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Performance Analysis of the Prototype Ice Cream Sandwich Enveloping System

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ABSTRACT

The Prototype Ice Cream Sandwich Enveloping System was manufactured with an automated sequential control procedure to envelop an ice cream sandwich made of softened ice cream and two slices of bread, which would be ready-to-serve as a deep-fried dessert. The prototype discharge softened ice cream on a slice of bread and sandwiched it with another slice. The automated system would then envelope the sandwich utilizing four air presses and four cavity molds. Performance was evaluated with a sample size of 120 slices of bread and softened ice cream. This system enveloped a row of four ice cream sandwiches at a time and was capable of enveloping more than eight ice cream sandwiches per minute at an efficiency of 94%. Weight of softened ice cream discharged on a sandwich ranged 45±3 g. The failure of enveloping ice cream sandwiches was due to horizontally positioned and protruding slices of bread.

1. Introduction

Fried ice cream is a dessert made from a breaded scoop of ice cream that is quickly deep-fried, creating a warm, crispy shell around the still-cold ice cream. Fried ice cream described as a small, solid (cake) of the ice cream is enveloped in a thin sheet of pie crust and then dipped into boiling lard or butter to cook the outside to a crisp. Served immediately, the ice cream is found to be as solidly frozen as it was first prepared.

Fried ice cream served in domestic market was made from one scoop of ice cream (40-45 g) which was sandwiched with two slices of bread (i.e., ice cream sandwich) and then enveloped using a food-safe shape-forming plastic frame (i.e., a cookie cutter). Ice cream sandwiching and enveloping processes are totally dependent on manual labor. The enveloped ice cream sandwiches were supplied to stores and/or distributors in frozen condition to be served as fried ice cream.

The manual process for hand-pressing an ice cream sandwich requires a slice of bread laid on a working table, with a scoop of ice cream topped onto the slice. Another slice of bread is laid on such that the ice cream was sandwiched between two slices of bread. The ice cream sandwich was then pressed with a cookie cutter. During this hand-pressing process, scraps of bread are generated.

This process requires intensive pressure to create a uniform shape and provide secure adherence of the slices of bread at the contacting edges. Any holes around contacting edges of the enveloped ice cream sandwich are not allowed to be served because the ice cream will melt during the deep frying process. This sandwiching and hand-pressing process may require experience and could be labor-intensive; high productivity is not to be expected.

The slice of bread feeding system was introduced[1] to feed

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a slice of bread to an ice cream discharge-unit from stacked slices of bread using a belt conveyor. Ice cream was discharged on the slice of bread, and another slice of bread was laid on top by hand. This system was limited in only employing a sliced bread feeding unit and ice cream discharge unit.

A vertical assembly extrusion ice cream sandwich making machine[2] was introduced to manufacture ice cream sandwiches with two wafers. This machine discharged the ice cream on a wafer, and sandwiched the ice cream on to another wafer.

This current research proposes a prototype ice cream sandwich enveloping system and evaluated its performance. Expected performances considered was the weight of discharged ice cream range of 45±3 g and capability of enveloping of ice cream sandwiches of at least 8 pieces per minute. This research evaluated discharging accuracy of softened ice cream, efficiency of enveloping of ice cream sandwiches and economic feasibility of the prototype Ice Cream Sandwich Enveloping System.

