DEVELOPMENT OF A CHOCOLATE ENROBING MACHINE FOR COOKIES

by

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Summary and Conclusion

CHAPTER V
SUMMARY AND CONCLUSION

Cocoa (*Theobroma cacao L.*) belongs to the family *Malvaceae* and the genus *Theobroma*. The cocoa tree produces fruits, referred as cocoa pods which contain approximately 30–40 seeds commonly known as cocoa beans, which are embedded in a sweet mucilaginous pulp. The pulp is rich in fermentable sugars and high in acidity (pH 3.0–3.5). In India, cocoa is cultivated in an area of 1,05,975 ha with an annual production of 28,426 MT, of which Kerala contributes 17,770 ha and 10,130 MT, respectively. Cocoa is mainly grown in Kerala, Karnataka, Andhra Pradesh and Tamil Nadu. In India Kerala stands second position in terms of cocoa production after Andhra Pradesh.

Chocolate is the most popular cocoa-derived product, highly valued by consumers around the world. The key ingredients in chocolate formulation are cocoa mass, cocoa butter, sugar, emulsifiers, aroma and milk components. Different contents of cocoa solids, milk fat and cocoa butter define the primary chocolate categories known as dark, milk and white chocolate.

Compound chocolates are chocolate like products made with a fats such as modified palm kernel oil and coconut oil, where the melting characteristics of the vegetable fat have been modified to imitate those of cocoa butter. Compound coatings are used primarily for economic reasons, since these vegetable fats are less expensive than cocoa butter. All of these fats are obtained from a natural plant such as palm kernel oil (PKO), palm olein (PO), mango seed fat, soy oil, rapeseed oil, cotton oil, groundnut oil and coconut oil. Cocoa butter alternatives (CBAs) derived from Shea butter, palm oil or other sources are used to replace the cocoa butter.

Chocolates can be used for coating various food products like fresh cut fruits and vegetables, cookies, nuts, wafers and biscuits by the process called enrobing. Enrobing refers to apply a coating of chocolate or compound coatings to the outside of a product. Chocolate coating introduces a moisture barrier between the products and the atmosphere, thus increasing the shelf life of the product and it also increases the sensory property of the final product.

Chocolate coating is usually applied by means of an enrober. This is a machine in which the products to be coated pass through a continuous curtain of chocolate. The purpose of an enrober is to apply chocolate to all surfaces of the product and produce a product that is attractive, has a glossy surface, free of voids or holes in the coating and has a controlled uniform thickness. Butter cookies, with their blend of rich texture, buttery flavour and simplicity are particularly well-suited for chocolate enrobing.

Chocolate-enrobed products are becoming increasingly popular. However, a small capacity enrobing machines suitable for small and medium-sized entrepreneurs are not available. Hence, an attempt has been made to develop economically feasible chocolate enrobing machine for cookies that will be suitable for small and medium-scale entrepreneurs and beneficial to SHGs.

The present study entitled “Development of a Chocolate Enrobing Machine for Cookies” was undertaken with the following objectives: i) Development of a chocolate enrobing machine for cookies ii) Optimization of process parameters for chocolate enrobing process iii) Performance evaluation of the developed machine in terms of capacity, energy requirement and efficiency

Physicochemical and engineering properties of cookies and chocolate were determined prior to the development of machine. The engineering properties of chocolate such as bulk density, moisture content, protein, ash, fiber and fat content were determined as per the standard procedures. Rheological measurements of compound milk chocolate were performed at 40°C using a controlled stress– strain rheometer.

The bulk density, moisture content and water activity of the chocolate were recorded as 1228 ± 0.08 kg/m³, 1.28 ± 0.32%(wb) and 0.46 ± 0.03, respectively. The chocolate contained 30.69 ± 0.97% fat, 11.32 ± 0.08% protein, 1.402 ± 0.01% ash, 0.74 ± 0.08% fiber and 54.56 ± 0.68% carbohydrate, with an energy value of 539.73 ± 3.42 kcal. Milk compound chocolate indicated a shear thinning behaviour and the viscosity of chocolate was found to be 3.69 Pa.s. By using casson model, casson plastic viscosity and yield stress value of chocolate were determined as 2.28 Pa.s and 6.43 Pa, respectively.

The physicochemical properties of cookies such as weight, thickness, diameter, moisture content, water activity, protein, ash, fiber and fat content were determined as per the standard procedures. The cookies had an average weight of 11.90

± 0.39 g, diameter of 5.05 ± 0.02 cm and thickness of 13.73 ± 0.09 mm. The moisture content was recorded as 2.04 ± 0.08% (wb), while the water activity was measured as 0.32 ± 0.02. The total fat content of cookies was determined to be 19.78 ± 0.57%. Additionally, protein, fiber and ash contents were found to be 6.78 ± 0.08%, 0.24 ± 0.03% and 0.67 ± 0.04%, respectively, with the carbohydrate content of 70.50 ± 0.67%. The energy value of the cookie was determined to be 487.17 ± 2.46 kcal.

