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Development and Fabrication of Pineapple Rolled Tart Machine

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ABSTRACT

A pineapple rolled tart machine is required in the manufacturing of pineapple rolled tart. In this research, a machine that would reduce processing time and operating cost and that would be affordable for small-scale industries was designed. The machine was tested at different screw rotating speeds and dough formulations. The rolled tart throughput rates were significantly increased ($p<0.05$) with screw rotating speeds and butter percentages of dough. However, it was significantly decreased ($p<0.01$) with sugar and corn flour percentages. The hardness of baked tart and the hardness and stickiness of unbaked tarts were not significantly different between various screw rotating speeds and manual method. It was found that the rolled tart produced by this machine was acceptable in texture and mouth feel. The maximum and minimum rates for the standard dough formula were 4320 and 720 pieces h^{-1}.

Key words: Pineapple rolled tart, texture, screw rotating speed, throughput rate, operating cost

INTRODUCTION

The pineapple tart is a well-known sweet pastry in Malaysia and is particularly popular during the festive seasons. Pineapple tarts are especially in demand during the Chinese New Year as pineapple signifies prosperity and luck for the Chinese (Nazlina, 2009). Pineapple tarts are small, bite-sized pastries filled with, rolled with or topped with pineapple jam and they are popular in Singapore, Malaysia, Indonesia and Brunei. The dough for making pineapple tarts consists of a large amount of butter, which gives it a rich, buttery, tender and melt-in-the-mouth texture (Siahaja, 2009).

Currently, the majority of pineapple tarts are produced manually and only an insignificant amount is machine-produced. The pineapple tart has great international commercial potential and can be machine-produced. Machine just can perform satisfactorily within a certain range of physical and rheological properties of the inputs (Matz, 1992). Currently, the productivity of pineapple tart is very low and unable to meet market demand because it is manually produced. The current traditional manual method of making pineapple rolled tart in Malaysia is troublesome. The end products are not always uniform in shape and size, the method is labour intensive, inefficient and time consuming. The tart-making process begins with sheeting the casing dough into the required thickness, continues with shaping the pineapple jam into the required cylindrical shape and putting it on the sheeted casing dough and finally rolling up the casing dough. The dough for making pineapple tarts is short dough, which is easily pulled apart, but coheres under tension (Wade, 1988). The most critical parts in making the pineapple rolled tart are the rolling and wrapping processes.

As the short dough is suitable for extruding but not for roller sheeting (Cheng, 1992), the extrusion concept was emphasized in this design. While there have been a number of designs proposed for filled bar cookies, no machine has yet been designed for the making of pineapple rolled tart. There are three types of extrusion: screw extrusion, roller extrusion and piston ram extrusion (Rauwendaal, 1998). The US 4465452 and 4456450 are food extruders which employ the concept of piston extrusion; US 4645064 and 7083321 are screw extruders; US 4251201, 4469475, 4748031 and 5449281 are machines which apply the concept of co-extrusion, while US 4190410 is a cookie-forming device which applies the concept of roller extrusion.

Benbow and Bridgwater (1993) state that co-extrusion is the process in which two or more extrusions occur concurrently at the opening of the nozzle horn, thus this process is suitable for making filled-products. The types of extruding force consist of screw compression, piston ram and roller compression. The roller extruder requires an automation system to govern the roller turning magnitude and timing, thus, making this method too costly for small scale industry. The piston ram is not suitable for extruding short dough because this type of dough is compact and lacks fluidity. Therefore, the screw co-extrusion method is considered most suitable for making the pineapple rolled tart. However, a fully automatic machine for making the pineapple rolled tart is still not available. Currently in Malaysia, the pineapple rolled tart industry uses the extruder method to produce the empty cylinder casing dough without the filler. The empty casing dough is subsequently filled manually, resulting in low productivity and higher labour intensity.

Textural analysis is important in relation to food quality. It involves assessing the mouth feel of a food. It consists of sensory analysis and instrumental method. Instrumental methods are preferable for investigating food texture rather than sensory analysis, as the conditions can be controlled. Furthermore, sensory analysis is time consuming and expensive, while the instrumental method is more economical and provides more consistent results (Meullenet *et al.*, 1997).

The objective of this research was to develop a machine for manufacturing pineapple rolled tarts that had a higher production rate, was less labour intensive and more economical than the manual method. The idea was to provide an inexpensive but promising machine for small scale industry.

MATERIALS AND METHODS

The development of the design process was started in year 2009 and completed in year 2010.

Design principles and theory: This machine was designed for making the pineapple rolled tart. It simplifies the time consuming and troublesome traditional handmade method into two steps, which are, feeding dough and jam into hoppers and cutting the rolled tart into the required length. The benefits are higher productivity and lower operating and labour cost compared with the traditional handmade method.