2. Material and Methods

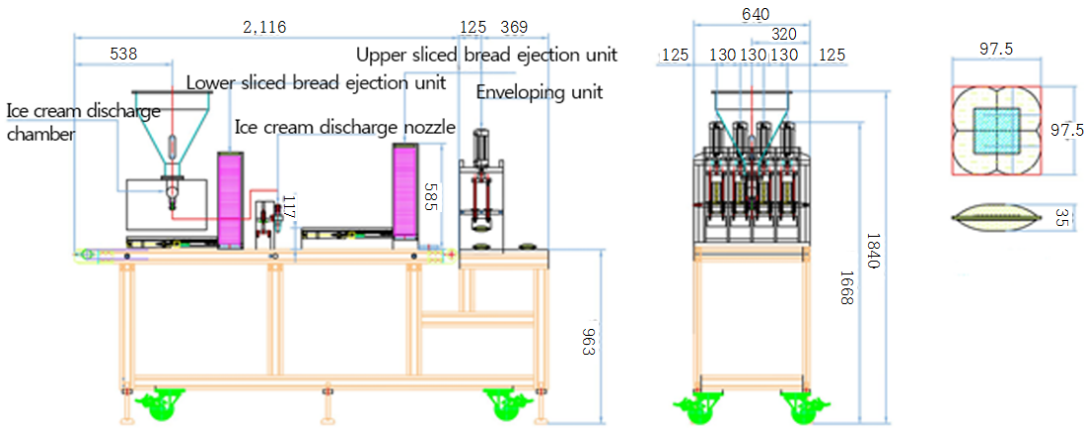
2.1 Material

2.1.1 Ice Cream Sandwich Enveloping System

Prototype Ice Cream Sandwich Enveloping System (ICSES; H1840 × L2610 × W640 mm) was custom designed and manufactured to envelope ice cream sandwiches for fried ice cream (Fig. 1). ICSES was expected to be capable of enveloping at least eight ice cream sandwiches per minute. ICSES ejected four slices of bread, discharged ice cream on the bread then sandwiched ice cream with other four slices of bread ejected. The ice cream sandwiches were then enveloped with fully automated sequential procedure.

ICSES system consisted of: control unit, belt conveyor, Lower Sliced Bread Ejection Unit (LSBEU), discharge unit, Upper Sliced Bread Ejection Unit (USBEU), locating unit, and enveloping unit.

The control unit, which employed a control-panel, controlled ICSES with a sequential procedure by a Programmable Logic



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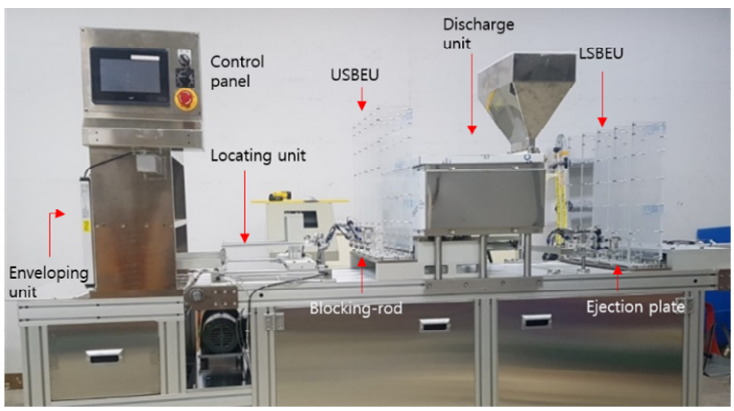

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Fig. 1 Prototype ICSES: (a) Design sheet of ICSES, (b) Photograph of ICSES

Controller (PLC).

The LSBEU, activated by pneumatic cylinders with on/off control, ejected four slices of bread in a row onto the belt conveyor. Rotation of the belt conveyor was activated by a 0.75 kW geared motor (Model H2805T0750, SMC, Korea) with a reduction ratio of 5:1. The four slices of bread were conveyed and placed under four ice cream discharge nozzles, which were mounted in a row to discharge the ice cream.

The displacement sensor, which was located above the belt conveyor, sensed the slices of bread and sent a signal to the ice cream discharge unit. Revolution of the ice cream discharge unit was activated by a 0.2 kW geared motor (Model H2830T020, SMC, Korea) with a reduction ratio of 30:1. Softened ice cream was then discharged through four nozzles onto the four slices of bread.

When discharge was complete, the belt conveyor continued to convey the four slices of bread with softened ice cream to the USBEU. When the belt conveyor stopped, another four slices of bread was ejected by the USBEU on top of the ice cream.

