Development of Molding Machine for Petal-Shape Gum Paste

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Abstract

This study focuses on the design and development of a molding machine that can be used in the process of making edible gum paste petals for export-quality cake decorations of a certain company situated in the Philippines. During the period of the study, the company employs manual labor in their production process. The processes of making these cake decorations (rose gum paste) include kneading/sheeting of sugar gum paste followed by manual cutting of petals or herbs, then manual thinning, and forming the cut petal tips, and finally, manual joining or sticking of petals to form a rose decoration. The researchers were able to develop a molding machine with the application of Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) and pneumatics technology to speed up the company's cutting, thinning, and forming processes of rose gum paste. Sheets of gum paste were used to evaluate the performance of the molding machine.

Keywords
Molding machine, gum paste, CAD/CAM

1. Introduction
Rose petals decorations for cakes are produced manually with the use of the machine during the kneading process of sugar gum paste. Sugar gum paste or gum paste is a blend of shortening, protein, powdered confectioner's sugar (sucrose), protein, shortening, gum, and water (Phillips, 2008). It is widely used for cake decorations, artificial flower arrangements, and historical reformation (Mason, 2004). This study is about the design of a machine used to form a rose petal made from sugar gum paste. Principles of pneumatics and compression molding and computer-aided design technique were applied. Different machines and tools are already available in the market that are being used in the food manufacturing industry making food products of complex shapes. A Circuit Cake Machine was developed by Provo Craft, a US company familiar with performing or cutting of different products. In 2007, Provo Craft started the initial research and development of the Circuit Cake machine. This machine is capable of cutting the different shapes of kneaded gum paste for cake decorations and is limited to cutting of 2- Dimensional (2D) gum paste only. This foodstuff crafting machine was patented in 2011. The Three-dimensional (3D) printing or additive manufacturing (AM) technology is driving major innovations in food manufacturing due to its capability to produce 3D objects with complicated geometry. One of the 3D printing techniques today is the "soft-material extrusion" which is used to print cake frosting (Godoi, Prakash and Bhandari, 2016). In line with the forming of 3D objects, three-dimensional molding is also one of the techniques being used today in forming three-dimensional objects such as in the molding of plastics and in the molding of furniture parts with unusual shapes (warped). This technique was applied to form a rose petal made of gum paste. Mechanization is one of the techniques applied to the industry to improve the production process since it can save money, time, and reduce drudgery. Therefore, in line with the process mentioned, the researchers aim to speed up the process of cutting, thinning, and forming of rose petals by designing and developing a machine that cuts and forms the rose petal gum paste. With this, the main objective of this study to speed up the company's cutting,

thinning, and forming processes of rose gum paste. The specific objectives of the study are the following: (1) to apply CAD/CAM, 3D molding, and pneumatic technology to the design of molding machine for the rose petal made of gum paste; (2) to test and evaluate the machine in terms of cycle time and productivity; and (3) to determine the payback period of the molding machine.

This study could help the company to reduce the time in their process of producing rose-shape gum paste. It can reduce the manual processes being done by company's workers. To future researchers, this study may provide necessary information for any improvement related to the field of food manufacturing mechanization. Furthermore, since the company manufactures different molded products made of gum paste, this study can be used as a reference to develop another machine with the same working principles that can be used for other moldable products. Therefore, a more improved company process will be the results. Also, the molding machine can be used as instructional material.

2. Review of Literature

2.1. Benefits and Advantages of Pneumatics

One of the equipment manufacturers that uses pneumatics technology is Evergreen Packaging based in Cedar Rapids, Iowa. Since the company manufactures machines for dairy or juice company, pneumatics is their best solution. Pneumatics is known for its characteristics as being a clean technology, enabling it as the first choice for packaging and food companies. Pneumatic systems components are easy to configure and they can be designed easily. Other advantages of pneumatics are its durability and affordability and ease of maintenance. According to the Evergreen development project manager, Tim Hughes, pneumatics is less expensive compared to a fully mechanical system. Compared to hydraulics, pneumatics makes it suitable for food applications due to these advantages. Pneumatics products withstand tough environments, with longer lifespan because of their simple design and the internal components have limited numbers. Some of the important considerations in using pneumatics in food applications are the proper selection of the right product for each application and filtration of compressed air according to applications (Lyngstad, 2007).