The machine was designed and fabricated by considering critical parameters related to both cookies and chocolate. The developed chocolate enrobing machine consists of chocolate tank with agitator, water tank with heater, conveyor belt, chocolate flow pan, air flow duct connected with ring blower, vibrator, collecting tank and control panels.

The chocolate tank, made of 3 mm wall thickness made of stainless steel, measures 21 cm in diameter and 30 cm in depth, acting as the chamber for melting the chocolate. It can holds 10 kg of chocolate per batch. An agitator was installed inside the tank to ensure uniform and efficient melting. The chocolate tank was placed inside a water tank, which provides the necessary heat to melt the chocolate using double boiling method. The water tank made of stainless steel and holding 42 L (44.5 cm × 39.5 cm × 24 cm). A 2 kW tubular heating coil was employed to heat the water and an external water level indicator was installed to monitor the water level. The chocolate melting process uses the double boiling method, where water being heated to 70°C and the steam transfers heat to the chocolate tank to melt the chocolate. The conveyor belt, made of food-grade stainless steel, transport products through the enrobing machine on a wire belt. This design allows chocolate to coat the top of the products while excess chocolate drains off. The movement of belt was powered by a motorized shaft and roller mechanism, with speed adjustable from 9 to 39 rpm using a control knob. The trapezoidal stainless steel chocolate flow pan direct melted chocolate from the tank onto products below. A slot on the underside of the chocolate flow pan creates a curtain of chocolate for coating as it flows.

A stainless steel ring blower with a heater produces hot air to remove excess chocolate, forming an air curtain over the products. The airflow and temperature can be adjusted to achieve the desired chocolate thickness, with excess chocolate flowing down the sides. The vibrator reduces the excess chocolate, particularly on the sides, by creating vibrations through a frame in contact with the wire belt. Vibrator was powered by a compressor, it ensures uniform coating and removes additional chocolate for a smooth finish. The rectangular stainless steel tank, measuring 24×25×30.5 cm, positioned at the bottom side of the conveyor belt collects excess chocolate from the products and belt after coating. The recovered chocolate has been manually returned to the chocolate tank for reuse. The machine includes two control panels. The first panel controls the heater, conveyor belt and agitator with a temperature controller for the heater, knobs to adjust conveyor speed and switch for the agitator. The second panel regulates the hot air flow rate and temperature. The readings were displayed on the screen.

The Box-Behnken experimental design was employed to identify the optimal combination of process parameters for the chocolate enrobing process. The chocolate enrobed cookies were prepared using varying combinations of flow rate of chocolate (3, 4.5, 6 kg/min), belt speed (2.1, 2.3, 2.5 m/min) and flow rate of hot air (3.3, 3.6, 3.9 L/s). These process parameters were optimized to achieve the desired quality of the final product. A total of 17 experiments were conducted and the process parameters for enrobing were evaluated based on the dependent variables viz. capacity, enrobing efficiency, energy requirement and coating thickness.The optimal conditions for the chocolate enrobing process were chocolate flow rate of 4.5 kg/min, belt speed of 2.5 m/min and hot air flow rate of 3.3 L/s with the desirability of 0.877.

Production of chocolate enrobed cookies using a chocolate enrobing machine involves the following steps. Chocolate and cookies procured from various institutes were the raw ingredients for enrobing process. Chocolate enrobing machine was turned on, followed by setting the heater temperature to 70°C, to heat the water inside the tank attached with heater to melt the chocolate by double boiling method. After the water attains a temperature of 70°C, required quantity of chocolate was fed into a chocolate tank fitted with an agitator and the chocolate was allowed to melt for approximately 3 hours to reach the required consistency for flowing. An agitator was mounted inside the chocolate tank to mix the chocolate properly, that helps in melting of chocolate. Monitoring was done to ensure the chocolate melted completely. Once the chocolate reached the desired flowing consistency, the conveyor belt was activated and set to a speed of 33 rpm (2.5 m/min). Then, the blower was turned on and adjusted to a flow rate of 3.3 L/s by regulating the air velocity to 5.5 m/s using a control valve, while the heater temperature was set to 60°C to produce hot air of 30–40°C at the outlet of an airflow duct.

