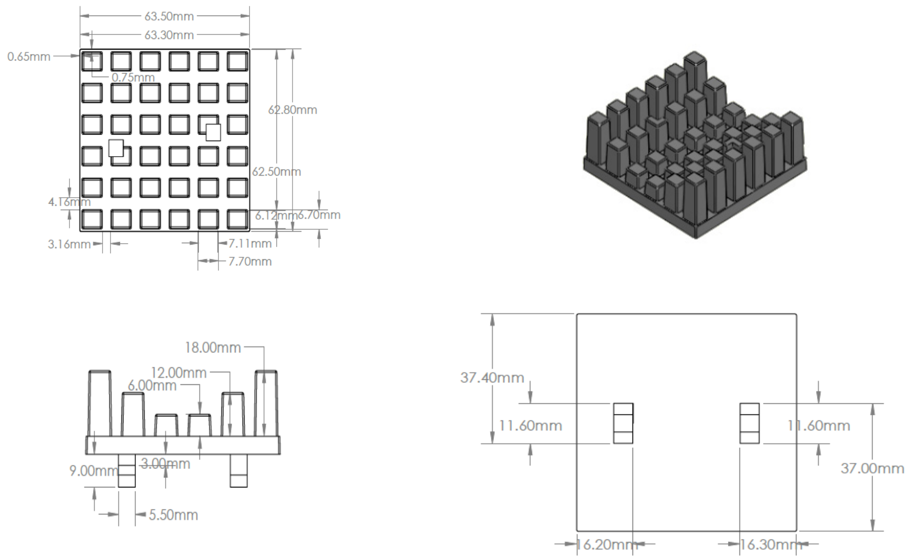


FIGURE 6. Overview of jig design dimension

FINITE ELEMENT ANALYSIS (FEA)

The Computer-Aided Design software used in this study was SolidWork. The FEA was also performed to simulate the jig's capability to handle the load applied during the cutting operation. The main parameters of this analysis are the material, force acting on the jig, and fixed support of the jig. The material used was polyethylene terephthalate glycol (PETG), a thermoplastic material with the advantages of easy printing, food-grade material, and strong characteristics. The material properties of the PETG used are tabulated in Table 3.

TABLE 3. Material properties of PETG (Huysamen et al. 2020)

Property	Value	Unit
Elastic Modulus	2200	MPa
Poisson's Ratio	0.33	N/A
Shear Modulus	470	MPa
Mass Density	1290	Kg/m^3
Tensile Strength	53	MPa
Compressive Strength	55	MPa
Yield Strength	47.9	MPa

The material's properties were used to calculate the component of Von Misses stress, displacement, and factor of safety (FOS) under a load of 176.58 N acted downward, which was simulated to the jig. This load was chosen from an average load required to manually cut an average-size potato, as reported in an experimental study by Zin A.F.M et al. (Zin et al. 2021). The meshing size used for the FEA analysis was 2 mm.

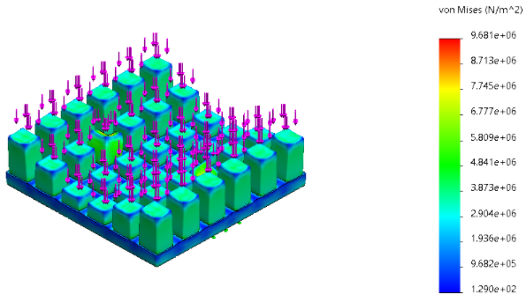


FIGURE 7. Von Mises stress analysis

The 47.9 x 10^6 N/m^2 is an allowable stress indicator, which will deform if the stress value exceeds this value. Therefore, if the Von Misses stress value does not exceed the allowable stress value, yielding will not occur. In this FEA analysis, the maximum Von Mises stress value is 9.681 x 10^6 N/m^2 (Figure 7). This shows that the result is less than the maximum allowable stress. Therefore, no yielding will occur to the jig under the applied load. However, the jig will still undergo elastic deformation throughout the cutting process, so the structure will become slightly distorted once the load is applied. However, as soon as the load is released, the base plate will return to its original shape.