Design process: Ullman (2003) stated that the design process is initiated by the needs of the customer. Similar to the Pugh model, the design process started with market information and customer needs, continued with specification of product, concept design, detailed design, manufacture and sale. In this research, the systematic steps were carried out during the design process, which included understanding customer needs and problems, review of literature, patent

Table 1: Requirements, criteria and specifications of machine

Requirement	Criteria	Specification
Functional	Flow of materials	The flow is fast, 4000 tart pieces h^{-1}
Performance	Operational steps	2 steps
Human	Ease of controlling	1 step
Factors	Ease of operating	2 steps
Physical	Size and weight	100 cm length×60 cm width×80 cm height 100-120 kg of weight
Life-cycle	Maintainability	Materials and components are standard size
	Cleanability	And available in market
	Installability	Machine parts easy to disassemble and assemble for cleaning purpose
Resource	Capital cost	Below RM 4000

search, specification definition, creation of conceptual design and alternatives, design calculations, selection of conceptual design, part drawing and assembly drawing of machine, materials and dimension determination and finally, the creation of a refined drawing using Autodesk Inventor.

Specification: In this research, the target customers for this machine are small-scale cookie manufacturers who are unable to invest in expensive machines for manufacturing the cookies. After the customers have been identified, the next step is to determine the customers' requirements, as shown in Table 1. Determining customer requirements can be difficult because many customers are unable to state their requirements specifically (Salit *et al*., 2000). Ullman (2003) stated that the engineering specification is measurable and developed from customers' requirements.

Conceptual design: This invention, which relates to a machine for making pineapple rolled tarts, is a machine which can extrude dough and jam concurrently at the same point of the nozzle horn in a process referred to as co-extrusion. Ullman (2003) stated that the conceptual design is created based on the results of planning and specifications. Customers' requirements act as the basis for developing a functional model of the machine. Concepts must be detailed and refined to evaluate their manufacturability and functionality. A rough flow diagram, a proof-of-concept prototype, a set of calculation and textual notes, are all used to represent the concepts (Ullman, 2003). The generation of concepts is iterative with their evaluation.

Development of the machine's equipments and the operational research: Mazlina *et al*. (2010) stated that in developing the machine, two important methods need to be mentioned which are fabrication of the machine and operational research of the fabricated machine.

Fabricated machine: As shown in Fig. 1-6, the present invention is comprised of an assembly of the means to produce the pineapple rolled tart from casing dough and pineapple jam. The present invention has two hoppers as shown in Fig. 10, which are attached to two barrels as shown in Fig. 9. Figure 11 shows that there are two different dimensions of screws in this present invention, which are used to convey, compress and extrude dough and jam from the nozzle horns as shown in Fig. 7 and 8. These two nozzle horns are assembled with a connector tube as shown in Fig. 7.

Figure 1-3 show the schematic drawing of the screw co-extruder drawn using Autodesk Inventor software. Figure 4-6 show the front, side and top views of the actual fabricated screw co-extruder. The main components of this machine are the dough and jam barrels, screws, dies, hoppers, motors and gear boxes. The dimension of the machine is 850 mm (length)×470 mm(width)

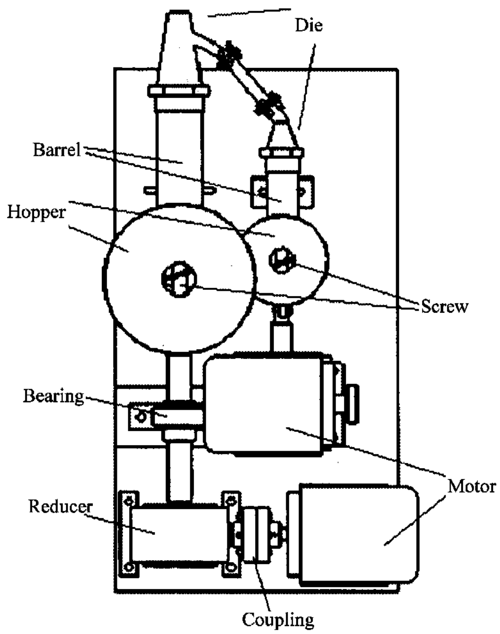

Fig. 1: Top view schematic drawing

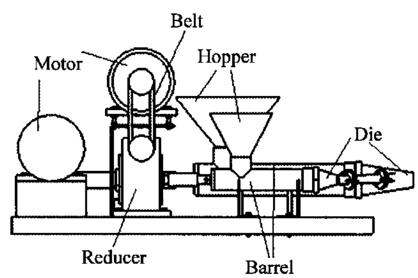

Fig. 2: Left side view of schematic drawing

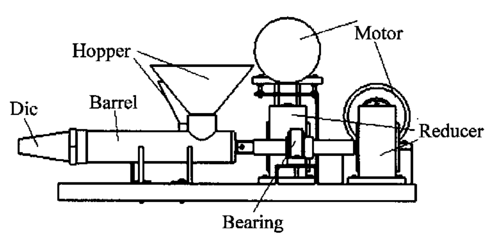

Fig. 3: Right side view of schematic drawing

×450 mm (height). The screw for conveying jam is driven by a 0.5 horsepower motor and the screw for conveying dough is driven by a 1 horsepower motor. When, the machine is operating, the jam and dough are loaded manually into the hoppers.

