

Development of a Pasting and Garnishing Machine for Manufacturing Kimbugak

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Abstract

Purpose: Kimbugak is one of Korea's traditional snack foods made of laver. Mechanization of the manufacturing process is necessary to produce kimbugak in large quantities and standardize the products for industrialization. This study was conducted to develop a machine that can simultaneously accomplish the two processes of pasting and garnishing for manufacturing kimbugak, and test its performance. **Methods:** A pasting and garnishing machine was designed, and its target work efficiency was set at 720 sheets/h. The performance was tested based on the physical characteristics such as work efficiency, pasting uniformity, and garnishing uniformity. **Results:** With the developed technology, kimbugak could be produced up to a productive rate of 840 sheets/h on a single machine. The pasting uniformity ranged from 91.5% to 96.8%, and a garnishing uniformity of more than 90% could be obtained. **Conclusions:** It is expected that this approach to developing a machine with the functions of pasting and garnishing can contribute to the mechanization of the manufacturing process to produce Korean traditional foods including kimbugak in large quantities and standardize the products for industrialization.

Keywords: Garnishing, Kimbugak, Laver, Manufacturing machine, Pasting

Introduction

Korea produced 416,024 tons of laver in 2014 (KOSIS, 2014). As laver became known as a healthy marine product, a variety of foods made of laver have been developed and laver consumption has been steadily increasing. However, laver is mostly consumed in the form of dried laver, not processed types. Japan is one of the largest importers of Korean laver and produces many types of processed foods made of laver. To promote the Korean laver industry, not only should new processed foods be produced but a mechanization system for mass production should also be developed.

Although interest in the industrialization of traditional Korean foods has been rising recently, most of the foods are made to orders on a small scale because they are

produced manually. Among the processed laver foods, seasoned laver is the only product that is manufactured on a massive scale with machines. Kimbugak is one of Korea's traditional snack foods made of laver and is often used during the country's traditional holidays or wedding ceremonies. The demand for kimbugak has been increasing because of rising standards of living and needs for healthy foods. However, the entire manufacturing processes are done manually, leading to non-standardized products in small volumes. Thus, mechanization of the manufacturing process is necessary to produce kimbugak in large quantities and standardize the products for industrialization. Kimbugak is a traditional snack food that is made from the following sequential processes: uniform pasting of laver sheet with rice gruel, attaching another laver sheet to pasted laver, garnishing with sesame, and drying. A few studies on the food characteristics of kimbugak are available in the literature (Park et al., 2001). Technologies have been developed only for the mechanization of unit

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process (Choi, 2014; Ok, 2014), and no studies of the development of manufacturing machines have been reported.

In this study, a machine that can simultaneously accomplish the two processes of pasting and garnishing for manufacturing kimbugak was developed, and its performance was tested.

Materials and Methods

Laver, rice gruel, and garnish

The traditional way of manufacturing kimbugak involves pasting rice gruel on two dried laver sheets, and then spreading a garnish such as sesame on the laver sheet. In

this study, the process was simplified using a thick laver sheet to manufacture kimbugak within a range that makes little difference to the quality of the product. A preliminary test suggested that there was no difference in quality between the two methods. Therefore, custom-made thick laver sheets were used as the ingredient of kimbugak. The sheet was 4 g per sheet in size of general laver sheet and was made from a mix of underwater stone moss and green laver. Table 1 summarizes the composition of the glutinous rice gruel used in the study. 33 g of rice gruel, which was boiled for 15 min and cooled down to 10°C, was pasted on each laver sheet. The weight of the laver sheet and the volume of the pasted rice gruel were determined based on the evaluation results for the taste, color, smell, and shape. The pasting process was designed so that the rice gruel could be pasted on the laver mechanically when it passed through between two rollers. Roasted sesame was used as garnish, with a weight of 2.2 g per 1000 seeds. The garnishing machine was designed to broadcast 2.7 g of the sesame on a laver sheet based on the results of preliminary tests.