The safety factor calculated for this jig is 4.9. The design is considered safe since the calculated safety factor is greater than one. This safety factor was calculated using maximum Von Misses stress as the criterion. The safety factor calculation performed in the study utilising Equation 1 (Sagot et al. 2003):

$$\text{Safety Factor} = \frac{\sigma_{LImit\ (compressive\ strenght)}}{\sigma_{Von\ Misess\ Stress}} \quad (1)$$

$$\text{Safety Factor} = \frac{47.9\ x\ 10^6}{9.681\ x\ 10^6} = 4.95$$

JIG ASSEMBLY

The jig holder placement and previous jig connector were used to enable the adoption of the integrated cutting machine. The jig placement is where the jig was held when the cutting process was executed. This component eases jig installation as it does not need to be unscrewed to remove the jig from the system. Next, the jig placement is a place that locks the jig to the system. The jig holder connects the jig placement to the old jig connector at the machine. This is shown in Figure 5.

SAFETY MECHANISM

Efforts have been made to study the important safety features to be equipped for the machine before designing the safety mechanism. A standard practice by every machinery industry uses the risk assessment tool, namely the Hazard Identification, Risk Assessment and Risk Control (HIRARC), to evaluate the potential threats to which the user is exposed to the machine (Ahmad et al. 2016; Yen Siong et al. 2018). The analysis shows that activities at the conveyor and cutting sections contributed to the highest level of risk compared to the risk imposed by other sections, such as the compressor or the electrical box. Conveyor presents several risks, including loud noise, rotating parts, vibration, and the risk of trapped clothing or human body parts (Giraud et al. 2004; Kecojevic et al. 2008). Meanwhile, the cutting section exposed the worker to a sharp cutting tool while conducting the job. Thus, this assessment concluded that a safety system must be developed to protect the worker from the potential risk at the conveyor and cutting section while designing the new machine.

Figure 8 shows the flowchart for the safety system, which utilises proximity sensors to upgrade the safety system in the existing machines. This sensor works when it detects the presence of a human body part or obstacles inside the safety region after pressing the push button ON. When the sensor detects a foreign object, the conveyor will stop, the yellow tower light will illuminate, and a buzzer will alert by issuing an alert. Even if the user presses the ON button, the conveyor will only move once the object is no longer detected. Furthermore, the machine is also equipped with an EMERGENCY push button, which can be used during emergencies.

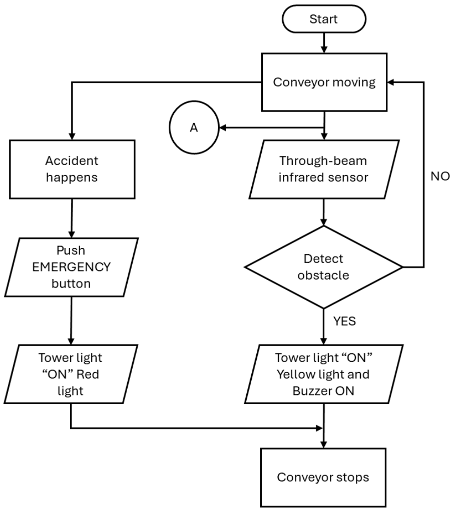


FIGURE 8. Flowchart of the safety system

AUTOMATION MECHANISM

Figure 9 demonstrates a flowchart of the automation system for the cutting process. The automated system for the cutting process uses a capacity proximity sensor to detect the marked position. When the ON push button is pressed, the green tower light will illuminate, and the conveyor will move and bring the potatoes arranged on the conveyor to the cutting area. The sensor will then detect the marked position, and the program will stop the conveyor and push the pneumatic cylinder, which is a jig, to press the potatoes to the cutter. The system will continue until the user presses the OFF button to stop the conveyor, and the system will end.