The belt conveyor continued to convey the four ice cream sandwiches to the end until it stopped at the locating unit. The locating unit initiated to locate the four ice cream sandwiches under the enveloping unit. It lowered and with horizontal sliding motion pushed the four ice cream sandwiches under the enveloping unit. The locating unit then raised and returned to its original position. Once the four ice cream sandwiches were placed under the enveloping unit, the air presses were initiated. With shape-forming cavity molds, the air presses enveloped the four ice cream sandwiches. The ice cream sandwich locating unit and enveloping unit were activated by pneumatic cylinders with on/off control.

2.1.2 Lower Sliced Bread Ejection Unit (LSBEU)

Lower Sliced Bread Ejection Unit (LSBEU) consisted of a square container, an ejecting plate, and four blocking-rods (Fig. 2). The square container was a rectangular parallelepiped (W530 × D140 × H535 mm) and it was made of food safe clear plastic plate. The square container was equally divided by four columns. Each column (W130 × D120 × H535 mm) was capable of vertically stacking 50 slices of bread. The total of 200 slices of bread could be stacked at the same time in the container.

The ejecting plate (W530 × D340 × H67 mm) was located

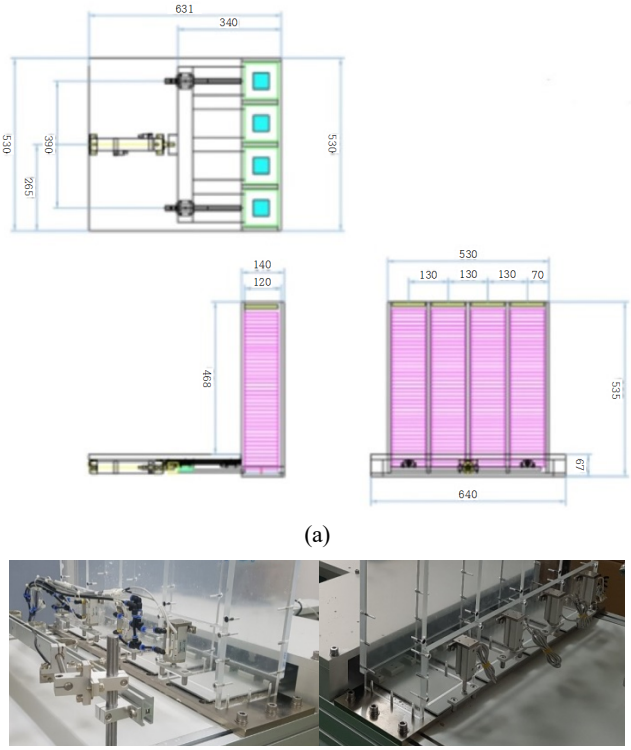

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Fig. 2 LSBEU of ICSES: (a) Design sheet of LSBEU, (b) Ejecting plate (left) and push plates mounted on ejecting plate (right)

under the square container. It consisted of four push-plates, which were mounted onto ejecting plate and had two notches (i.e., indentations). The four push-plates were spaced as the four columns of square containers.

The ejecting plate, which held up the stacked slices of bread in each column, acted as the bottom of each column and one by one ejected slices of bread. The initiated ejecting plate extracted horizontally to the conveying direction of the belt conveyor. While the ejecting plate was extracted, the four push-plates dispensed the bottom slices of bread from each column. Rest of the stacked slices of bread were lowered and laid on top of the push-plate while the four bottom slices of bread were placed on the ejecting plate.

When the ejecting plate was fully extracted, the four blocking-rods, mounted vertically outside each column, were extracted to the surface of the ejecting plate through the notches (i.e., indentations) of the push-plate.

The blocking-rod consisted of two parallel rods and was activated by a pneumatic cylinder. Each push-plate had two notches at the pushing-side of each push-plate (right, Fig. 2b) to allow the two rods (left, Fig. 2b) to be extracted up to the

surface of the ejecting plate, where the four bottom slices of bread were laid.