Nozzle horn (die): Figure 7 and 8 show the assembled dough and jam nozzle horns. Figure 8 shows the dough nozzle horn with insertion of a concentric tube. The outside diameter and inside

Fig. 4: Front view of fabricated machine

Fig. 5: Side view of fabricated machine

Fig. 6: Top view of fabricated machine

diameter of the tube are 2 cm and 1.6 cm, respectively. The tube is attached to the jam nozzle horn by six fasteners. For purposes of maintenance and cleanliness, the tube can be disassembled into separated parts. The inside diameter of the dough nozzle horn is 6.3 cm narrowing to 2.5 cm along

Fig. 7: Top view of nozzle horns

Fig. 8: Cross section view of dough's nozzle horn

the horn length of 12.5 cm. The thickness of the horn wall is 0.5 cm. The inside diameter of the jam nozzle horn is 4.3 cm narrowing to 2.2 cm along the horn length of 4.5 cm. The thickness of the horn wall is 0.25 cm.

The length and diameter of the dough nozzle horn are the most critical dimensions in this machine. If the nozzle horn length is too long, the extruding force will be insufficient and blockage of dough will occur. On the other hand, if the length is too short, the dough will not be completely compressed and it will easily break and separate into pieces. The diameter of the nozzle horn cannot be too small or high die pressure will be generated inside the nozzle horn. If die pressure is high inside the nozzle horn, high extruding force will be required to overcome the die pressure.

Barrels: Figure 9 shows the dough and jam barrels with their thrust bearing. The materials used to fabricate barrels are food grade stainless steel while thrust bearings are made from copper. The barrels are used to accommodate the screws as well as act as a channel for extrusion. These two barrels can be assembled and disassembled on a table by bolting. The thrust bearings act as alignments for the two screws and prevent the screws from moving forward or backward when turning at high speed. The outside and inside diameters of the dough barrels are 8.2 and 7.2 cm, respectively, with whole length of 33.5 cm. The outside and inside diameters of the jam barrels are 5.1 and 4.5 cm, respectively, with whole length of 23.6 cm. The length of thrust bearing is 4 cm.

Hoppers: Figure 10 shows the dough and jam hoppers, which are used to occupy the dough and jam before they enter the barrels. The two hoppers are made from food grade stainless steel. These

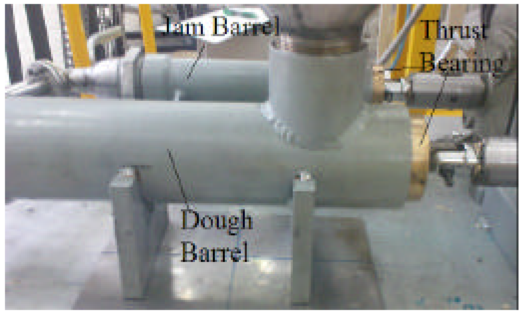

Fig. 9: Dough and jam's barrels

Fig. 10: Dough and jam's hoppers

Fig. 11: Dough and jam's screws

hoppers are fitted to their barrels by turning them in the direction of the screw thread. They are easily disassembled for cleaning purposes. These two hoppers are cone-shaped and the gradient enables dough and jam to easily flow downward into the barrels. The inside diameter of the dough hopper is 25 cm, narrowing to 5.4 cm along the length of 12 cm. The inside diameter of the jam hopper is 15 cm, reducing to 4.1 cm along a 10.5 cm length. The thickness of hopper wall is 0.1 cm.

Screws: Figure 11 shows the dough and jam screws, which are custom-made by fabricator because the minimum overall diameter of available existing ready made screws in the market is 7.5 cm. The screws are made from food grade stainless steel. The rotation of screws is used to convey the jam and dough inside the barrels and extrude them out from the nozzle horns. The screws are made from stainless steel rods and blades. For the dough screw, the diameter of the rod is 2.5 cm and the

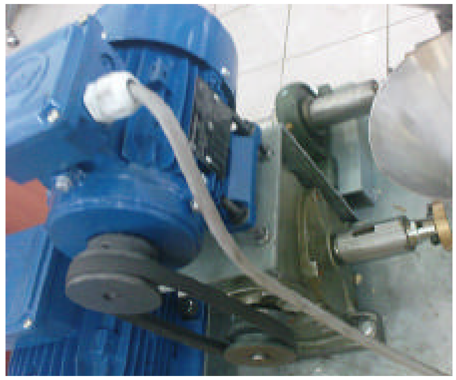

Fig. 12: Motor and gearbox for jam's screw

Fig. 13: Motor and gearbox for dough's screw

overall diameter is 5.2 cm, with a whole length of 37.5 cm. The pitch of the dough screw is 5.5 cm and that of the jam screw is 4 cm. The rod diameter of the jam screw is 1.8 cm and the overall diameter is 4 cm. The thickness of both screw blades is 0.4 cm. The screws are driven by motors and the screws are bolted to the driver by bolts and nuts. Therefore, the screws can be disassembled and taken out from the barrels for cleaning purpose.