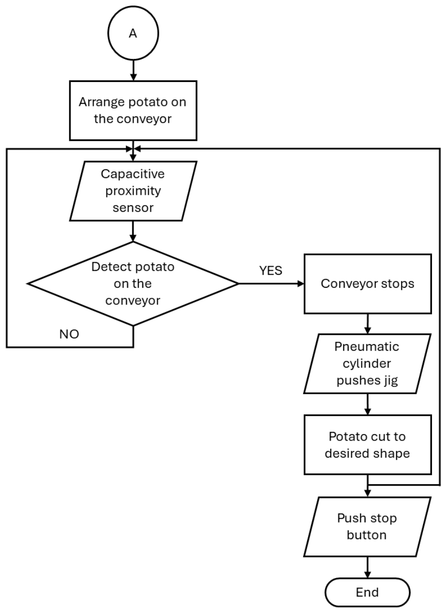


FIGURE 9. Flowchart of automation system for the cutting process

PLC LADDER LANGUAGE

To operate the overall system in this project, a PLC Ladder diagram serves as the language used. Programming and monitoring in this language are straightforward. The automatic mode is for measurement systems designed to operate by the flow of the process. When the proximity sensor located at the top of the conveyor detects the presence of the potatoes, the program will begin, and the operator's main responsibility will be to monitor the cutting process. The flowchart in Figure 10 illustrates the system's process in the Ladder language used to develop the software for PLC.

The electrical system schematic diagram, which demonstrates the input and output circuits, was built using AutoCAD Electrical software. Figure 11 shows the power wiring for the electrical design to be used in this project. This schematic diagram describes the power supply circuit connected to the inverter motor, relay, and OMRON PLC inside the control panel box.

Figure 12 is a schematic diagram for the input showing the sensor wire, which is PLC, connected to the OMRON system machine in the control panel box. This input wiring diagram was used to develop the system's circuit. Sensors and push buttons are inputs used to connect to the PLC. Furthermore, this schematic diagram also demonstrates the output wiring diagram for the electrical diagram. Actuators such as tower lights, motors, and buzzers were connected to the PLC. Next, the solenoid valves were connected to the output module of PLC, which is also located in the control panel box. Table 4 shows the input and output addresses of the wiring.

