The Development and Evaluation of Onion Peeling Machine for SMEs Industry

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Abstract

An onion peeling machine has been designed, developed and evaluated according to SMEs food industry needs. Previously the onion peeling process was done manually and required a lot of time and manpower. Therefore, this project was developed to produce onion peeling machine that can peel onions in larger quantities. The machine is designed by using drum application with AC motor control system and microcontroller. The drum speed is controlled through the use of a variable frequency drive (VFD) at a maximum speed of 40 rpm. Meanwhile, the microcontroller is used to control the motor rotation at the specified time. The drum will rotate the onions in one direction at maintain speeds without damaging the onion structure. The evaluation process was conducted under three different drum rotational speeds (30, 35 and 40 rpm), three different peeling times (2, 3 and 4mins) and three different batch loads (2, 4 and 6kg). The evaluation shows to achieved the quality of onion peeled in 2 to 4kg, 2 to 4 minutes' rotation with an ideal speed of 30 rpm to 35 rpm are used. It saves up to 2 times from the traditional peeling method. The usage of minimal electricity, low maintenance and can be operated by only one employee is also an extra benefit to the industry. With the innovation of this onions peeler machine, it is expected to meet the demands of small and medium Enterprises (SME) industries in producing low cost machines with high productivity products.

Keywords: onion peeler machine, larger quantity, SME industries

1.0 Introduction

Onions are widely used in cooking and give a sense of intriguing aroma for all types of cuisines in Malaysia. The process of producing food using onions as a base ingredient should require peeled onions either manually or automatically. Onion peeling is an important step in producing many onions based products such as onion dehydration, onion powder, onion paste and onion slices. Onion processing involves different processes such as washing, peeling, slicing, chopping and others. These processes involve the use of large labor for mass production of products. One of the main problems in onion processing is in the process of peeling the onion skin in large quantities and eyes that are very depressing. From the previous work, it is clear that the process of peeling through the hands is very miserable and cost-effective (Luer et al. 2016). Hence, the main purpose of this study is to design, fabricate, evaluate efficiency and produce low cost machine. This machine will be used in small and medium production units, such as restaurants, hotels and food sectors. The need to develop new methods and tools for peeling can be mechanically and automated to produce current peeling methods, machines and versatile equipment. The peeling method falls into three main groups of mechanical, thermal and chemical peelers. Many research has been published with different peeling methods and various publications based on the techniques used (Emadi, 2010). The method commonly used in the modern vegetable processing industry is mechanical peeling. Mechanical peeler concept is designed to adjust the peeling of a specific products. The mechanical equipment involved includes drums, rollers, knives, and milling cutters. In general, the quantity of skin fragments is still high, but these peeled vegetables are still fresh and good quality (Emadi, 2010). According to Nazrul (2010), designed and manufactured on an onion peeler machine using a friction concept on the surface of onions and on it using water to help soften the onion surface before the peeling process is done. Meanwhile, the method and the use of the machine are based on the soft brush rotation attached to the shaft and fully controlled by a single phase AC motor. This machine is designed to meet the demands of small and medium industries in design, function, and price. Suter (2002) developed a peeling machine to control the efficient and effective peeling operation. It uses a rough set of rollers. The rollers come together in longitudinal directions and the distance between them can be adjusted. Feeder feed rollers are controlled based on the sensed load in the rollers by the relevant sensors.

According to Srivastava, VanEe, Ledebuhr, Welch & Wang (1997) designed and tested a medium-size onion peeling machine. The novelty of the machine was four scoring blades assisted by compressed air jets to slit the outer layers of the onion skin. Tests were made to determine peeling performance as affected by onion size, onion shape, compressed- air pressure, and onion feeding rate. The performance of the machine was characterized by peeling efficiency, peeling losses, and throughput rate. Feeding chain speed and air pressure significantly affected the machine's performance. The interactions of onion size with air pressure and onion shape with chain speed significantly affected all performance parameters. El-Ghobashy et al. (2014) designed, fabricated and tested onion peeling machine with the optimum peeling efficiency of 74.9%, 65.24%, 80.08% and 85.45% were obtained at 24kg batch load (0.36 ton/h). (Naik, Annamali & Ambrose, 2007) designed and tested a batch type multiplier onion peeling machine suitable for farm-level operation. Interaction studies were carried out between the speeds of rotation versus peeling efficiency. Damage percentage, unpeeled samples and operational parameters were optimized. The capacity of the peeler is 50-60kg/hr. The peeling efficiency was about 92% with unpeeled and damaged percentages of 6 and 2%, respectively. The cost of peeling was worked out to be $27 per tones.