Table 1. Composition of glutinous rice gruel

Glutinous rice gruel		Kelp sauce	
Gradient	Volume	Gradient	Weight
Kelp sauce	2000 ml	Onion	100 g
Glutinous rice flour	200 g	Anchovy	30 g
Mined garlic	50 g	Kelp	30 g
Korean soy sauce	50 ml	Shiitake mushroom	30 g
* for 100 kimbugak sheets		Daikon	240 g
		Water	2000 ml

Design of pasting and garnishing machine

A pasting and garnishing machine is composed of three units: supplying unit, pasting unit, and garnishing unit

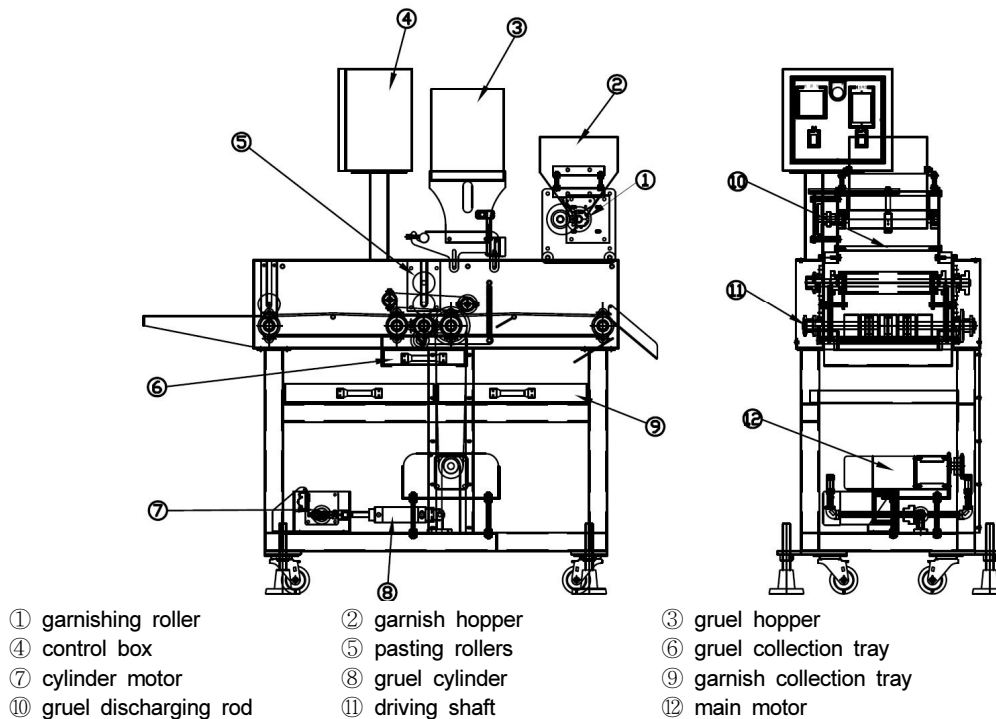


Figure 1. Schematic of the developed pasting and garnishing machine.

(Figure 1). The two processes of pasting and garnishing are performed in consecutive order on one machine. The laver sheet is automatically sent to the pasting-garnishing machine after it is loaded on the supplying unit, which is the same unit used for manufacturing the seasoned laver. The supplying unit is a separate machine with an independent power transmission system. Only pasting and garnishing units were developed in this study. The pasting unit consists of a laver feeding device, pasting rollers, a driving device, a control unit, a rice gruel supplying device, a hopper, and a discharger. The garnishing unit consists of a hopper, discharging roller, controlling unit, and collection tray. Figure 1 shows a schematic of the pasting and garnishing machine. Although the machine was designed to be able to adjust the amount of rice gruel pasted and sesame garnished, it was fixed to use 33 g and 2.7 g of the two, respectively, for one laver sheet.