2.2. The Pneumatic and Electro-Pneumatic Control Systems

A pneumatic system is a fluid power system that uses compressed air as a working fluid. Fluid power is the term used to describe the technologies that use oil (Hydraulics) and compressed air (Pneumatics). Figure 1 shows the basic components of a pneumatic system. It consists mainly of a compressor, air treatment, reservoir, pressure regulator or service unit, directional control valve, and cylinder (actuator).

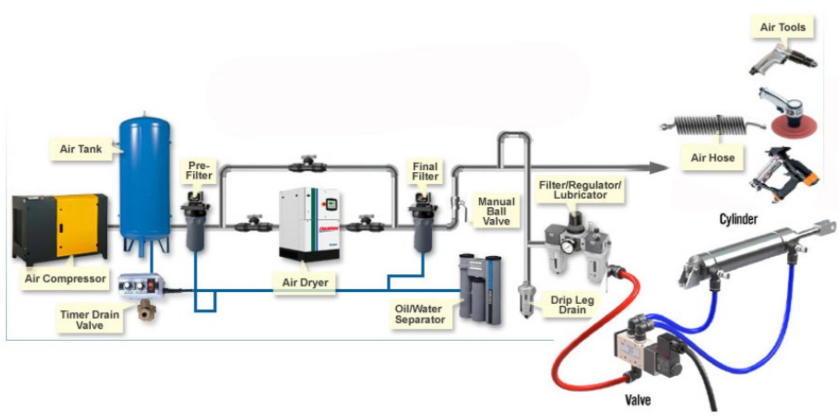


Figure 1. Pneumatic System Components

In electro-pneumatic control, the input, processing, and final control elements are made up of electrical components such as limit switches, relays, and solenoids. The typical components of an electro-pneumatic control system are a pneumatic cylinder, relays, solenoids, and sensors or reed switch. Some advantages of electro-pneumatic control system over a purely pneumatic control are higher reliability (which means fewer moving parts subject to wear), lower installation effort particularly when modern components such as valve terminals are used, simpler exchange of information between several controllers (Croser and Ebel, 2002).

2.3. Unitary Elastic Mold and Cutter Combination

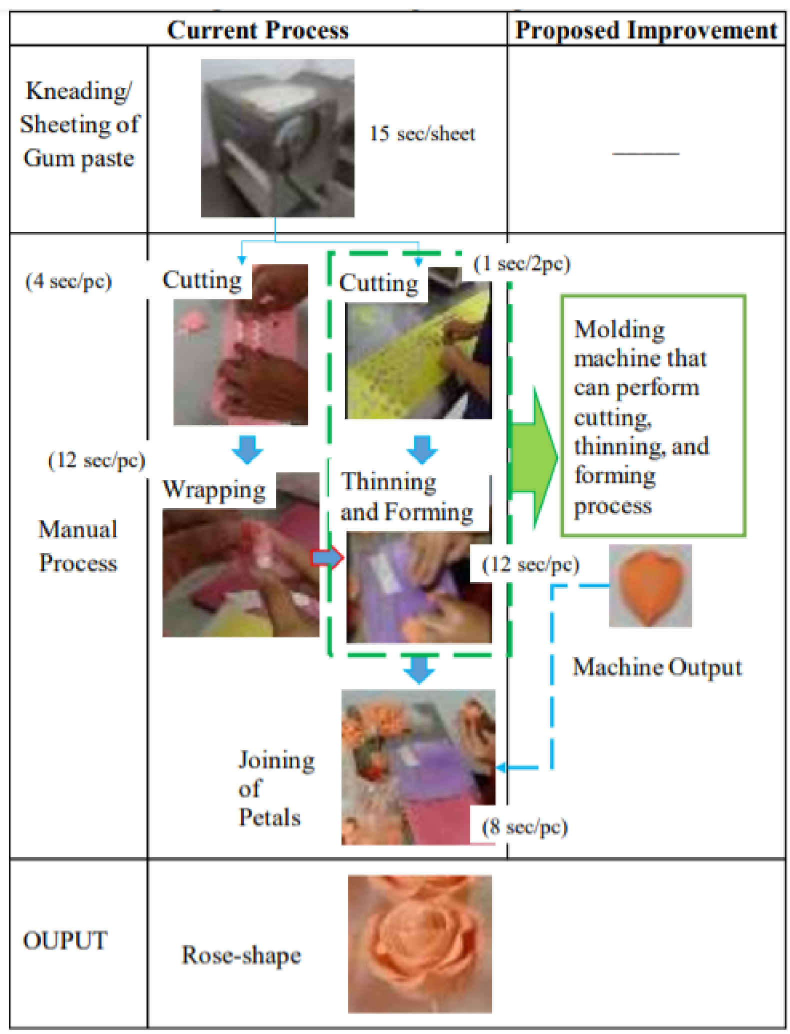
Dominic Palazzolo (2012) invented the "Unitary Elastic Mold and Cutter Combination" apparatus. This apparatus is used for molding and cutting edible or nonedible moldable materials like fondant, modeling chocolate, clay, cookie dough, gum paste, pastillage, and other confectionery compositions, and craft moldable compound. The materials used in this apparatus are made of flexible, elastic, stretchable, or have other additional properties. These materials may comprise polymeric materials, rubber, and silicone. Its elastic property enables the user to release the molded and cut material. The present study combined both molding and cutting operations in the design of the molding machine and used high-density polyethylene (HDPE) as mold material and at the same as cutter material.