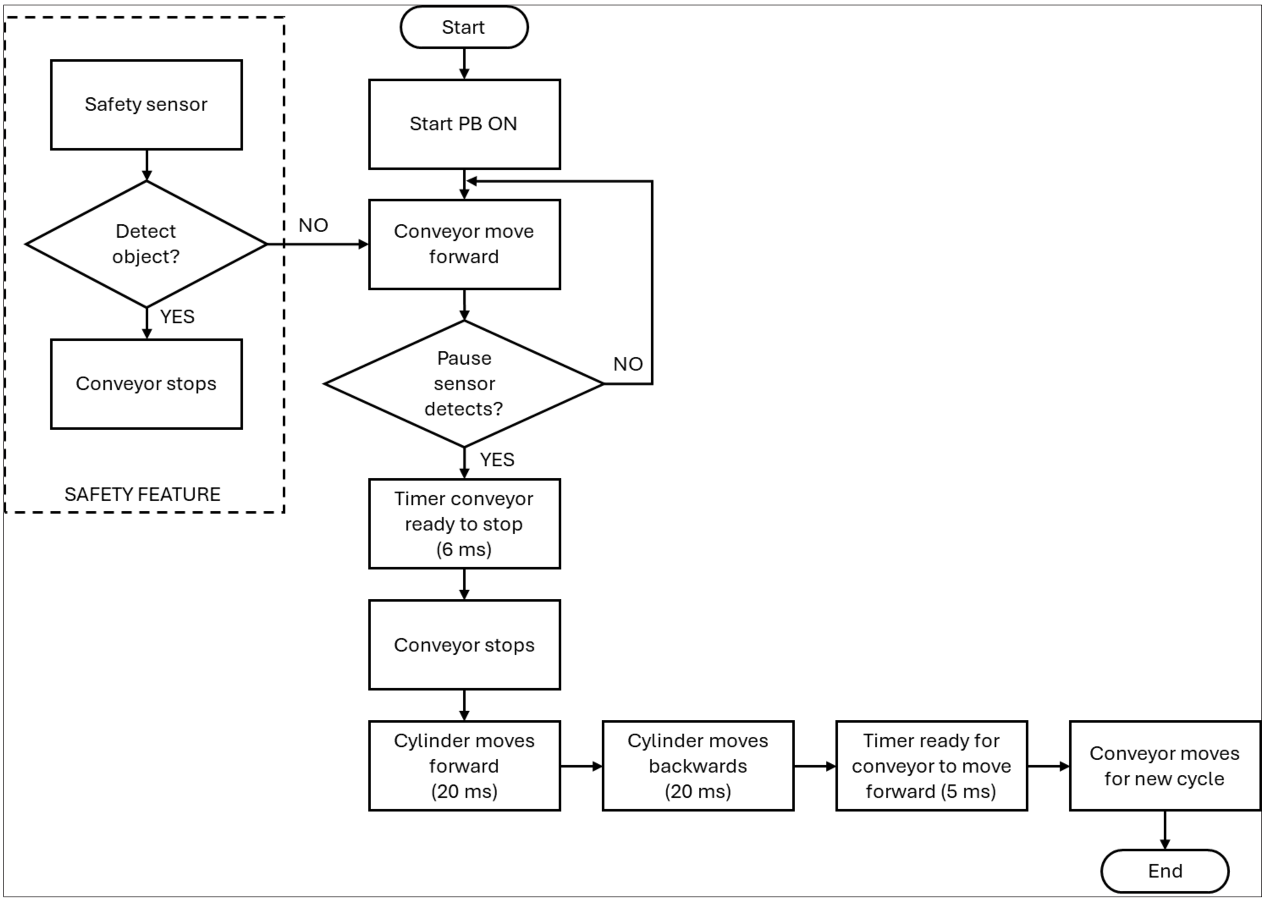


FIGURE 10. Flowchart for the process of the Ladder Language

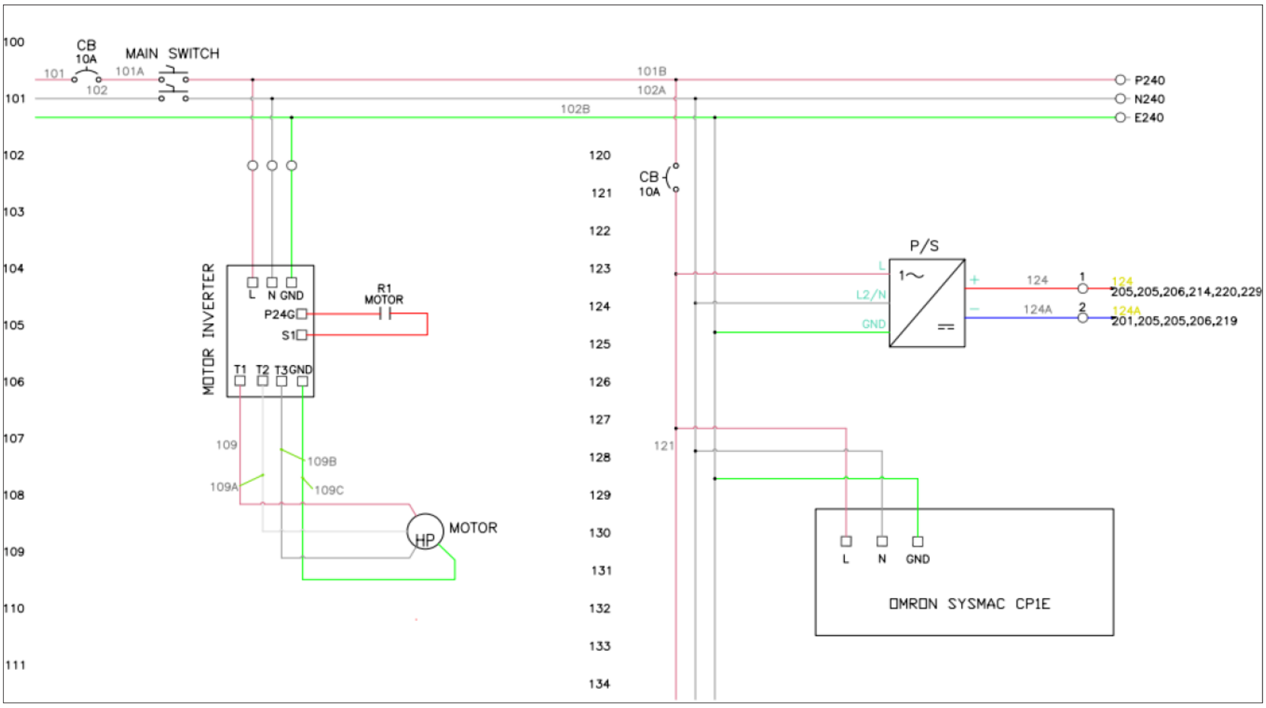


FIGURE 11. Schematic diagram for power wiring

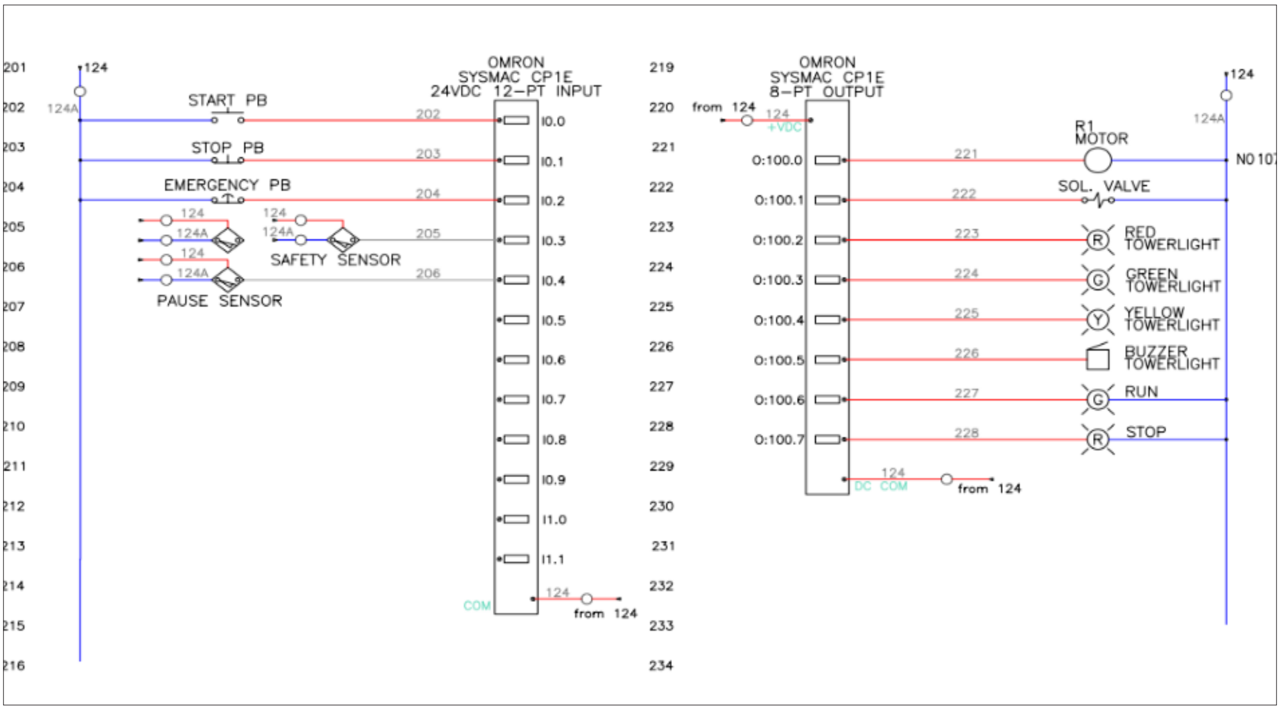


FIGURE 12. Schematic diagram for input and output wiring

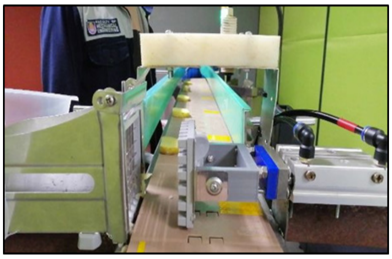
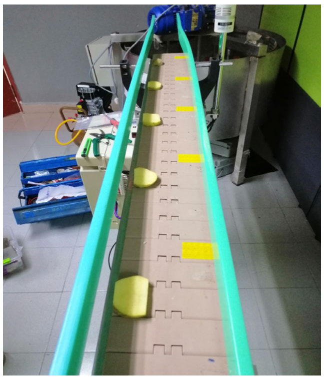
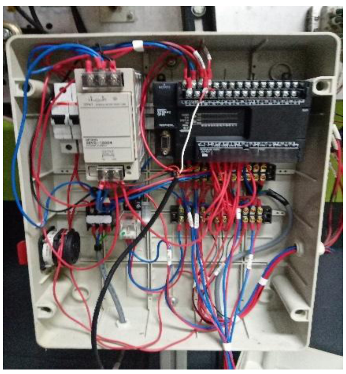
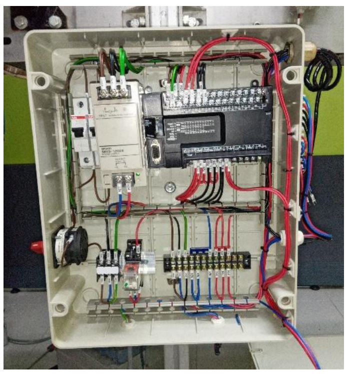
TABLE 4. Input and output address

Input address	Command	Output address	Command
I0.0	Start push button	O:100.0	Motor
I0.1	Stop push button	O:100.1	Solenoid valve
I0.2	Emergency push button	O:100.2	Tower light (Red)
I0.3	Through-beam infrared sensor	O:100.3	Tower light (Green)