The four blocking-rods were employed to place each slice of bread onto the belt conveyor. It also prevented irregular movement caused by friction between the slices of bread and surface of the ejecting plate while the ejecting plate was being retracted to its original position. When the ejecting plate was retracted, the stacked slices of bread in the column were then lowered down onto ejecting plate.

2.1.3 Discharge Unit

Discharge unit (Fig. 3) consisted of: hopper (20 litter), chamber (W520 × D80 × H70 mm), four ice cream discharge nozzles, geared motor (Model H2830T020, SMC, Korea), revolution connecting rod with a discharge shaft, revolution connecting rod with two pistons, and a controller.

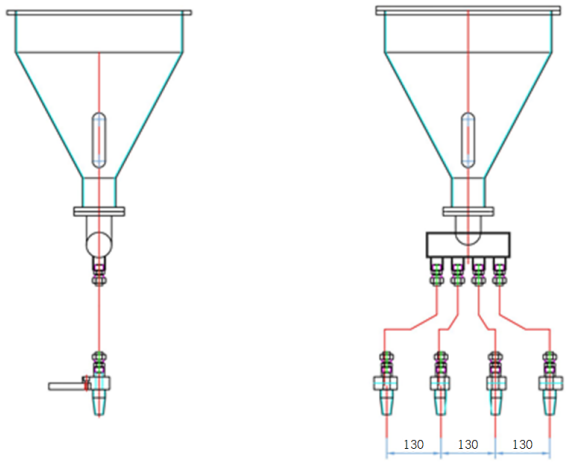
Revolution of the geared motor was transferred by the revolution connecting rod to the discharge shaft in the ice cream chamber. Rotation of the discharge shaft pulled out the ice cream from the hopper to the chamber. The ice cream in the chamber was pushed by reciprocal motion of the two pistons, which was connected to the geared motor with a revolution connecting rod. This action discharged the ice cream in the chamber onto the four slices of bread through the four nozzles, which were evenly spaced at 13 cm and attached to the chamber. The amount of ice cream discharged was controlled by setting number of revolutions of the geared motor with the ice cream discharge.

The discharge unit was initiated when the four slices breads were conveyed and stopped under the unit. When the four slices of bread were being conveyed, the displacement sensor, which was around 30 cm from the bread eject unit and mounted above the belt conveyor, detected the slices of bread and sent a signal to the ice cream discharge controller. The controller detected this signal, stopped the belt conveyor, and initiated the ice cream discharge unit to discharge the ice cream onto the slices of bread.

2.1.4 Upper Sliced Bread Ejection Unit (USBEU)

The Upper Sliced Bread Ejection Unit (USBEU) ejected four slices of bread at the same time onto the ice cream, which was discharged on the four slices of bread. The ice cream was then sandwiched with two slices of bread (i.e., ice cream sandwich).

The mechanism and constitution of the USBEU were the



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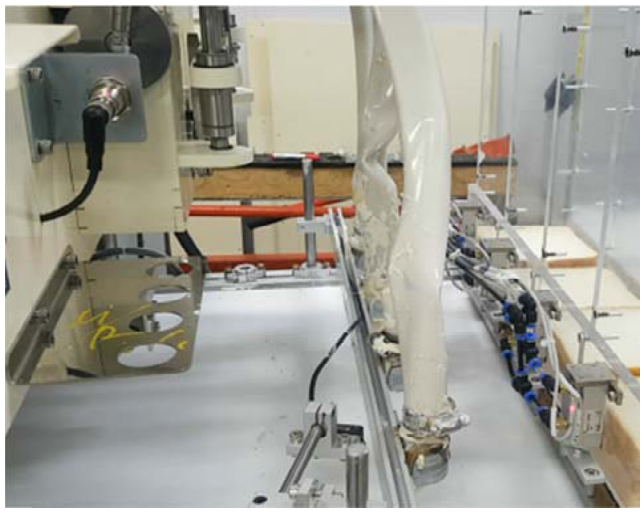

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Fig. 3 Ice cream discharge unit: (a) Design sheet of ice cream discharge unit, (b) Photograph of ice cream discharge unit

same as the LSBEU, except its elevation of mounting onto the frame of the enveloping system. The elevation of the USBEU was set higher than elevation of the LSBEU to allow vertical conveying space of 67 mm from the surface of the belt conveyor and the ice cream topped slices of bread.