Drive system: Figure 12-14 show motors, gearboxes and inverter which are used for driving the jam and dough screws. To reduce the dimension of the whole machine and minimize the distance between the two barrels, the motor for driving the jam screw is located above the gearbox. If the distance between these two barrels is too far, the extrusion force will be insufficient for pushing the jam from the jam barrel to the center of the dough barrel. For the jam screw, the motor used for driving the gearbox is assembled by a belt and pulley system. The diameters of the two pulleys are identical with a speed ratio equal to one, thus, there is no for speed reduction. The motor is hung above the gearbox by four pairs of long bolts and nuts. Hence, the height of the motor can be adjusted to tighten or slacken the belt. The belt can not be too tight to prevent damage to the screw

Fig. 14: Inverter

or nozzle horn when blockage occurs. On the other hand, the belt should not be too slack to avoid slippage of the belt when it is overloaded. The motor used for driving the dough screw is assembled to the gearbox by direct coupling. The brand of both gearboxes is Chenta Gear from Taiwan, with a speed ratio 1: 10.

The 0.5 horse power motor is used to drive the jam screw, while the one horse power motor is used to drive the dough screw. The speed of both motors is 1400 rpm. Therefore, the output speeds of the gearboxes are reduced to 140 rpm. Norton (2001) stated that the power of the motor is equal to the torque multiplied by the speed. If the speed is reduced, the torque is raised because the power is always constant. The screws used for conveying dough and jam require high torque but low speed to extrude the dough and jam from the nozzle horns.

$$P\ (\text{Watt}) = T\ (\text{Nm}) \times S\ (\text{sec}^{-1}) \qquad (1)$$

Where:
P = Power
T = Torque
S = Speed

The 1 horse power (745.7 Watt) motor is used to drive the dough screw. The torque of the dough screw is calculated by Eq. 1:

$$745.7\ \text{Watt} = T \times (2\pi \times 140\ \text{rpm}/60)$$
$$T = 50.864\ \text{Nm}$$

The 0.5 horse power (372.85 Watt) motor is used to drive the jam screw. The rpm is identical with that of the dough screw. Thus, the torque of the jam screw is half of that of the dough screw, which is 25.43 Nm. A higher torque is required to drive the dough screw because the casing dough is compact and it becomes harder when it is compressed. Therefore, a higher torque is required to avoid blocking of the dough inside the nozzle horn. In contrast, the jam is soft and a low torque is sufficient to extrude the jam from the nozzle horn.

Both electric motors used are three-phase Marellimotori motors from Italy. The inverter is used to manipulate the magnitude of the current electricity. Thus, both the motor speeds can be regulated to equalize the linear velocity of jam and dough. The input of the inverter is single-phase with 200 to 230 volt and current 50 to 60 Hertz, 9.2 Ampere, while the output is three-phased with 400 to 450 volt, 5 Ampere, 0- to 400 Hertz. The brand of the inverter is an LS Industrial System from Korea. The current electricity is manipulated from range 0 to 60 by the inverter. Therefore, the speed of the motor can be raised or reduced.

Tension force of belt: For the jam screw, the motor power is transmitted into the gearbox by a belt drive. The belt is a V-belt, with a unit weight, W_u of 2.25 N m^{-1}, wedge angle, **β** at 36°, coefficient of friction, μ at 0.3 and the allowable tensile force at 900 N. The driving and driven pulley diameters are identical at 6 cm with the speed ratio equal to one. The designed power is calculated by Eq. 2:

$$\begin{aligned} \text{Designed power: } P_d &= \text{Power of motor, } P\times 1.6 \\ P_d &= 372.85\text{ W}\times 1.6 \\ &= 596.56\text{ W} \end{aligned} \tag{2}$$

$$\begin{aligned} \text{Motor torque: } T_1 &= P/(2\ \times \text{rpm}/60) \\ &= 372.85\text{ W}/(2\ \times 1400/60) \\ &= 2.543\text{ Nm} \end{aligned} \tag{3}$$

$$\begin{aligned} \text{Belt peripheral speed: } V_1 &= \ \text{X dp}\times\text{rpm} \\ &= \text{X } 0.06\text{ m}\times(1400/60) \\ &= 4.398\text{ m sec}^{-1} \end{aligned} \tag{4}$$

where, d_p is the pulley diameter.

$$\begin{aligned} \text{Centrifugal force: } F_C &= (Wu/g)\times(V_1)^2 \\ &= (2.25\text{ N m}^{-1}/9.81\text{ m sec}^{-2})\times(4.398\text{ m sec}^{-2}) \\ &= 4.436\text{ N} \end{aligned} \tag{5}$$

where, g is the gravity acceleration.

$$\text{Belt pitch length: } L = 2C + \pi.(r_1 + r_2) + (1/C).(r_1\text{-}r_2)^2 \tag{6}$$

where, C is the center distance of the two pulleys, r_1 is the radius of the driving pulley and r_2 is the radius of the driven pulley. In this case, the two radiuses are identical.

$$\begin{aligned} L &= 2\times 16.5\text{ cm} + \pi\ (3\text{+}3\text{ cm}) + (1/16.5\text{ cm}).(0) \\ &= 51.85\text{ cm} \end{aligned}$$

$$\text{Contact angle: } \theta = (180°\text{-}2\alpha) \tag{7}$$

While:

$$\begin{aligned} \alpha &= \sin^{-1}[(r_2 - r_1)/C] \\ \alpha &= \sin^{-1}[(3\text{-}3\ \text{cm})/16.5\ \text{cm}] \\ \alpha &= \sin^{-1}(0) \\ &= 0 \end{aligned} \tag{8}$$

Thus, the contact angle is 180°.