I0.4	Capacitive proximity sensor	O:100.4	Tower light (Yellow)
		O:100.5	Tower light (Buzzer)

RECONSTRUCTION ACTIVITY

During the reconstruction activity, several components that were identified as suitable for usage were repurposed and reused to reduce the overall cost of the machine. This is detailed in Table 5, which also highlights the issues and changes made to the final machine.

TABLE 5. Machine problem identification and solution

Before	After
	
The cutter was broken and cannot be used.	A Stainless-steel cutter blade and jig were mounted to the previously positioned cutter.
	
The console guard was bent at the side conveyor.	The console guard was repaired and realigned to the conveyor.
	
Cluttered cables with most components' wires do not connect with wire connectors and are not properly labelled. Rearrange the cables and label each wire according to categories such as source, input (sensors), and output (tower light, inverter motor).	

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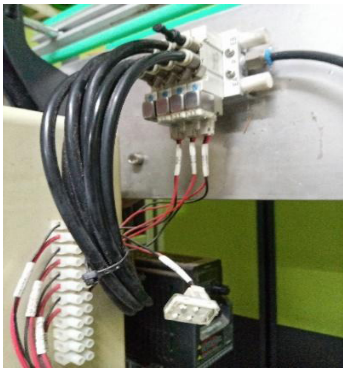
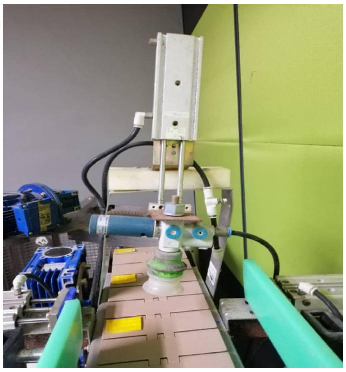
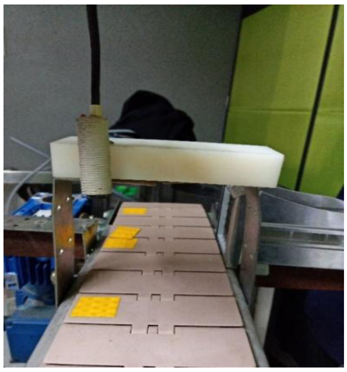
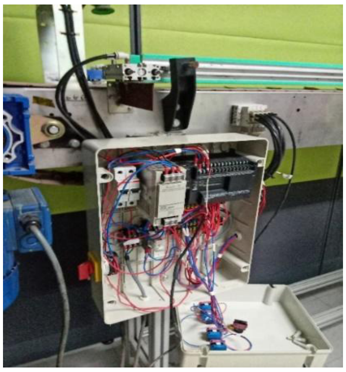
	
Initially, the machine used 4 pneumatic solenoid valves to control the pneumatic cylinder. A pneumatic cylinder is used to control the movement of the cutter and suction cup.	The pneumatic solenoid valve was reduced to 1 to move the jig. The remaining 3 pneumatic solenoid valves were closed with valve covers to prevent leakage of air pressure.
	