Performance test of pasting unit

Work efficiency

The work efficiency of kimbugak production depends on the feed rate of laver sheets from the supplying machine and the conveying speed of the sheets by the pasting and garnishing machine. The supplying machine and the pasting and garnishing machine are separate machines, and the laver sheet conveying speed can be individually controlled with separate speed controllers. However, the conveying speeds of the two machines are adjusted to be synchronized so that the two machines can have the same speed. The design criterion of work efficiency was 720 sheets/h, and the work efficiency could go up or down depending on the conveying speed. The work efficiency was measured by counting the laver sheets pasted over a period of one minute. The speed synchronization of the supplying machine and the pasting and garnishing machine was adjusted by measuring the rotational speed of the driving shaft of each machine with a digital tachometer (accuracy ± 1 rpm) and converting it to linear velocity.

Pasting uniformity

The pasting process is carried out when the laver sheet passes through between two contacting rollers. The spacing of the rollers is the major factor that determines the pasting uniformity and can be adjusted. To find the spacing condition for the best pasting uniformity, the weight of each pasted sheet laver and pasting uniformity were

measured at three different levels of roller spacing of 0 mm, 2.6 mm, and 5.2 mm. For every level, the target conditions of work efficiency and the weight of rice gruel were kept at 720 sheets/h and 33 g/sheet, respectively. The pasting uniformity was used as a standard to evaluate how uniformly rice gruel was pasted on the laver sheet. To measure the uniformity, a pasting uniformity measuring device was used that had 1 cm \times 1 cm grids on a clear acryl board. Sensory evaluation was carried out to find the number of grids that were considered to have proper pasting. The number of grids was divided by the entire number of grids corresponding to the size of one laver sheet to express the pasting uniformity as a percentage. For the pasting uniformity measurement, sensory evaluations were repeated 10 times and the averaged values were recorded at each level.

Performance test of garnishing unit

Garnishing uniformity

The garnishing unit has to uniformly garnish 2.7 g of sesame on each sheet at the target work efficiency of 750 sheets/h. The garnishing roller speed determines the performance of garnishing uniformity. The performance of the garnishing unit was evaluated according to both the weight of sesame garnished on one laver sheet and its uniformity. These were measured at the garnishing roller speed levels of 3.2 rpm, 3.5 rpm, 5.5 rpm, and 8 rpm. The weight of sesame garnished was measured by subtracting the weight of the pasted laver sheet from the weight of the garnished and pasted laver sheet for each laver sheet. An acryl board with 2 cm \times 2 cm grids was used to measure the garnishing uniformity. For one laver sheet (21.5 cm \times 20 cm), the number of sesame seeds with a total weight of 2.7 g that should be garnished on each grid and the number of grids were about 1227 and 110, respectively. Therefore, the number of sesame seeds that should be garnished on one grid was 11. In this study, the grids having 11 \pm 10% sesame seeds were counted among the good garnished grids. The number of good garnished grids was divided by the total number of grids corresponding to the size of one laver sheet to express the garnishing uniformity as a percentage. For the garnishing uniformity measurement, sensory evaluations were repeated 10 times and the averaged values were recorded at each level.

Results and Discussion

Pasting machine design

The pasting machine consists of a laver feeding device, pasting rollers, a power transmission device, a control unit, a gruel supplying device, a hopper, a gruel collection tray, and a laver discharging device (Figure 2).

Feeding device and discharging device

The feeding device moves the laver sheet coming from the supplying unit to the pasting rollers. Urethane strings were used to support and smoothly move the laver sheet. The discharging device was designed to have the same structure and function as the feeding device.

Gruel supplying device

Rice gruel is stored in the hopper before being supplied to the pasting device by an air cylinder (ACS3-N-B40-S50). The air cylinder operates with a cylinder motor installed independently from the main motor. The two motors are AC motors (220 V). The cylinder operates according to the signal from a light sensor that senses the movement of the laver sheet. The feed rate of rice gruel depends on the cylinder pumping speed. When the laver sheet passes through the feeding device from the supplying unit, its passage is detected by the light sensor (BM200-DDT), which generates one pulse per passage. The cylinder motor rotates according to the controller's signal, which is generated corresponding to the light sensor's output. One output signal of the controller causes one cylinder motor rotation by using a cam. The cylinder pumps rice gruel once per rotation of the cylinder motor. One rotation of the motor causes one reciprocating motion of the cylinder, which pumps rice gruel to the pasting roller. The volume of pumped rice gruel corresponds to the volume of the cylinder. In this study, the pasting machine was set so that the cylinder motor could rotate twice per pulse from the light sensor. Therefore, the cylinder pumps rice gruel twice to the pasting roller at the passage of every laver sheet. This condition is determined to meet the target work efficiency and the weight of rice gruel pasted on one laver sheet of 720 sheets/h and 33 g, respectively. The volume of the rice gruel hopper made in the form of a rectangular parallelepiped with SUS304 is 17.3 l.