2.0 Problem statement

The processing of onion for industrial or domestic use involves different operations where the onion skin peeling process is the main part to consider. Peeler efficiency affects the quality of the product produced primarily in relation to unwanted content. Peeling the onions manually is very distressing, time consuming and requires a lot of workers to peel in bulk. In hotels, hostel mess and restaurants high manpower is required for the peeling and cutting the onion and also it consumes more time (Ravichandran, 2019). Therefore, to solve these problems, a practical onion peeling machine is needed. It is difficult to design the onion peeling machine capable of decomposing all the onion skins efficiently without lowering the quality of the onion which has been peeled. This is the beginning of the process of designing a machine capable of peeling off large onions that have been cut. Therefore, the study effort is to design the onion peeling machine at low cost, easy to use and can produce onion in quantity that satisfies the needs of onion based product operators.

3.0 Methodology

3.1 Principle of operation

The methods used in this research involve design, develop, testing and evaluation process. All drawing parts are successfully being design and simulated in Solidworks Software version 2018 before proceed to the next stage. Figure 1 shows a block diagram of a planned onion peeling machine. Each part is designed to provide strength and stability to the system during operation to obtain efficient output. The machine is powered by an AC motor used for power and torque transmission from the main drive to the drum. The cut onions were inserted into the peeling drum through the opening of drum body. When rotating, there will be friction between the onion and the wall of the drum. The movement of the drum is controlled by the VFD at a time set by the controller. When the spinning time is over, the drum will stop and the peeled onions will fall into the waste collection drawer. The material of the body machine using stainless steel is a significant improvement in terms of access to the hygiene team and reduced maintenance time.

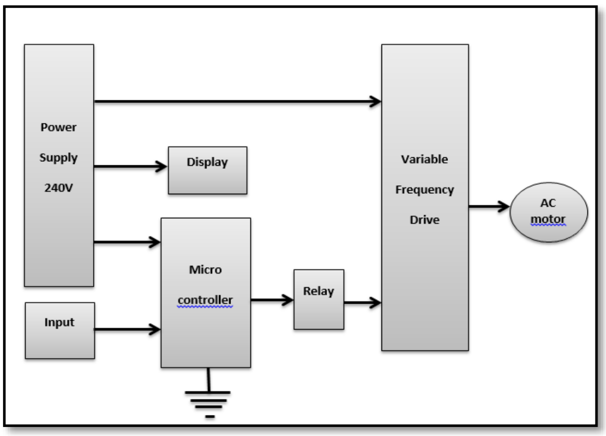


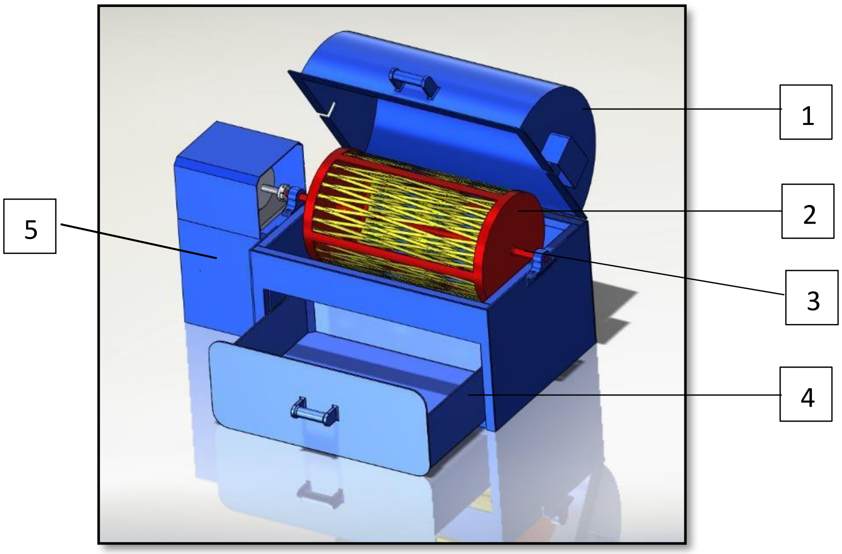
Figure 1: Block diagram of onion peeler machine