3. Methodology

3.1. Process Assessment and Solutions Development

The researchers conducted actual manufacturing process observations to identify the company needs and/or problems then the workers and managers were interviewed. Initial data was gathered such as processing and cycle time. The company simple process of making rose-shape gum paste have four steps: kneading/sheeting; manual cutting; thinning, using marbles, the edge of cut gum paste then forming it into rose petal-shape like; and joining the petals together. A proposed problem solution was generated. The existing process and the proposed improvement of this study are shown in Table 1.

Table 1. Comparison of Current Process and Proposed Process Improvement



3.2. Machine Conceptual Modeling and Design
All the machine parts were drawn in Autodesk Inventor HSM 2016 and Autodesk Inventor 2017 version considering the dimensions and pneumatic components and the mold's size to be used. The machine was designed with upper and lower molds that form the kneaded sugar gum paste into a rose petal-shape like. The upper and lower molds assembly were designed in such a way that the cutting and forming of the existing process can be done at once. Upper molds were designed to form the one side of the rose petal and the lower molds for the other side. Figure 2 shows the upper and lower molds (left) design with the rose petal (right) in between them. All of the materials used for the machine in contact with the food product is made of food-grade stainless steel and engineering plastic (high-density polyethylene).

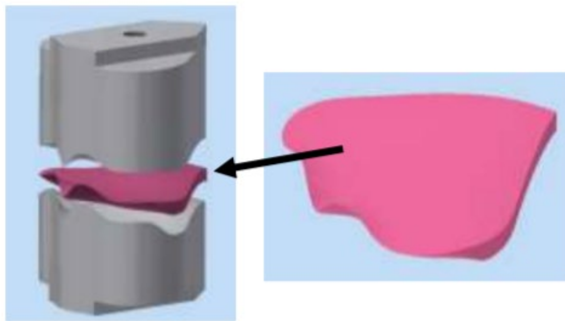


Figure 2. Conceptualized Upper and Lower Molds and Rose Petals

In addition, Fluidsim software was used to design and simulate the pneumatic and electrical circuits of the machine. This enabled the researchers to check and visualize the sequence of movements of the pneumatic components. The molding machine of this study was designed with three main parts namely: the machine frame, the upper and lower molds part, pneumatics part, and control panel as shown in Figure 3.

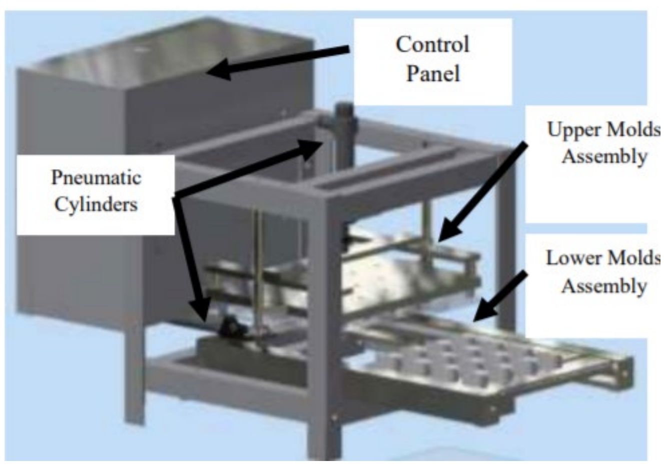


Figure 3. Molding Machine (3D CAD Model) Isometric View

3.3. Systems Integration, Molds Initial testing, and Prototyping
After outsourcing and gathering all materials needed, it is then followed by the fabrication of customized components such as the machine frame and the upper and lower molds. CNC Machine was used by the researchers for the fabrication of the molds and scrapper. CNC operations were simulated and GCodes were generated using Autodesk Inventor HSM 2016 as shown in Figure 4.