Pasting rollers

Pasting rollers made of silicone are used to evenly spread the rice gruel before it directly reaches the laver sheet. The rice gruel is transferred to the gruel discharging rod by the pumping of the cylinder, and then falls free from the gruel discharging rod. The roller rotates with the frictional force between the roller and urethane strings connected to the stainless shafts on both sides of the roller. The laver sheet passes through the roller, and the rice gruel is pasted on it. The roller spacing can be adjusted.

Power transmission device

The pasting device has one motor for operation. Power is transmitted by chains and gears to each shaft. The motor has a power of 180 W (single phase, AC 220 V) and has a reducer with a gear ratio of 10. The motor is used to transmit power to the main shaft, and the main shaft

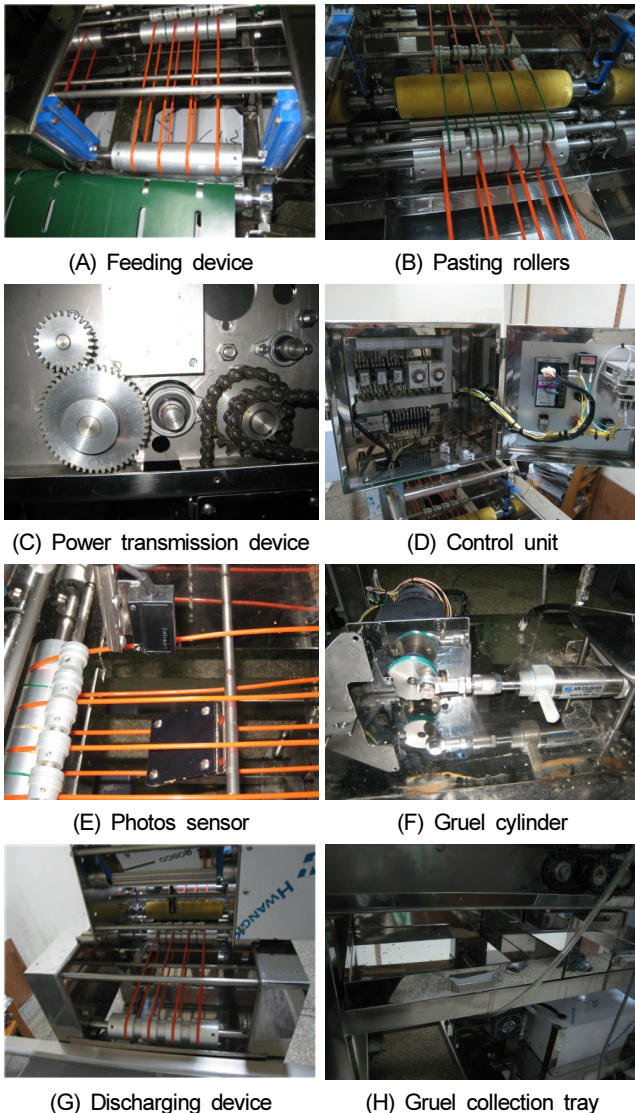


Figure 2. Main parts of the pasting machine.

transmits power to driven shafts such as the shaft of the feeding device, shaft of the discharging device, and shaft of the pasting rollers.

Control unit

The control unit of the pasting device consists of a sensor and a controller. A photo interrupter and a limit switch are used as the sensor. The photo interrupter checks whether or not the laver is supplied. The limit switch, which is in contact with the cam, controls the number of reciprocating motions of the cylinder. The control unit can control the feed rate of laver sheets and the number of cylinder pumping operations per passage of laver sheets. The number of cylinder pumping operations determines the feed rate of rice gruel on laver sheets.