3.2 Materials used for experiments

The materials and tools used for this project include, the mechanical engineer drawing instrument, flat iron, sheet metal, aluminum stainless steel, single phase motor, drilling machine, grinding machine and milling machine were used during the construction of the machine.

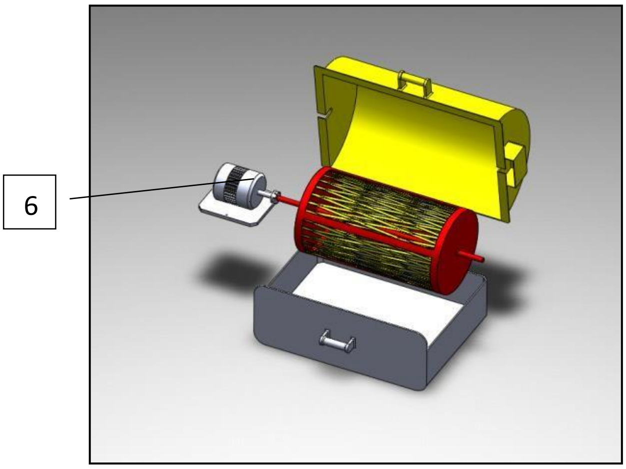
3.3 Description of the onion peeler machine

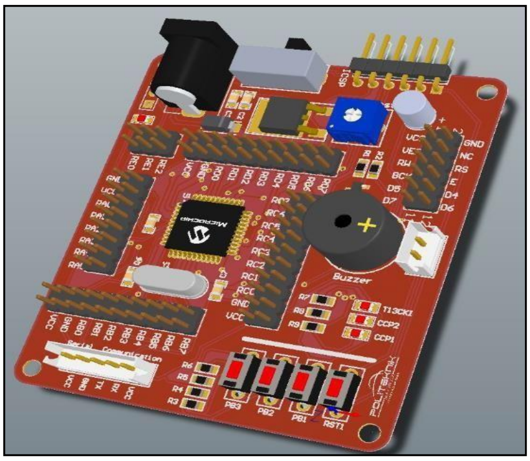
The onion peeler machine consists of four main parts, included: Main frame, drum, controller board, Waste collection drawer, and Power transmission.



No	Part name
1	Cover
2	Drum
3	Shaft
4	Drawer
5	Controller board
6	AC Motor

(a) Main parts of onion peeler





(b) Motor AC (c) Controller board

Figure 2: Drawing parts of onion peeler machine by Solidworks version 2018

3.4 Power transmission system

The Peeling drum is driven by a 0.8 KW, AC motor. The motor is directly connected to the vertical shaft and this vertical shaft transfers the rotary motion to peeling drum. Variable frequency drive

(VFD) was used to vary speed (rpm) of the AC motor.

3.5 Controller system

The microcontroller board were used to limit the time to rotate and stop the machine automatically.

3.6 Evaluation of the onion peeling machine

Machine peeling capacity, peeling efficiency and the percentage of removed peels were the main items of the peeling machine performance evaluation. These parameters were evaluated at different drum rotational speeds (30, 35 and 40 rpm), different peeling residence times (2, 3 and 4 min) and different batch loads (2, 4 and 6 kg).

3.7 Modifications for improvement of the onion peeling machine

After determining the most effective factors for the performance of the proposed machine as a result of the previous evaluation tests, the water pump and air compressor were used individually to improve the peeling efficiency. Pressurized air or water is used to blow the peel down to the drawer.