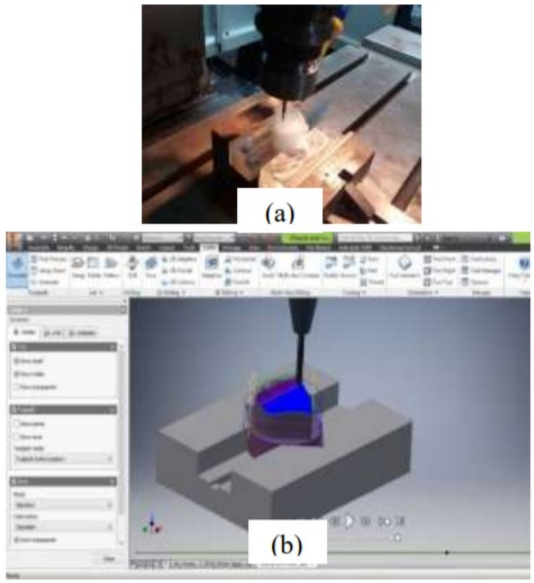


Figure 4. Molds Actual Fabrication and CNC Simulation

The number of pair of molds are delimited to sixteen pairs only and are based on 1-m length of high-density polyethylene (HDPE) rod, and all materials used in contact with the food materials are food grade. Initial testing of a pair mold is done to ensure that the designed molds are good to use or molds the desired shape (rose petal-like). The initial testing of molds is shown in Figure 5 while Figure 6 shows the assembled and working molding machine.

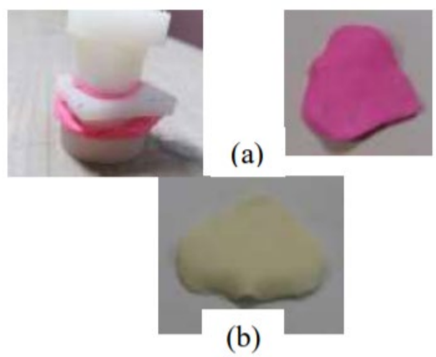


Figure 5. Molds Actual Fabrication and CNC Simulation

Figure 6. Gum paste Molding Machine

4. Results and Discussion

Figure 7 shows the molded petal (peach) during the initial trial and the manual molded petal (white). The manual forming process was not eliminated since the formed petals sometimes changes due to handling. Figure 8 shows the final output of the process of making rose shape gum paste by using the molding machine to mold the petals and by manual molding.

Figure 7. Comparison of manual and machine molded petals

Machine-molded rose gum paste

Manual-molded rose gum paste

Figure 8. Comparison of machine-molded and manual-molded rose gum paste

Figure 9 shows the results of cycle time gathered during the trial as discussed in the preceding section. The inner part processing is not shown. The difference between the existing process with the process using the molding machine of this study is noticeable. From the process with a molding machine, 'cutting' and 'thinning' processes can be eliminated, thus reducing the worker 1 time from 20 to 12.6 seconds per piece of petals. The molding machine cycle time is 2.19 sec/pc, faster than worker 2, which means the production capacity calculation will be based on 12.6 sec/pc. An improvement of 7.4 sec per piece of petal or equivalent to 37 seconds per piece of rose can be achieved. The annual order of medium size rose gum paste of the same color and geometry, which the machine of the study addressed, is 50, 000 pcs per year. Each rose gum paste needs 5 pieces of petals, therefore 250, 000 pcs of petals are needed to produce 50,000 pcs orders.