Ejected sliced bread by the push-plate of the ejection unit was dispensed, slanted downward from the leading edge of the sliced bread at the edge of the ejecting plate, and placed on top of the ice cream while the ejecting plate was being retracted to its initial position.

2.1.5 Locating Unit

The locating unit (W640 × D55 × H45 mm) was designed and manufactured as shown in Fig. 4. The locating unit consisted of a rod less pneumatic cylinder (Model MY1B20G-80L, SMC, Korea), a guided pneumatic cylinder (Model

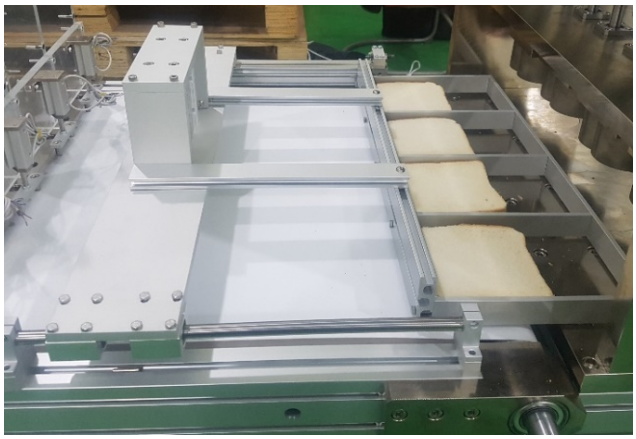


Fig. 4 Bread locating unit and rectangular enclosures

MGPM25-50, FNC, Korea), and a rectangular frame. The rod less pneumatic cylinder and the guided pneumatic cylinder carried out horizontal and vertical reciprocating motions of the rectangular frame, respectively, to locate the four ice cream sandwiches under the enveloping unit.

The rectangular frame was split by four equally spaced rectangular enclosures (Fig. 4) to push the four ice cream sandwiches individually during horizontal motion of the locating unit. Size of a rectangular enclosure was selected to be a little larger than the size of sliced bread which was commercially obtained at markets. This allowed more space to confine each ice cream sandwich within each rectangular enclosure.

The locating unit was interlocked with the belt conveyor to locate the four ice cream sandwiches under the enveloping unit. Operation of the locating unit was initialized with the on/off control of the belt conveyor. When the four ice cream sandwiches were conveyed and placed at the end of the belt conveyor, the belt conveyor was stopped, and the ice cream sandwich locating unit was initiated.

When the four ice cream sandwiches were conveyed and placed at the end of the belt conveyor, the rectangular frame was lowered to the surface of the belt conveyor and confined the four ice cream sandwiches one by one within the four rectangular enclosures. The rectangular frame moved horizontally forward by the rod less pneumatic cylinder to push and locate the four ice cream sandwiches under the enveloping unit. The rectangular frame was then lifted vertically by the guide pneumatic cylinder and retracted to its original position by the rod less pneumatic cylinder to finish its cycle of operation.

The four ice cream sandwiches were pushed forward by horizontal slide motion of the rectangular frame. During the push motion of the rectangular frame, only one side of an ice cream sandwich was pushed by contacting the rectangular enclosure, which is vertical to the direction of the forward motion.

Operating speed of the locating unit was controlled by setting a lag time of initiation of the rod less pneumatic cylinder and guide pneumatic cylinder with the control unit. The control unit initiated the locating unit by receiving a signal from the belt conveyor.

2.1.6 Enveloping Unit

The enveloping unit (W640 × D240 × H520 mm) consisted of four air presses and four cavity molds. The cavity mold (W97.5 × D97.5 × H35 mm) was designed and manufactured as an upper-moveable-mold-half with aluminum to envelop and trim out the ice cream sandwich. Bottom plate, as a base frame of the air press, was substituted as a lower-fixed-mold-half (Fig. 5).