3.8 Economic evaluation

According to the report of Iowa State University (2015), farm machinery costs can be divided into two categories: annual ownership costs, which occur regardless of machine use, and operating costs, which vary directly with the amount of machine use. The cost of operation for the machine was worked out by calculating the fabrication, fixed and Variable costs. Estimation of annual and hourly operational costs of the power-driven onion peeler were based on capital cost of the peeler, cost of repairs and spare parts, labor cost, and depreciation.

3.9 Data analysis

All the data collected during the laboratory and field performance evaluations were analyzed using MS Excel version 2018. The excel software chosen because it is simple and more understandable. It provides almost all of the statistical analysis techniques and also simple to draw different types of graphs.

4.0 Results and discussions

4.1 Laboratory test results

After completion of fabrication, onion peeler machine is being switched to examine the effects of rotational time and onion load. The rpm speed testes at different speeds with the quantity and quality of the peeled onion. The onions physical properties were also tested in this study to optimize the design of machine tools for various sizes of onions. Performance indicators such as capacity, peeling efficiency and rotational speed are used to assess the achievement of the built in machine function. Table 1 shows the details of the physical properties of the onions used and the performance evaluation of the machine.

Table 1: Machine peeling efficiency (%) of tested onions

Drum speed(rpm)	Minutes of rotation	Batch load, kg and Quality peeled					
		2kg	Quality	4kg	Quality	6kg	Quality
30 rpm	2	73.13	Good	69.54	Good	68.84	Good
	3	77.22	Good	74.33	Good	72.56	Good
	4	80.52	Good	76.8	Good	74.95	Good
35 rpm	2	74.11	Good	71.25	Good	69.55	Good
	3	75.26	Good	73.55	Good	71.18	Good
	4	77.33	Good	75.31	Good	72.23	Moderate
40 rpm	2	75.21	Good	72.56	Good	70.22	Good
	3	78.76	Good	76.14	Good	74.21	Moderate
	4	81.26	Moderate	78.23	Moderate	75.42	Moderate

Remarks
Good: peeled more than 60% and high peeled onions quality Moderate: peeled more than 60% but less peeled onions quality

4.2 Effect of drum load and drum speed on peeling efficiency

A decrease in peeling efficiency was observed to increase in drum load. The peeling efficiency, reduced significantly from 73.13% to 68.84% as drum load increased from 2kg to 6kg at drum speed of 30 rpm for 2 min peeling duration Figure 3(a). Likewise, for drum speeds of 35 rpm and 40 rpm the efficiency, reduced from 74.11% to 69.55%, 75.21% to 70.22% respectively. The peeling efficiency, thus decreased with increase in drum load and increased with increase in drum speed at constant peeling duration of 2 min.

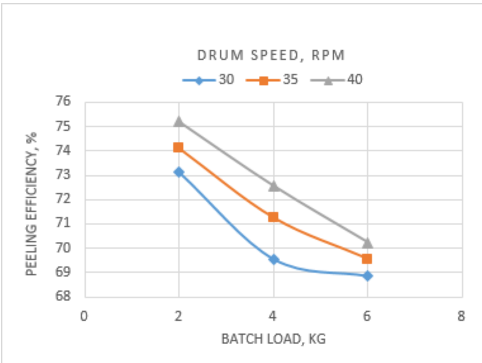


Figure 3(a): Effect of drum loads and drum speed on peeling efficiency of onion at constant peeling duration of 2 min

A decrease in peeling efficiency was observed to increase in drum load. The peeling efficiency reduced significantly from 77.22% to 72.56% as drum load increased from 2 kg to 6kg at a drum speed of 30 rpm for 3 min peeling duration Figure 3(b). Likewise, for drum speeds of 35 rpm and 40 rpm the peeling efficiency, reduced from 75.26% to 71.18%, 78.76% to 74.21% respectively. The peeling efficiency, thus decreased with increase in drum load and increased with increase in drum speed at constant peeling duration of 3 min.