Work efficiency

From the preliminary tests, the work efficiency of the developed machine for manufacturing kimbugak was 600 sheets/h, 720 sheets/h, and 840 sheets/h at the linear velocity of the laver sheet conveying of 11.3 cm/s, 13.6 cm/s, and 16.0 cm/s, respectively. The target work efficiency was set at 720 sheets/h. The developed machine was designed to control both the pasting weight of gruel and the garnishing weight on the laver sheet. The results of the performance test showed that with the developed machine, kimbugak could be produced up to the productive rate of 840 sheets/h on a single machine. Therefore, the productive capacity could be increased easily by parallel combination of the machines.

Pasting performance

The roller spacing and the number of cylinder pumping operations are major factors for pasting 33 g of rice gruel on a laver sheet. From the preliminary test, it was found that two pumping operations of the cylinder were needed for this pasting condition. The roller spacing is the most

important factor. Therefore, the effect of the roller spacing was tested to find the optimal condition with a range of 2.6–5.2 mm. The pasted weight and the uniformity were measured at five levels (Table 2). From the test results, the relation between the roller spacing and the weight of pasting was given by a regression equation (1). From the equation, it was estimated that the target weight of rice gruel of 33 g could be pasted at a roller spacing of 4.5 mm. However, the test results showed that the target weight could actually be pasted at a roller spacing of 4.0 mm. Even though there was a small difference, it was expected that the regression equation could be used to find the optimal spacing for pasting a target weight of rice gruel. The pasting uniformity was found to range from 91.5% to 96.8% in the range of the test levels, and the difference was not significant at the 5% level using Duncan's multiple range test (DMR-test). Thus, pasting uniformity was unrelated to the roller spacing. It was expected that the uniformity could be enhanced if the spacing of the hole pierced on the gruel discharging rod was narrow or a multiple supply system was established instead of supplying the gruel from just the two sides of the current gruel discharging rod.

$$y = 6.25e^{0.37x} \quad (R^2 = 0.94) \quad (1)$$

where y is the pasted gruel weight (g) and x is the roller spacing (mm).

Garnishing unit design

For garnishing sesame, the garnishing unit adopted the broadcasting method using a grooved roller. As the garnishing unit was designed to use the same motor of the pasting machine for its operation, it was developed as one body with the pasting machine. That is, the garnishing is carried out to broadcast sesame continuously after the rice gruel is pasted on the laver sheet. The garnishing unit

Table 2. Effect of roller spacing on pasting performance for two pumping operations of cylinder

Production (sheets/h)	Number of pumping operations	Laver weight (g)	Roller spacing (mm)	Laver weight after pasting (g)	Pasted weight of gruel (g)	Pasting uniformity (%)
720	2	4.2	2.6	16.4	12.2 ^e	94.6 ^a
720	2	4.2	3.9	36.8	32.5 ^d	93.8 ^a
720	2	4.2	4.2	38.5	34.3 ^c	91.6 ^a
720	2	4.2	4.9	42.1	37.6 ^b	91.5 ^a
720	2	4.2	5.2	44.1	39.9 ^a	90.8 ^a

Means in each column followed by the same letter are not significantly different at the 5% level by DMR-test

consists of a hopper, garnishing roller, driving device, control unit, and garnish collection tray (Figure 3). The weight of sesame garnished is determined by the rotational speed and operation time of the garnishing roller made of aluminum. The motor for driving the roller is controlled by a photo sensor and a timer. Both the photo sensor installed at the end of the pasting unit and the timer of the control unit make the roller motor rotate to broadcast garnish while the pasted laver sheet passes through the garnishing unit. The photo sensor detects the entrance of the laver sheet, and the timer controls the operation time of the roller motor. A roller with 12 grooves is employed to use sesame as garnish. The collection tray installed at the bottom of the garnishing unit collects the garnish not attached to the laver sheet.