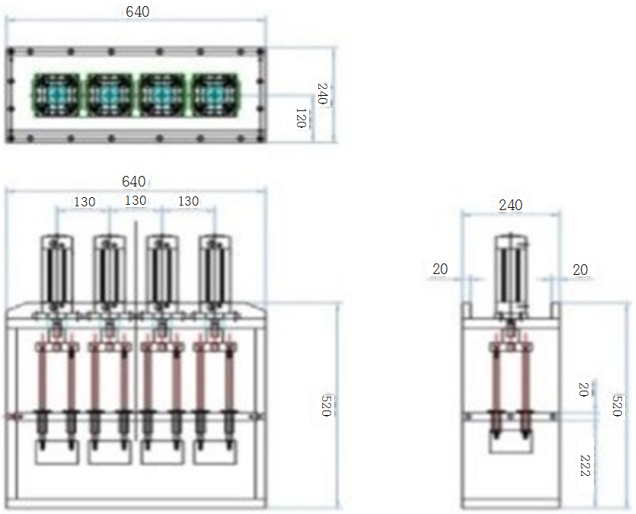
Four ice cream sandwiches placed on a flat aluminum bed (i.e., lower-fixed-mold-half) were enveloped and trimmed out by the edge of the four cavity molds while the air presses were being extracted[3]. Scraps of bread were generated by enveloping and trimming the outside of the cavity molds.

2.1.7 Belt Conveyor

Belt conveyor system (W640 × L2116 mm), which was powered by a 0.75 kW geared motor (Model H2805T0750, SMC, Korea) with a reduction ratio of 5:1, was employed to convey slices of bread from one end to the other with intermittent movement. The belt conveyer was initiated after the four slices of bread were ejected onto the belt conveyor by the LSBEU. The belt conveyor conveyed and placed the four slices of bread under the ice cream discharge nozzles. Once discharge process was finished, the belt conveyor conveyed and placed the four ice cream topped slices of bread under the USBEU. The belt conveyor waited until the four slices of bread were ejected onto the four ice cream topped slices of bread. The belt conveyor then conveyed and placed the four ice cream sandwiches to the end of the belt conveyor[5].

2.1.8 Control Unit

The control unit employed a PLC XGT CPU (LS, model XGF-H02A) and controlled the enveloping system as a



(a)

(b)

Fig. 5 Ice cream sandwich enveloping unit: (a) Design sheet of ice cream sandwich enveloping unit, (b) Photograph of ice cream sandwich enveloping unit

sequential procedure of the automation[6].

2.2 Experimental Methods

2.2.1 Samples

Slices of bread and hard ice cream in containers were purchased at markets and prepared for this experiment. Slices of bread were heated for 30 seconds using a microwave to moisten for ease of enveloping of ice cream sandwiches. Ice cream was softened to be employed in ice cream topping unit before it was dumped into the ice cream hopper.

2.2.2 Range of Weight of Discharged Ice Cream

Prior to this experiment, weight of ice cream discharged from the topping unit was measured and controlled by adjusting speed of revolution of the geared motor. The weight of the ice cream discharged from nozzle of the topping unit was estimated and proposed to be 45 g.

Ice cream, which was discharged from each nozzle, was collected into a paper cup. The weight of the paper cup with ice cream was measured with a digital scale and the weight of the paper cup (i.e., 3 g) was deducted. This test was replicated 30 times and data from each nozzle was averaged then compared.

Out of range weight of ice cream was classified as discharge failure. Ratio of out of range to the total number of ice cream discharged was determined.

2.2.3 Efficiency of Enveloping

Efficiency of enveloping was determined as the number of failure to the total number of 120 enveloped ice cream sandwiches. Failure of enveloping by the enveloping unit was classified as insecurely enveloped including one that had a teared surface. For this experiment, enveloping failure was evaluated by visually inspecting status of sliced bread.