The suction cup handle is loosely mounted on the conveyor machine and does not work.	The suction cup was replaced with a proximity sensor and lowered to make it easier for the sensor to detect the marked position.
	
The control box was placed away from the user to control the machine system. This resulted in an unbalanced conveyor because both the control box and motor were positioned on the same side of the conveyor.	To facilitate controlling the machine system, the control box was moved to the other side of the conveyor and closer to the operator.

RECONSTRUCTION COST

Cost-effective machine development is a common goal in machine design. This ensures affordability among small business owners (Khan et al. 2023). For the reconstruction activity, over 50% of the existing components, such as sensors, control panel boxes, and PLC system machines, were reused from the existing machine to construct the potato cutting machine from a readily available mangosteen cutting machine. Table 6 details the components that were reused and bought for this project except for the rail guards and the conveyor. Both were crucial components but are not listed because the value is unknown. Therefore, this repurposing concept reduces manufacturing costs by more than 85%, which is RM4716.05 from the total cost of RM5442.71.

TABLE 6. Saving the cost of sensor system development

No	Components	Price per unit (RM)	Quantity	Reuse	Buy	Total Price
Cutting mechanism						
1	Cutter blade with tray	27.61	1		/	27.61
2	L-angle mild steel	1.40	2	/		2.80
3	Bolt & nut (M3x8mm)	8.00	8		/	8.00
4	Pneumatic cylinder	126.00	1	/		126.00
5	Pneumatic fitting connector	3.00	2		/	6.00
6	Pneumatic fitting stopper	2.00	6		/	12.00
Conveyor system						
7	Power Supply	1161.53	1	/		1161.53
8	MOSTAZ Air Compressor	319.00	1		/	319.00
9	Motor inverter	645.78	1	/		645.78
10	Relay	6.71	1	/		6.71
12	Infrared sensor	32.20	1		/	32.20
12	Indicator lamp	2.00	1	/		2.00
13	Omron PLC	2424.48	1	/		2424.48
14	Main circuit breaker	4.30	1	/		4.30
15	Push button	8.78	1	/		8.78
16	Emergency push button	39.00	1	/		39.00
17	Proximity sensor	227.25	1	/		227.25
18	Pneumatic air hose tubing 8 mm (1 m)	1.80	2	/		3.60
19	Control panel box	58.00	1	/		58.00
20	Tower light with buzzer	279.00	1		/	279.00
21	Marking tape (1 m)	9.00	1		/	9.00
22	Selector switch	19.90	1		/	19.90
23	Wire	0.80	5		/	4.00
24	Spiral cable wrap	1.80	2		/	3.60
25	Plastic block	5.82	1	/		5.82
26	C-clamp	1.50	1		/	1.50
27	Screw	4.85	1		/	4.85
Total cost reuse						4716.05
Total cost buy						726.66
Total cost						5442.71

SYSTEM TESTINGS AND FINDINGS

SAFETY SYSTEM

The sensor was placed to detect objects within 2 cm of the conveyor. These were regarded as safe areas. The sensor as a safety mechanism works fine as the machine stops, and a warning light will illuminate together with the sound of a buzzer whenever there is an object within the safe areas of the machine. The system was tested and proven to work seamlessly based on the 15 trial runs (Table 7). When the sensor detects an object within 2 cm from the conveyor stop right away, the average time for the sensor to detect and the conveyor to stop is less than 1 second. In addition, the average time taken for the buzzer to issue a warning to the user is also less than 2 seconds. Table 8 shows the average time for the sensor to detect, stop and alarm the user at distances of 1 cm and 2 cm.

AUTOMATION SYSTEM

Based on 15 trial runs, the sensor detects the marked position each time. Each time the sensor detects the marked position, the conveyor stops for the jig to push the potato, to be cut to the required shape. The average time taken for one complete cycle is 0.85 seconds (Table 9).