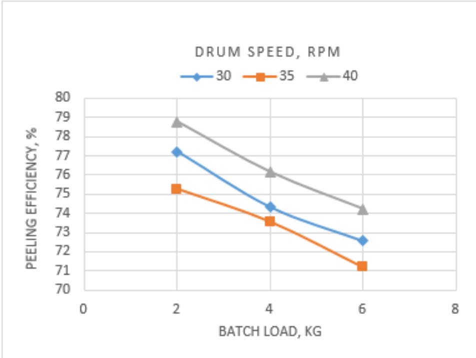


Figure 3(b): Effect of drum loads and drum speed on peeling efficiency of onion at constant peeling duration of 3 min

A decrease in peeling efficiency was observed to increase in drum load. The peeling efficiency, reduced significantly from 80.52% to 74.95% as drum load increased from 2 kg to 6 kg at drum speed of 30 rpm for 4 min peeling duration Figure 3(c). Likewise, for a drum speed of 35 rpm and 40 rpm the peeling efficiency, reduced from 77.33% to 72.23%, 81.26% to 75.42% respectively. The peeling efficiency, thus decreased with increase in drum load and increased with increase in drum speed at constant peeling duration of 4 min. According to (Ghanem, 2018) an imperial equation for peeling capacity as affected by rotational speed of drum.

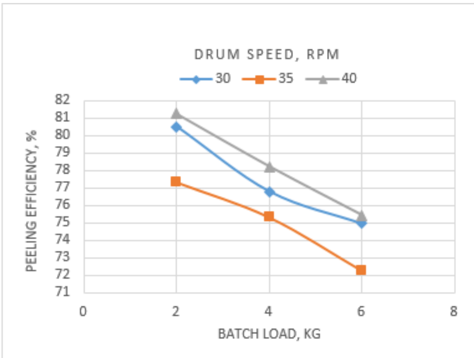


Figure 3(c): Effect of drum loads and drum speed on peeling efficiency of onion at Constant peeling duration of 4 min

4.3 Effect of drum load and peeling duration on peeling efficiency

As a drum load increased from 2kg to 6kg, for a peeling duration of 2 min at constant speed of 30 rpm, the peeling efficiency decreased from 73.13% to 68.84%, Figure 4(a). Similarly, for a given drum load of 2 kg to 6 kg for a peeling duration of 3 min and 4 min the peeling efficiency decreased from 77.22% to 72.56%, 80.52% to 74.95% respectively. But for a drum load of 4 kg, as a peeling duration increased from 2 min to 4 min the peeling efficiency increased from 69.54% to 76.85. The peeling efficiency thus decreased with increase in drum load and increased with increase in peeling duration at a constant drum speed of 30 rpm. The findings of this study are supported by (El-Ghobashy et al. 2014) which stated that the productivity of the onion peeling machine was mainly affected by the batch load and the peeling residence time.

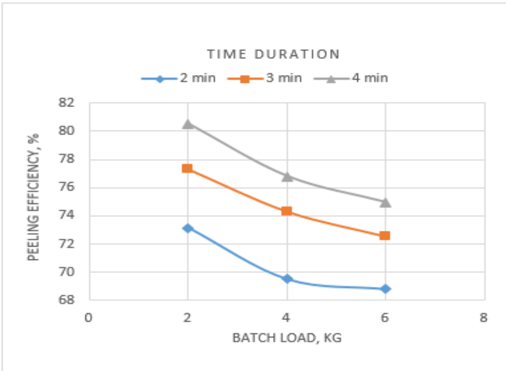


Figure 4(a): Effect of drum load and peeling duration on peeling efficiency of onion at constant drum speed of 30 rpm

As the drum load increased from 2 kg to 6 kg, for a peeling duration of 2 min at constant speed of 35 rpm, the peeling efficiency decreased from 74.11% to 69.55%, Figure 4(b). Similarly for a given drum load of 2 kg to 6 kg for a peeling duration of 3 min, 4 min and the peeling efficiency decreased from 75.26% to 71.18%, 77.33% to 72.23% respectively. But for a drum load of 4 kg, as the peeling duration increased from 2 min to 4 min the peeling efficiency increased from 71.25% to 75.31%. The peeling efficiency thus decreased with increase in drum load and increased with increase in peeling duration at a constant drum speed of 35 rpm.