In the belt tight side section, the tension force is calculated by Eq. 9 and 10:

$$F_1 = F_C + [Y/(Y-1)]\,(T_1/r_1) \tag{9}$$

While:

$$\begin{aligned} Y &= \exp^{\mu.\theta/\sin\beta} \\ &= \exp^{0.3(\pi)/\sin 18°} \\ &= 21.114 \end{aligned} \tag{10}$$

Thus:

$$\begin{aligned} F_1 &= 4.436\ \text{N} + [21.114/(21.114-1)]\,(2.543\ \text{Nm}/0.03\ \text{m}) \\ &= 93.42\ \text{N} \end{aligned}$$

In the belt slack side section, the tension force is calculated by Eq. 11:

$$\begin{aligned} F_2 &= [(F_1 - F_C)/e^{\mu.\theta/\sin\beta}] + F_C \\ &= [(93.42\ \text{N} - 4.436\ \text{N})/21.114] + 4.436\ \text{N} \\ &= 8.65\ \text{N} \end{aligned} \tag{11}$$

Therefore, the belt tension is safe since the maximum of the tension force, F_1 = 93.42 N is less than the allowable tensile force of 900 N.

Operational research: In this invention, the co-extrusion concept is applied in making pineapple rolled tarts. The dough and jam are extruded concurrently at the nozzle horns. The design concept of this invention is by screws conveying, compressing and extruding the dough and jam. The nozzle horn for extruding jam is extended into the concentric point of the nozzle horn for extruding dough by a stainless steel connector tube. Therefore, extrusion processes of dough and jam occur concurrently at the same point.

Firstly, the machine is switched on. Then, the dough and jam are put into the feeding unit. The feeding unit is comprised of two hoppers. These two hoppers are used to hold and occupy the dough and jam before they go down the extruding section in the barrels. The rotations of screws create a gradient pressure to suck the jam and dough down into the conveying and compressing section. The conveying and compressing section has two barrels, two screws and two thrust bearings. These screws push the dough and jam forward and compress the dough and jam inside the nozzle horns.

After that, the dough and jam are extruded in the extruding section. The extruding section has two nozzle horns, which are combined with a connector tube. The jam is compressed and extruded from the jam nozzle horn until the dough nozzle horn through the connector tube. The inside diameter of the connector tube is 15 mm. The opening point of the tube is where co-extrusion occurs. The opening dimensions of the two nozzle horns are 27 and 15 mm. As a result, the diameter of jam in the pineapple rolled tart is 15 mm and the whole diameter of the pineapple rolled tart is 27 mm with the casing dough thickness at 6 mm. The rolled tart is continuously extruded from the nozzle horn and cut into pieces at 25 mm length.

The properties of food are not constant with time. The consistency of dough and rheology of jam is always varied and therefore extrusion rates are not uniform with time. During the operation of the machine, the speeds of both screws are always regulated by manipulating the inverters to ensure that the linear velocities of jam and dough are identical. The equivalence of the dough and jam linear velocities is required to prevent the casing dough from breaking easily.

EXPERIMENTAL TESTING

Performance analysis: The performance characteristics of this machine were evaluated based on the throughput of the pineapple rolled tart, which is the linear flow rate of the tart in units of mm sec^{-1}. Semasaka *et al*. (2010) reported that the speed of the screws, formulations of feed material (moisture content), temperature of screw barrels and feeding speed are factors that affect the extrusion flow rate. In this section, the temperature and feeding rate were constant with time. Thus, Table 2 shows the speed of the screw and Table 3 shows the varied formulation of dough to investigate its effect on the extrusion flow rate.

Textural analysis: Textural analysis was evaluated based on hardness of baked rolled tart, hardness and stickiness of unbaked rolled tart with different methods of making the tart. The

Table 2: The inverter values and speeds

Inverter value	Speed of motor (rpm)	Speed of screw (rpm)
0	0.00	0.000
10	466.67	46.667
20	933.33	93.333
30	1400.00	140.000
40	1866.67	186.667
50	2333.33	233.333
60	2800.00	280.000

Table 3: Summary of dough formulas studied

Effect	Fixed quantity (g)	Studied percentages (%)
Butter	Wheat flour 200	
	Sugar 40	23, 26.6, 30, **35**, 38.5, 42, 45
	Corn flour 8	
Sugar	Wheat flour 200	
	Butter 135	0, 3, 5.5, 8, **10.5**, 15, 20
	Corn flour 8	
Corn flour	Wheat flour 200	
	Butter 135	0, **2.1**, 4, 6.25, 8, 11.8, 15
	Sugar 40	

Bold values correspond to the standard formula of the pineapple tart dough methods involved operating the machine at different rotation speeds of screw and the manual method. The comparisons were done between the tarts based on textural characteristics. This was important to investigate differences between tarts made manually and those made with the machine and the acceptance of the machine-manufactured tarts.