TABLE 7. Accuracy of safety sensor detection

No	Sensors detect the human body (Yes/No)	No	Sensors detect the human body (Yes/No)	No	Sensors detect the human body (Yes/No)
1	Yes	6	Yes	11	Yes
2	Yes	7	Yes	12	Yes
3	Yes	8	Yes	13	Yes
4	Yes	9	Yes	14	Yes
5	Yes	10	Yes	15	Yes

TABLE 8. Average time for distances 1 cm and 2 cm

1 cm			2 cm		
Time to detection (s)	Time to conveyor stop (s)	Time to buzzer sound (s)	Time to detection (s)	Time to conveyor stop (s)	Time to buzzer sound (s)
0.32	0.32	1.50	0.56	0.56	1.00
0.51	0.51	1.02	1.05	1.05	1.03
0.29	0.29	1.01	0.85	0.85	1.09
0.34	0.34	1.42	0.79	0.79	1.23
0.37	0.37	1.13	0.57	0.57	1.14
Average					
0.37	0.37	1.22	0.76	0.76	1.10

TABLE 9. Average time of automation for cutting system

No	Sensor detects potato (Yes/No)	Conveyors stop (Run/Stop)	Time to detect potato (s)	Time is taken for 1 cycle (s)
1	Yes	Stop	0.35	0.74
2	Yes	Stop	0.22	1.00
3	Yes	Stop	0.40	0.98
4	Yes	Stop	0.26	0.60
5	Yes	Stop	0.36	0.89
6	Yes	Stop	0.20	0.71
7	Yes	Stop	0.28	0.88
8	Yes	Stop	0.22	0.68
9	Yes	Stop	0.35	1.07
10	Yes	Stop	0.18	0.92
11	Yes	Stop	0.15	0.93
12	Yes	Stop	0.26	0.71
13	Yes	Stop	0.26	0.86
14	Yes	Stop	0.27	0.91
15	Yes	Stop	0.30	0.85
		Average	0.27	0.85

QUALITY AND EFFICIENCY OF MACHINE

The time needed to cut an already peeled and sliced potato with variable weight, length and thickness is less than 2 seconds. The output is consistent in size compared to the knife-cutting method. The potato must be peeled and cut to smaller dimensions because if it is too big, it cannot be pressed against the cutting tool efficiently.

The machine's effectiveness was evaluated by considering the characteristics of the potato slices. The potato slices were examined for damage to determine whether there were any broken or uneven slices. Based on the trial runs, less than 7% of potatoes were damaged during the process, with approximately 1-tenth of the time needed in manual labour.

CONCLUSION

The research project aims to modify and repurpose the existing mangosteen peeling machine to develop a potatoes-cutting machine that could be used in the small-medium food industry. The focus is on the cutting mechanism, safety system and automation system. The safety system uses a through-beam infrared sensor, which can detect the presence of objects within the safe operating region of the machine. This is to guarantee the safety of workers. On the other hand, the automation system uses a capacitive proximity sensor to detect the marked position on the conveyor to start the cutting operation. The operation is successful with each trial run. In addition, the repurposing concept applied in this project used more than 50% of the original component, saving more than 85% of the manufacturing cost.

The prototype model of the potato-cutting machine is designed and fabricated to reduce manpower and time. Based on the trial runs, less than 7% of potatoes were damaged during the process, with approximately 1-tenth of the time needed in manual labour. This potato-cutting technique will effectively reduce the preparation time for cutting.

Although the machine has shown a significant improvement compared to manual methods, several improvements can be imposed on the machine to increase machine efficiency, flexibility, and hygiene. The selection of material, especially in contact with the product, can be replaced with more suitable material with a specific grade. The cutting blade can be varied by making multiple shapes so that the potatoes can be of various types, sizes, and shapes. Using a higher-pressure pneumatic cylinder will also allow the cutting of thicker potatoes.

ACKNOWLEDGEMENT

The authors would like to thank the College of Engineering, Universiti Teknologi MARA for funding the publication.

DECLARATION OF COMPETING INTEREST

None

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