2.2.4 Rate of Topping Unit

Rate of topping unit was determined by measuring the weight of ice cream discharged per minute. Ice cream discharged from the four ice cream discharge nozzles (nozzle #1 – nozzle #4) was collected using a container, and time span of discharge was measured by a stop watch. This experiment was replicated 3 times. The rate of topping unit was determined by dividing the weight of ice cream (45 g) discharged per one minute.

2.3 Results and Discussion

2.3.1 Range of Weight of Topped ice cream

Acceptable range of weight of discharged ice cream from topping unit could be 42-48 g for an ice cream sandwich. There were 6 samples with less than 42 g and 2 samples with greater than 48 g among the total of 120 samples, which was 6.7% out of range discharged ice creams. 85.9% of samples were 42 to 46 g from nozzle #1 through nozzle #4 (Fig. 6).

Fig. 7 shows average, minimum and maximum weights of ice cream discharged from nozzle #1 through #4. The lowest

and highest range of weights of discharged ice cream was found from nozzle #2 and #4, respectively, from the 30 replications.

A Paired T-test (α = 5%, df = 29) was used to calculate the statistically significant mean difference of mean weight in 30 samples of discharged ice cream from the ice cream discharge nozzles #1 through #4. Results showed that there was no statistically significant difference among means as shown in table 1. Averages of weight of discharged ice cream from 120 samples from the four nozzles ranged 43.7-45.2 g.

The result of the discharging performance was considered dependable for the prototype ice cream sandwich enveloping system. Weight of ice cream discharged from the topping unit was considered to be fair enough for discharging and enveloping the ice cream.

2.3.2 Efficiency of Enveloping of Ice Cream Sandwich

Efficiency of enveloping the ice cream sandwiches by the enveloping unit was 94% from the total of 120 enveloped ice cream sandwiches. As shown in Fig. 8, the second enveloped ice cream sandwich was an example of failure of enveloping due to projected sliced bread.

Cause of enveloping failure resulted from positioning of upper sliced bread on the topped ice cream on the lower sliced bread. The upper slices of bread were ejected from the USBEU and dropped from the ejecting plate to the topped ice cream on the lower slices of bread when the ejecting plate was retracted. In this mechanism, a side of the sliced bread was lowered first at the edge of the ejecting plate when it was being retracted causing the bread to slant downward as it was lowered. The placement of the upper sliced bread depended on configuration and location of topped ice cream on the lower sliced bread. As this process could not be completely controlled, any degree of slight rotation, displacement or projection of the upper sliced bread in each ice cream sandwich could exist during placement. Vertical alignment of two slices of bread in ice cream sandwich also depended on configuration and location of discharged ice cream. This was considered to be a major factor in quality of enveloping of ice cream sandwiches.

The shape of each slice of bread was not dependable as they

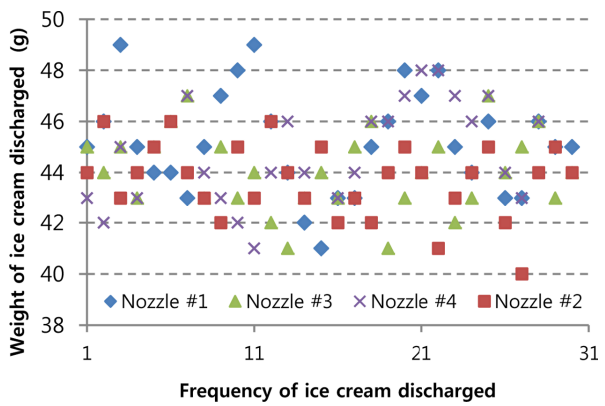


Fig. 6 Distribution of weight of ice cream discharged from ice cream topping unit