Operating cost estimation: The operating costs were calculated for tarts made manually, with the fabricated machine at highest and lowest rates, with the recommended fully-automatic machine. The operating costs were determined based on labour cost for the manual method and the labour and electricity costs for the machine method. The operating costs were determined based on one labour.

RESULTS AND DISCUSSION

Effect of dough formula and screw speed: Figure 15 shows the effect of different percentages of butter and speeds of screw on the throughput rates. The throughput rates of pineapple rolled tart increased significantly ($p<0.05$) with the speeds of screw for all butter percentages of dough. The throughput rates increased significantly ($p<0.05$) with the butter percentages for all speeds of screw. This result is in agreement with Harmann and Harper (1973), which reports that the flow rate increases with screw speed.

Drag flow is constant when the temperature and speed of screw are kept constant. The pressure flow and leakage flow are dependent on die pressure, which is inversely proportional to flow rate (Sokhey *et al*., 1997). Thus, the throughput rate increases with decreasing die pressure. Die pressure acts as a resistance to the flow. For the 280 rpm screw speed, the rate increased 48.15% when the butter percentage was increased from 30-45%. The moisture content of the dough for making pineapple rolled tart comes from the butter. Therefore, the moisture content of dough increases with increasing butter percentages. This result confirms the statement of Narpinder *et al*. (1998) which reported that the die pressure of extruder increases with decreasing moisture content. Hence, the rates increased with butter percentages as the die pressure was reduced with increasing butter percentages.

Figure 16 and 17 show the effects of sugar percentages, corn flour percentages and screw speeds on the throughput rates of the pineapple rolled tart. The throughput rates increased significantly ($p<0.01$) with screw speed for all sugar and corn flour percentages of dough. These results are also in agreement with Harmann and Harper (1973). The throughput rates decreased significantly ($p<0.05$) with the increase of sugar and corn flour percentages for all speeds of screw.

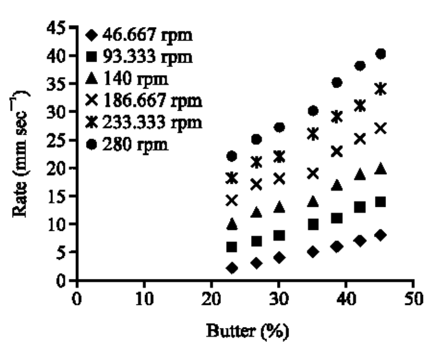

Fig. 15: Throughput vs. percentages of butter

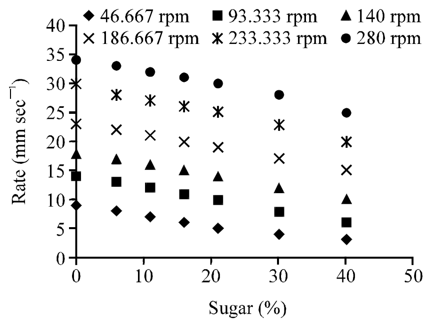

Fig. 16: Throughput vs. percentages of sugar

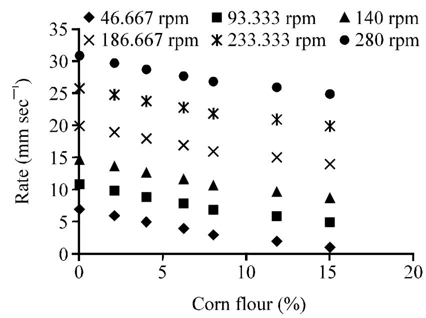

Fig. 17: Throughput vs. percentages of corn flour

When, the sugar and corn flour are increased in the dough formula, the moisture percentage of the dough is reduced. Hence, the die pressure increases with increase of sugar and corn flour percentages. As a result, the resistance flow at the die is increased resulting in possible reduction in throughput rates.

Production rate: The production rate was measured in terms of pieces of pineapple rolled tart produced h^{-1}. The length of the pineapple rolled tart was determined at 25 mm piece^{-1}. Thus, the production rate was calculated by Eq. 12:

$$\text{Production rate} = (\text{Throughput rate} \times 3600 \text{ sec})/25 \text{ mm} \qquad (12)$$

In the case of the effect of different formulations and speed of screw on the throughput rates in Fig. 15-17, the maximum and minimum production rates are 5760 and 288 pieces h^{-1}, respectively. For Fig. 15, the maximum and minimum production rates are 4896 and 432 pieces h^{-1}, respectively. For Fig. 16, the maximum and minimum of production rates are 4464 and 144 pieces h^{-1}, respectively. For the standard formula, the maximum and minimum rates are 4320 and 720 pieces h^{-1}. The production rate of handmade pineapple rolled tarts is defined at 300 pieces h^{-1}. Therefore, the production rate of the standard formula is equal to 14.4 times of the production rate of handmade pineapple rolled tarts.