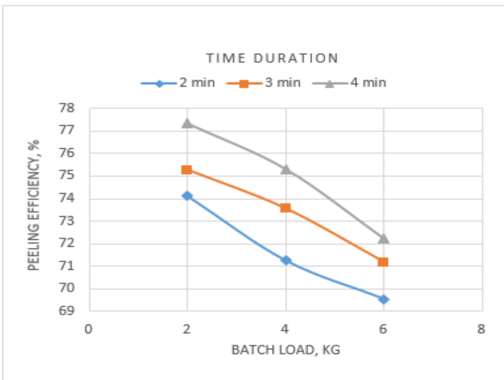


Figure 4(b): Effect of drum load and peeling duration on peeling efficiency of onion at constant drum speed of 35 rpm

As the drum load increased from 2 kg to 6 kg, for a peeling duration of 2 min at constant speed of 40 rpm, the peeling efficiency decrease from 75.21% to 70.22%, Figure 4(c). Similarly, for a given drum load of 2 kg to 6 kg for a peeling duration of 3 min and 4 min the peeling efficiency decreased from 78.76% to 74.21%, 81.26% to 75.42% respectively. But for a drum load of 4 kg, as the peeling duration increased from 2 min to 4 min the peeling efficiency increased from 72.56% to 78.23%. The peeling efficiency thus decreased with increase in drum load and increased with increase in peeling duration at a constant drum speed of 40 rpm.

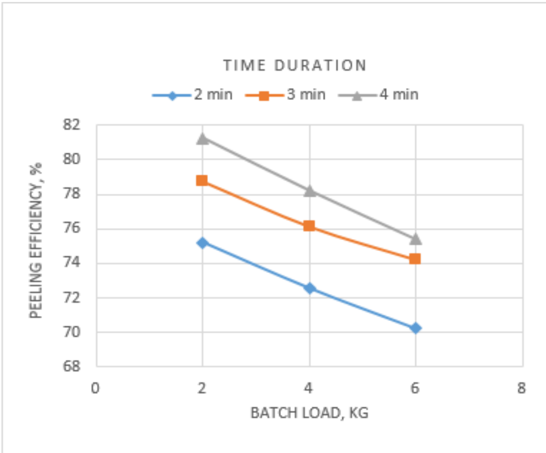


Figure 4(c): Effect of drum load and peeling duration on peeling efficiency of onion at constant drum speed of 40 rpm

4.4 Cost of onion peeling machine

4.4.1 Fixed cost

Fixed costs are costs that are independent of output. These remain constant throughout the relevant range and are usually considered sunk for the relevant range (not relevant to output decisions). Fixed costs often include rent, buildings, machinery, etc. A fixed cost is a cost that does not vary in the short term, irrespective of changes in production or sales levels, or other measures of activity. A fixed cost is a basic operating expense of a business that cannot be avoided, such as a rent payment. The concept is used in financial analysis to find the breakeven point of a business.

4.4.2 Variable cost

Variable costs are costs that vary with output. Generally variable costs increase at a constant rate relative to labor and capital. Variable costs may include wages, utilities, materials used in production, etc.

Assume 1 onion peeling machine Total onion load in a day
= 50kg Working hours in a day
= 3 h Working days in a month
= 24 day

Table 2: Total variable and fixed Cost of onion peeling machine

No	Item	1 Unit Cost	Unit/day	RM per month	RM per year
I	Variable costs				
1	Electricity	RM 2/day	1 unit/day	RM 48	RM576
2	Human Labour	RM15/person	1 person/day	RM 360	RM4320
3	Lubrication	-	-	RM 10	RM 50
4	Repair and maintenance	-	-	RM 10	RM 50
	Total variable cost			RM428	RM4996
II	Fixed costs				
1	Machine frame	-	-	RM13000	RM 13000
2	Peeling drum	-	-	RM 2500	RM 2500
3	shaft	-	-	RM 250	RM 250
4	AC motor	-	-	RM 500	RM 500
5	VFD	-	-	RM 260	RM 260
6	Microcontroller board	-	-	RM 400	RM 400
	Total Fixed cost			RM16910	RM16910