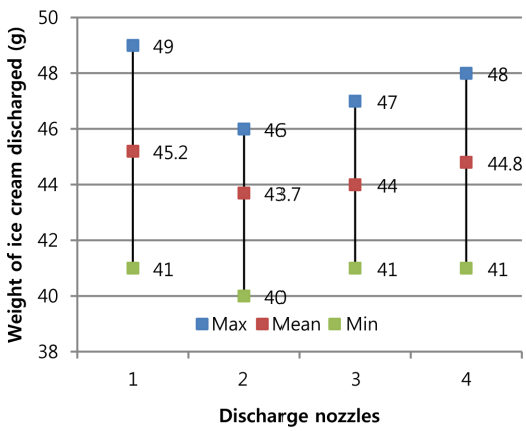


Fig. 7 Range of weights of ice cream discharged from nozzle #1 through #4

Table 1 Average weight of ice cream discharged from nozzle #1 through #4

Nozzle	Average weight of discharged (g)	Standard deviation	95% confidence interval
#1	45.2	2.0356	±0.7284
#2	43.7	1.4657	±0.5244
#3	44.0	1.5643	±0.5597
#4	44.8	1.8458	±0.6604

Fig. 8 Example of enveloping failure of sliced bread in ice cream sandwich

were not perfectly rectangular. As misshapen bread was ejected, a geometrical center line to the moving direction of sliced bread could not be vertical to the pushing-side of the enclosure. The physical condition of sliced bread also affected poor vertical alignment of the two slices of bread in ice cream sandwich, causing failure of enveloping.

Vertically misaligned either upper or lower sliced bread with trimming edge of the cavity mold in the air press also caused enveloping failure of ice cream sandwich. This resulted in holes around the edges of enveloped bread.

Ratio of failure of teared surface of sliced bread was 4.1% from the total of 120 enveloped ice cream sandwiches. Cause of teared surface was due to non-uniform texture of sliced bread. Curved inner surface of the cavity mold stretched out the upper sliced bread while the lower sliced bread was laid on flat surface as the cavity mold was being extracted in enveloping process. This discrepancy resulted in teared surface of the upper sliced bread; the uniformity of sliced bread was not evaluated in this research.

The teared surface in the upper sliced bread was considered improved by replacing the flat base frame of the air press (i.e., a lower-fixed-mold-half) with a cavity mold as the lower-fixed-mold-half. This would improve both the lower and upper sliced bread to stretch out evenly during the enveloping process.

2.3.3 Rate of Ice Cream Discharged

Total weight of ice cream discharged per minute from all four nozzles was calculated in three successions; the total weight equaled 548 g, 551 g and 550 g per replication. With the weight of a discharged ice cream of being 45 g, the unit had the capacity to discharge 12.1, 12.2 and 12.2 samples of ice cream sandwiches per minute from all four nozzles.

2.3.4 Economic Feasibility

Prototype ICSES was capable of enveloping 115,200 ice cream sandwiches per month, which was based on the capability of enveloping 8 ice cream sandwiches per minute, 8 hours per day, and 30 days per month. This capacity could replace 5 to 6 well-experienced laborers for ice cream sandwich enveloping, increase productivity, and lower production cost.

3. Conclusion

Prototype ICSES was designed and manufactured with fully automated sequential procedure, and its performance was evaluated with samples of slices of bread and softened ice cream. Following is summarized results obtained from this research.

- Prototype ICSES was capable of enveloping over 115,200 ice cream sandwiches per month.
- Mean weight of ice cream discharged was found to be 45±3 g, as was initially predicted.
- Average weight of ice cream discharged for ice cream sandwich was 45.2 g, 43.7 g, 44.0 g, and 44.8 g from nozzle#1 through nozzle #4, respectively and there was no statistical significant difference between the nozzles.
- Efficiency of enveloping of ice cream sandwich by the enveloping unit was 94%.
- The discharge unit was capable of discharging ice cream with a rate of 12 ice cream sandwiches per minute.
- Inaccurate placement of the upper sliced bread on topped ice cream on lower sliced bread caused defective products in enveloping process.
- Time span required for discharging ice cream is a major factor affecting productivity of the prototype ICSES.

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