Textural analysis: The results of hardness and stickiness of the unbaked tart are shown in Fig. 18 and 19. The results from Fig. 18 and 19 show no significant differences with different

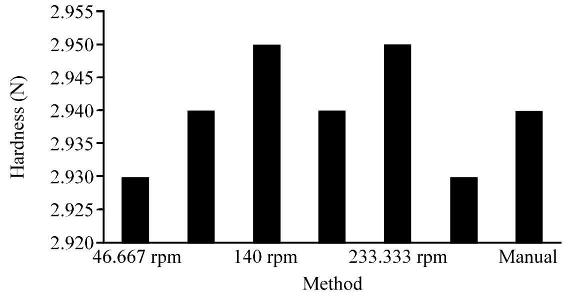

Fig. 18: Hardness of unbaked tart vs. methods of making tart

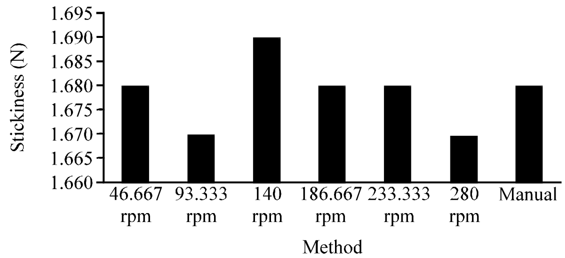

Fig. 19: Stickiness of unbaked tart vs. methods of making tart

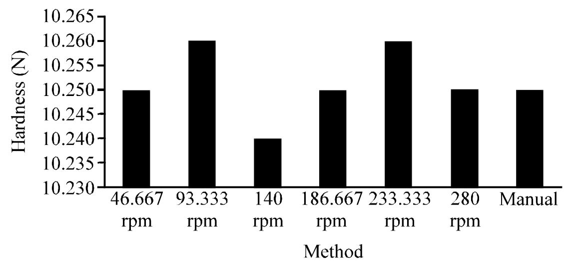

Fig. 20: Hardness of baked tart vs. methods of making tart

methods of making tarts. Therefore, the unbaked tart produced by this machine is no different from the original manual method in aspect of hardness and stickiness. Figure 20 shows hardness of baked tarts versus methods of making tarts. There is no significant difference in hardness of baked tarts with different methods of making tarts. Thus, there are no differences in mouth feel between tarts produced with the machine at different screw speeds and those made using the manual method.

Operating cost estimation: One of the objectives of this research is to design a machine that will allow pineapple rolled tarts to be made more economically in terms of operation cost compared to the manual method. The operating costs of the manual method, fabricated machine with the highest and lowest range of production rates and the recommended fully automatic machine, were determined. Table 4 shows the production rates of different pineapple rolled tart making methods. The manual operation of 300 pieces h^{-1} requires one person. On the other hand, the fabricated pineapple rolled tart machine requires two persons to operate the machine.

Table 4: Production rates of different methods

Method	Rate
Manual	300 piece h^{-1}
Machine (highest rate)	4320 piece h^{-1}
Machine (lowest rate)	720 piece h^{-1}
Fully automatic	6000 piece h^{-1}

Table 5: Production rates of different methods based on one labor

Method	Rate
Manual	300 piece h^{-1}
Machine (highest rate)	2160 piece h^{-1}
Machine (lowest rate)	360 piece h^{-1}
Fully Automatic	6000 piece h^{-1}

Table 6: Total operating cost/h/labor of three types of methods

Type of cost	Cost h^{-1}
Manual	
One labor	RM 4
Total cost/h//labor	RM 4/h/labor
Machine	
Electricity	
One hp Motor (0.75 kW)	0.75 kW×1 h×RM 0.218
	RM 0.1635
Half hp Motor (0.375 kW)	0.375 kW×1 h×RM 0.218
	RM 0.08175
Labor cost	
Two labors	RM 4×2 = RM 8
Total cost h^{-1}	RM 8.24525/h/two labor
Total cost/h/labor	RM 4.122625/h/one labor
Fully auto machine	
Electricity	
One hp motor (0.75 kW)	0.75 kW×1 h×RM 0.218
	RM 0.1635
Half hp motor (0.375 kW)×3	0.375 kW×1 h×RM 0.218×3
	RM 0.24525
1/4 hp motor (0.1875 kW)	0.1875kW×1 h×RM 0.218
	RM 0.040875
Labor cost	
One labors	RM 4
Total cost/h/labor	RM 4.45/h/labor