Total cost (year) = Total variable cost + Total fixed cost = RM21906

4.5 Cost of traditional method peeling

Assume
Total onion load in a day = 50kg
Total labor = 5 persons
Working hours in a day = 8 h
Working days in a month = 24 days

Table 3: Total cost of traditional peeling method

No	Item	1 Unit Cost	Unit/day	RM per month	RM per year
1	Human Labor	RM 25/person	5 person/day	RM 3000	RM36000
2	Tools manual peeler	-	-	RM 100	RM200
	Total cost			RM3100	RM36200

4.6 Project return on investment

The figure below shows the total cost for traditional peeling method and onion peeling machine. The results show onion peeler machine 2 times cheaper than traditional peeling method and get the benefit in duration for 1 year. Apart from low cost data it also shows onion peeler machine savings up to 39% over traditional peeling method. The important parameter of any product which determines its success rate is the cost of the device (Ravichandran, 2019).

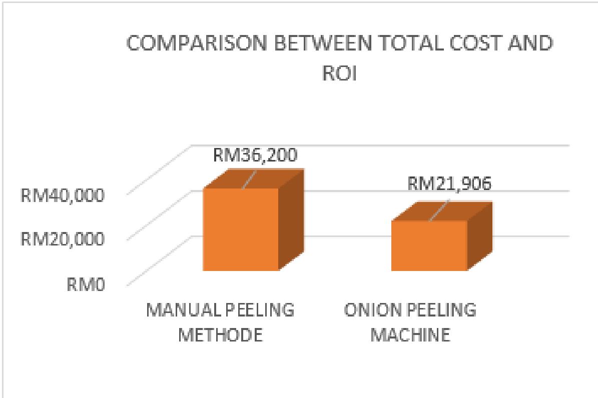


Figure 5: Total cost for manual peeling method and onion peeling machine

Return on Investment (ROI) = (Project financial gain – projects cost) / projects cost)
= (36200/21906) = 2 times

5.0 Conclusion

Experiments for peeling onions were carried out using drums at a capacity of 2 kg, 4kg and 6 kg, at three different speeds of 30 rpm, 35 rpm and 40 rpm and for three different time periods of 2 minutes, 3 minutes and 4 minutes. Each loads rotate three times at different speeds. The period for assessing the quality of the peeling is taken and compared with traditional hand methods. The weight of the onion is well fused without breaking the onion structure and weighed. The peel efficiency has been calculated using the percentage formula.

From the observations, it is found that a drum load of 2 kg to 4 kg, drum speed of 30 rpm to 35 rpm and time rotation of 2 minutes to 4 minutes shows the efficiency of peeling over 70% and producing excellent onion quality. For 6 kg drum load at drum speed 40 rpm and 2 minutes it is possible to peel the onion skin 70% up well. The peeling efficiency decreases with the increase in drum load and increases with the retention period of drum speed. The whole shows the ideal drum load, speed and time without harming the quality of onions is estimated at 2 kg to 6 kg on rotation estimated at 30 rpm to 35 rpm with estimated time between 2 to 4 minutes as more onions can be processed and in good condition.

The total cost of the peeler machine (variable and fixed cost) has been estimated to be RM21906. An economic analysis was calculated for peeling onion by comparing the machine cost with traditional hand peeling cost. Cost of operation per hour, cost of peeling per kg of onion, were estimated using standard procedures in order to determine the economic viability of the equipment. By this technic of onion peeling will effectively reduce the preparation time for onion (Ravichandran, 2019). This also includes Electricity hours of use per year (RM576), labor charges (RM 15/per person), Lubrication (RM50) and repair and maintenance charges (RM50 /per year). The machine also uses minimal electricity (0.01865KWH for 3 min rotation), easy to operate, continuous operation, low labor requirement, high quality output and the most important things is easy maintenance.

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