Garnishing performance

To determine the performance of the garnishing machine, the weight of broadcast sesame and its uniformity were

measured when the laver sheet was conveyed at the garnish roller speeds of 3.2 rpm, 3.5 rpm, 5.5 rpm, and 8 rpm. For all the speed levels, the conveying speed of laver sheet was fixed to be 13.6 cm/s, which corresponds to the target work efficiency of 720 sheets/h. The results are summarized in Table 3. The sesame weight garnished on one laver was 2.2 g, 2.7 g, 6.1 g, and 10.7 g at the respective roller speeds. The target weight of sesame of 2.7 g could be garnished at the roller speed of 3.5 rpm. From the results, the relation between the roller speed and the weight of garnished sesame on one sheet was given by a regression equation (2).

$$y = 1.77x - 3.51 \quad (R^2 = 1.0) \quad (2)$$

where y : is the weight of garnished sesame on one sheet (g) and x is the roller speed (rpm).

The garnishing uniformity was 90.1%, 90.6%, 92.3%, and 95.6%, respectively. The difference was not significant between the garnish roller speeds of 3.2 rpm and 3.5 rpm. However, a higher roller speed resulted in a greater uniformity. Hence, it was concluded that the target weight of sesame garnished and a uniformity of more than 90% could be obtained at the roller speed of 3.5 rpm.

Conclusions

Kimbugak is a traditional Korean snack food made of laver. In this study, a pasting and garnishing machine was developed, and its performance was tested for manufacturing kimbugak. The machine consisted of a laver supplying unit, pasting unit, and garnishing unit. Custom-made thick laver sheets (4 g/sheet) were used to paste rice gruel because the pasting process needed to be simplified for mechanization. Based on preliminary tests, the target pasting weight and garnishing weight on one laver sheet were 33.0 g of rice gruel and 2.7 g of sesame, respectively. The best operational conditions and performance of the developed machine for the productive capacity of 720 sheets/h were as follows—conveying speed of laver sheet: 13.6 cm/s, pumping frequency of gruel cylinder: 2 times/sheet, spacing of pasting rollers: 4.0 mm, weight of pasted rice gruel: 33.0 g/sheet, pasting uniformity: 93.8%, rotational speed of garnishing roller: 3.5 rpm, weight of garnished sesame: 2.7 g/sheet, minimum garnishing uniformity: 91.5%.

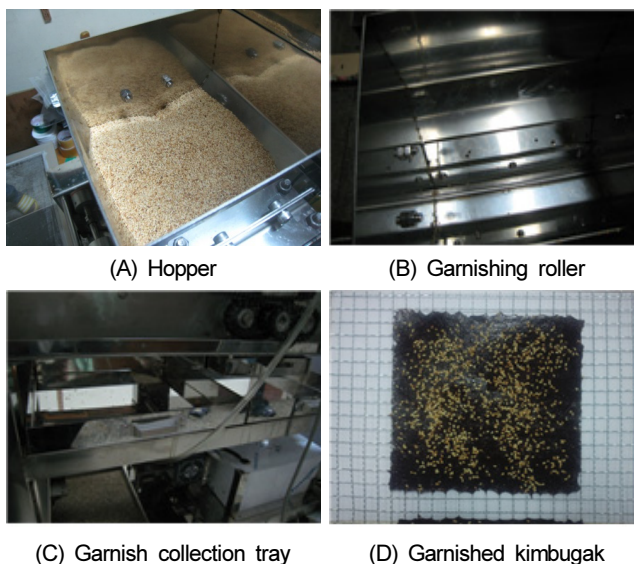


Figure 3. Main parts of the garnishing machine.

Table 3. Effect of roller speed on garnishing performance

Conveying speed (cm/s)	Speed of garnish roller (rpm)	Sesame weight garnished on one laver sheet (g)	Garnishing uniformity (%)
13.6	3.2	2.2 ^d	90.1 ^c
2.8	3.5	2.7 ^c	90.6 ^c
2.8	5.5	6.1 ^b	92.3 ^b
2.8	8	10.7 ^a	95.6 ^a

Means in each column followed by different letters are significantly different at the 5% level by DMR-test

Conflict of Interest

The authors have no conflicting financial or other interests.

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