After attaining the required working condition, the control valve of the chocolate tank was opened, allowing the chocolate to fill the flow pan beneath it. As the pan filled, the slot provided at the base was opened to create a flowing curtain of chocolate. Cookies were placed on the conveyor belt in a single/double row, spaced 5 cm apart to maintain proper alignment as they passed through the chocolate curtain for coating. The chocolate coated cookies continued along the conveyor were allowed to pass under an air flow duct, that applied a layer of hot air to remove the excess chocolate (trimming of chocolate) from the coated cookies. Then, the cookies passed through a vibrating section operated by a compressor, which helped remove additional chocolate from the sides and ensured an even coating. At the collection end, the coated cookies were placed on a tray lined with butter paper. These cookies were then transferred to the refrigerator set at 8–12°C for 15 minutes for rapid cool and solidifying the chocolate layer. Cookies were coated on both sides separately by first passing them through the machine to coat the bottom, followed by a second pass to coat the top. Bottom coated cookies were placed back on the conveyor belt for top side coating and the process was repeated as mentioned above. Once the chocolate was fully set, the cookies were wrapped in an aluminium foil and stored in the cold storage at a temperature of 8°C.

Performance evaluation of machine was done under optimized condition in terms of capacity, enrobing efficiency and energy consumption. The machine achieved a capacity of 190 cookies/hour, enrobing efficiency of 94.74%, energy consumption of 5.48 kWh. Coating thickness and enrobing ratio of chocolate enrobed cookies were found to be 2.79 mm and 76% respectively.

Sensory analysis was done using 9 point hedonic scale to find the consumer acceptance of the samples in terms of appearance, colour, taste, flavour, crispiness and also to find the overall acceptability of the product. Optimized enrobed sample was compared with other samples produced with different flow rate of chocolate and commercial enrobed cookie (Oreo enrobed).

The sensory evaluation revealed that the developed chocolate enrobed cookies were significantly preferred over the control cookies in appearance, colour, taste, flavour, crispiness and overall acceptability. The chocolate coating enhanced visual appeal, provided richer flavour and preserved crispness, offering a more indulgent sensory experience. Results on each sensory parameter indicated no significant difference between the developed cookies but there was a considerable difference between the control and developed optimized sample. Hence, it is inferred that the developed optimized chocolate enrobed cookies was found to be superior among the other enrobed samples.

Physicochemical properties of chocolate enrobed cookies were estimated using standard procedures. The cookies had an average weight of 20.97 ± 0.08 g, diameter of 5.22 ± 0.03 cm and thickness of 16.52 ± 0.03 mm. The moisture content and water activity of cookies were recorded as 2.82 ± 0.06% and 0.41 ± 0.01, respectively. The fat content, protein, fiber and ash contents were found to be 22.94 ± 0.78%, 9.45 ± 0.05%, 0.43 ± 0.03% and 0.99 ± 0.04%, respectively. Carbohydrate content of enrobed cookie was calculated as 63.37 ± 0.79%. The energy value of the cookies was found to be 497.77 ± 3.76 kcal.

The results revealed that chocolate enrobing enhanced the fat, protein, fiber and ash content of the cookies, which demonstrated an increase in the nutritional values of chocolate enrobed cookies. Sensory evaluation indicated superior for chocolate enrobed cookies, particularly in terms of colour, appearance, taste, flavour and overall acceptability. The comparison between the cookies before and after enrobing showed a significant improvements in sensory and quality parameters. Addition of chocolate coating effectively enhanced the sensory and nutritional properties of the cookies.

The cost of operation of chocolate enrobing machine was estimated as Rs.340/hour. The benefit-cost of operation of chocolate enrobing machine was calculated as 1.05:1. The payback period of chocolate enrobing machine was determined to be 3.15 years.

Following conclusions were derived based on the findings:

- The developed chocolate enrobing machine marks a significant step towards supporting small and marginal cocoa growers and entrepreneurs.
- The optimal conditions for the chocolate enrobing process were chocolate flow rate of 4.5 kg/min, belt speed of 2.5 m/min and hot air flow rate of 3.3 L/s.
- The machine achieved a capacity of 190 cookies/hour, enrobing efficiency of 94.74%, energy consumption of 5.48 kWh under optimized condition.
- Coating thickness and enrobing ratio of chocolate enrobed cookies were found to be 2.79 mm and 76%, respectively.
- Sensory evaluation revealed that the optimized enrobed cookies were superior in terms of colour, appearance and overall acceptability among the other samples.
- The cost of operation of chocolate enrobing machine was estimated as Rs.340/hour.
- The benefit-cost of operation of chocolate enrobing machine was calculated as 1.05:1 with payback period of 3.15 years.

Scope of future work:

- The chocolate enrobing machine can be scaled up for industrial chocolate production.
- Storage experiments on chocolate enrobed cookies can be carried out with various packaging materials and packaging techniques to enhance the shelf life of the product.