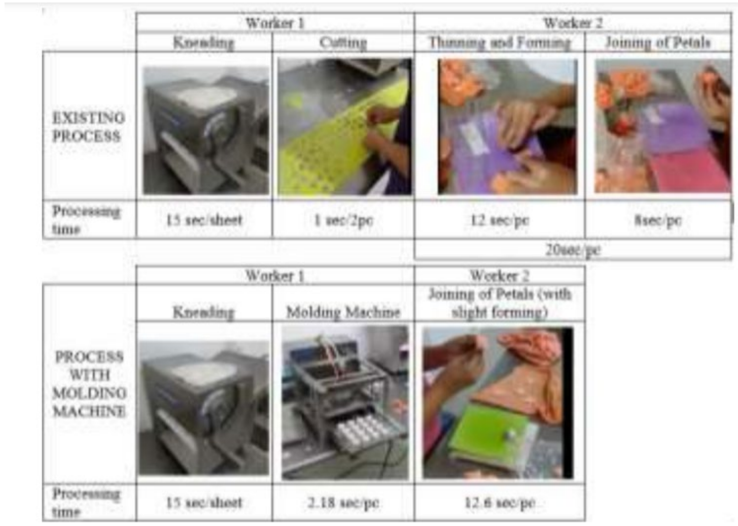


Figure 9. Cycle time comparison of existing process and the process with the molding machine

Figure 10 shows the monthly productivity comparison of the existing process to the process with the use of a molding machine wherein the production capacity can be increase by 4,397 pcs/month, or 58.72%. A 50,000 pieces of rose order than can be produced in 4.21 months (approximately 5 months) period using the molding machine and the existing process will take 6.68 months (approximately 7 months), which means 2 months advanced compared to the existing.

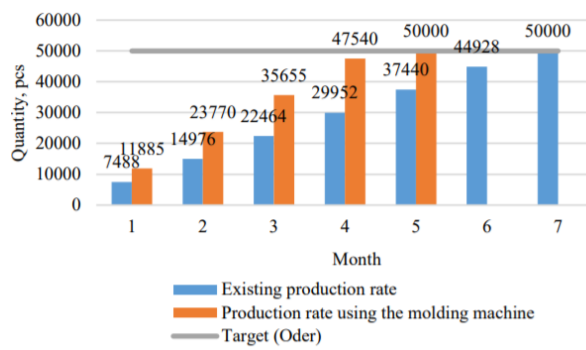


Figure 10. Monthly production capacity comparison

To get the payback period of the molding machine of the study the cost of investment was divided with the difference of net income of the existing process and the process with the use of the molding machine. In this study, the cost of investment is the molding machine cost which is Php 53,665.45. The net income of both processes from Figure 9 was calculated based on gross income (quantity of product produce times selling price) less than the expenses (material, labor, overhead, and electricity cost). The selling price of rose gum paste is Php 7.1897. The labor cost of the company is 12.66% of rose gum paste selling price and 10.43% for material cost. The overhead and mark-up costs are 46.91% and 30% respectively. Table 2 shows the cost of operation comparison between the existing process and the process with the molding machine. As shown in Table 3, the monthly net income generated by using the machine is equivalent to Php 25,614.64/month while the existing is Php 16,145.21. Therefore, by dividing the cost of investment by the difference of Php 9,469.43 between the net incomes, the payback period will be 6 months.

Table 2. Monthly comparison of existing process and the process with the molding machine

Item	**Existing process**	**Process with molding machine**
Compressor operation cost	----	1.86
Labor cost	6, 812.99	10, 810.17
Material	5, 612.92	8, 906.01
Overhead cost	25, 244	40, 055.68
Total	37, 669.91	**59, 773.72**

Table 3. Monthly net income comparison of existing process and the process with the molding machine

Item	**Existing process**	**Process with molding machine**
Gross income	53, 815.12	85, 388.36
Total cost	37, 669.91	59, 773.72
Net income	**Php 16, 145.21**	**Php 25, 614.64**

5. Conclusion

The researchers were able to develop a molding machine for petal shape gum paste with the use of CAD/CAM and Fluidsim software. The molding machine was fabricated based on the final design and its components were selected based on design calculation, availability, and costs. Also, the trial shows that the molding machine was able to meet the desire functions to produce 3D molded gum paste of rose petal in shape. Manual cutting of the existing process was eliminated and the process was improved, but the operator risk of being lacerated was eliminated also. Since the production capacity can be increased by 58.72% or 4,397 roses/month, therefore, the company's cutting, thinning, and forming processes for rose gum paste can be improved with the use of the molding machine. With a monthly net income difference of Php 9,469.43, the investment can be recovered based on a payback period of 6 months, therefore, the project is feasible and good to invest in.

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