For comparison purposes, all production rates are based on one person as shown in Table 5. Table 6 shows the total cost/h/person of four types of pineapple rolled tart making methods. The highest and lowest of total operating costs/h/person are the fully automatic machine and the manual method, respectively. The operating cost h^{-1} per person of the fully automatic machine is highest because it comes with motors of one horse power, 3½ horse power and 1¼ horse power. However, the production rate of the fully automatic machine is the highest, thus, the operating cost of every piece of pineapple rolled tart produced is the lowest, followed by machine with the highest rate and machine with the lowest rate. Although, the operating cost/h/person is the lowest for the

Table 7: Total operating cost for pieces of pineapple rolled tart produced with different methods

Method piece	Manual	Machine (highest rate)	Machine (lowest rate)	Fully auto machine
1000	RM 13.3333	RM 1.9086	RM 11.4517	RM 0.7417
2000	RM 26.6667	RM 3.8172	RM 22.9035	RM 1.4833
5000	RM 66.6667	RM 9.5431	RM 57.2587	RM 3.7083
8000	RM 106.6667	RM 15.2690	RM 91.6139	RM 5.9333
10000	RM 133.3333	RM 19.0862	RM 114.5174	RM 7.4167
15000	RM 200.0000	RM 28.6293	RM 171.7760	RM 11.1250
20000	RM 266.6667	RM 38.1725	RM 229.0347	RM 14.8333
30000	RM 400.0000	RM 57.2587	RM 343.5521	RM 22.2500

manual method but its production rate is also the lowest, hence the operating cost of every piece of pineapple rolled tart produced is the highest as shown in Table 7.

An example from Table 7 shows that the number of tarts to be produced is 30,000. The operating cost for producing 30,000 using the manual method is RM400, but the operating costs of tarts from the machine with the highest rate and the fully automatic machine are RM57.26 and RM22.25, respectively. The operating costs of tarts using the machine with the highest rate and the fully automatic machine are reduced by 85.68 and 94.44%, respectively, compared with the operating cost using the manual method. This shows that the objective to obtain a more economical operation cost is achieved.

CONCLUSION

A pineapple rolled tart machine was designed and fabricated. The advantages of this machine are its simplicity of operation, ease of assembly and disassembly, maintenance, cleanliness and installation. It is also easy to control by manipulating the magnitude of the inverters. It involves simple steps to operate, is easy to fabricate and the low cost of the machine makes it an affordable option for small-scale industries. The flow of material of this machine is smooth and fast because the feeding of dough and jam into the hoppers is continuous. The production rate of this machine is 14.4 times that of the manual method. Moreover, the baked rolled tarts made with this machine are not different from hand-made tarts with respect to mouth feel. This machine reduces the operating cost of production and thus achieves the economical objective.

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REFERENCES

Benbow, J. and J. Bridgwater, 1993. Paste Flow and Extrusion. Oxford University Press Inc., New York.

Cheng, L.M., 1992. Food Machinery for the Production of Cereal Foods, Snack Foods and Confectionery. Ellis Horwood Ltd., England.

Harmann, D.V. and J.M. Harper, 1973. Effects of extruder geometry on torque and flow. Trans. ASAE, 16: 1175-1178.

Matz, S.A., 1992. Cookie and Cracker Technology. 3rd Edn., Van Nostrand Reinhold, New York.

Mazlina, M.K.S., A.R.N. Aliaa, H.N. Hidayati, M.S.I.S. Shima and W.H.W. Zuha, 2010. Design and development of an apparatus for grating and peeling fruits and vegetables. Am. J. Food Technol., 5: 385-393.

Meullenet, J.F.C., J.A. Carpenter, B.G. Lyon and C.E. Lyon, 1997. Bi-cyclical instrument for assessing texture profile parameters and its relationship to sensory evaluation of texture. J. Texture Stud., 28: 101-118.

Narpinder, S., A.C. Smith and N.D. Frame, 1998. Effect of process variables and monoglycerides on extrusion of maize grits using two sizes of extruder. J. Food Eng., 35: 91-109.

Nazlina, 2009. Pineapple tart tat nenas. http://www.pickles-and-spices.com/pineapple-tart.html.

Norton, R.L., 2001. Design of Machinery. 2nd Edn., McGraw-Hill, New York.

Rauwendaal, C., 1998. Understanding Extrusion. Verlag, Germany.

Salit, M.S., M.A.H. Mollah and N. Yusoff, 2000. Concurrent Engineering, Product Design and Development. Prentice Hall, Petaling Jaya, Malaysia.

Semasaka, C., X.Z. Kong and Y. Hua, 2010. Optimization of extrusion on blend flour composed of corn, millet and soybean. Pak. J. Nutr., 9: 291-297.

Siahaja, E., 2009. Cookies Wonderland. Seashore Publishing, Kuala Lumpur, Malaysia.

Sokhey, A.S., Y. Ali and M.A. Hannab, 1997. Effects of die dimensions on extruder performance. J. Food Eng., 31: 251-261.

Ullman, D.G., 2003. The Mechanical Design Process. 3rd Edn., McGraw-Hill, New York.

Wade, P., 1988. Biscuits, Cookies and Crackers, The Principle of Craft. Vol. 1. Elsevior Applied Sciences, London.