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Development of a Plum (Japanese Apricot) Seed Remover for Multipurpose Plum Flesh Processing

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Abstract

Purpose: Japanese Apricot, a type of plum, has various medicinal and economical applications. Plums are quite popular worldwide, but their deseeding remains a serious impediment to their processing. Therefore, a plum (Japanese Apricot) seed remover (PSR) was developed that can use various types of cutters according to the purpose of the plum processing, and its performance was evaluated. **Methods:** The proposed PSR, which allows multipurpose cutters, namely, zero-, two-, and four-blade cutters, to be installed, was first designed and manufactured. To identify appropriate parameters related to the cutting pressure, plums were harvested from three regions during three harvesting periods, and their geometrical and mechanical properties were measured. After application of the parameters related to the cutting pressure, a performance test was carried out on both fresh and frozen plums by identifying the ratios of the flesh recovery, seed recovery, seed breakage, deseeding efficiency, and machine efficiency. **Results:** The results show that, using the proper calculation of the processing parameters, 100% deseeding efficiency was facilitated regardless of the type of cutter used. However, in the case of a four-blade cutter, there are significant differences in the flesh recovery ratio according to the plum setting angle. Between the fresh and frozen plums, all cutters showed a significantly better flesh recovery ratio for the case of fresh plums. **Conclusions:** This machine will advance the plum processing technology, and eventually help the plum industry flourish.

Keywords: Automation, Manual labor, Plum, Productivity, Seed remover

Introduction

The Rep. of Korea is one of the flourishing plum producers in the world. In 1980, the plum production was 601 tons on 156 ha of land; however, through an increase in domestic demand and the development of processing technology, by 2008, its production had increased to 28,251 tons on 3,513 ha (Lee et al., 2011). In particular, Jeollanam-do province cultivates about 45.7% of the total area of plums grown, and Gwangyang-gun province produces 28% (Lee et al., 2011). Thus, the plum industry is very important in these two provinces. Plums have an abundance of minerals (Ca, P, K, Al, carotene, iron, etc.), fiber, organic acids (citric acid, malic acid, succinic acid, tartaric acid and oxalic acid), vitamins (C, A, K, E, niacin, thiamine, etc.) and phytonutrients (Kang et al., 1999). They are also effective at relieving blood fluidity, fatigue, coughs, and diarrhea (Chung et al., 2013). It is well known that oxidative damage to the biological molecules in the human body is involved in degenerative or pathological processes such as aging, strokes, diabetes, and coronary heart disease (Shi et al., 2008). The excellent detoxification ability of plums helps in the treatment of stomach pain, food poisoning, constipation, and skin problems. Plums have recently been determined to be a cancer-fighting food (Jeong et al., 2006). Owing to these advantages, plums and processed plum products have been highlighted as functional health foods. When making

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various processed products from plums, the quality can be changed by the characteristics of the plums used, which can vary according to the harvest time, application, and processing methods. In addition, the size and color of the plums differ from one another with respect to the variety. The physical properties of plums, such as their hardness and geometric characteristics, vary depending on the harvest time and storage conditions (Shin et al., 1995). Furthermore, separation between the seeds and flesh is an important factor in the post processing of plums because most post products use only the flesh. In general, plum fruits contain 84-90% (w/w) flesh and 10-16 % (w/w) seeds. Therefore, the development of a system to separate the seeds and flesh is crucial for the development of the plum industry.

Plum post-processing methods commonly include deseeding and cutting operations using a pressing force. Conventional methods still depend on a manual process, through which the plums are placed on a table or concrete floor, and the seeds are squeezed out while pressing down with the hands or a tool. This method is old-fashioned, unhygienic, and requires large amounts of labor and time. Serious injury to the fingers associated with a low flesh recovery ratio also occurs. To promote the plum industry, an advanced high-quality plum seed removal system should be developed to improve the processing technology and industry maturation. Recently, a plum seed extraction machine developed in Japan was demonstrated to perform well. However, this particular machine only includes one type of cutter, an O-shape cutter. To utilize seed-extracted plum flesh, extra labor is required to treat the flesh. The productivity of this plum deseeding machine also needs to be improved. For an improvement in productivity, the machine parameters should be adjustable. Furthermore, a generally developed plum seed remover should be useful for the seed separation of both fresh and frozen plums. Therefore, the efficacy of the machines should be evaluated according to the condition of the plums.

The objectives of this study are to design, manufacture, and evaluate our developed plum seed remover (PSR). First, we designed a PSR in which four cutters can be installed on a machine, all of which can be moved by air pressure concurrently. To calculate the exact deseeding pressure and apply the calculated values in the machine, we collected plums from three regions during three different periods, and measured the required pressure for cutting. After calculating the cutting pressure, the derived values were applied to the machine, and the characteristics based on the various cutters used were analyzed. Finally, the PSR was applied to frozen plums to evaluate its effectiveness.

Materials and Methods

Design and fabrication of plum seed remover

The PSR was manufactured and fabricated using locally available materials. The design, components, and images of the PSR are shown in Figure 1. An air compressor was used to generate pressure for plum deseeding, and a plastic box was used as the flesh and seed collector. The components of the PSR can be classified into five units, such as the supply unit, punching and cutting unit, output unit, operation-control unit, and power transmission unit. A plum holding tray with four holes in each tray is used to hold and move the plums randomly. The punching and cutting unit was mounted on the main frame of the PSR. It contains an air cylinder (CR-TGQL 40-75, ϕ63), which helps to create pressure and can easily push different types of cutters. The main cutters move up and down at the same time, and the cutting and punching of the plums occur continuously through the aid of the air pressure. The up and down movements of the different cutters depend on the sensor (HYP-30S15NA) signal, which takes 3 s for each operation. After this operation, the plums seeds are dropped directly into the seed collector, which is placed under the cutting and punching unit. Also the fleshes of plum were gone to the flesh outlet. Conveying trays were boosted for carrying the recovery flesh to the flesh outlet.

The operational control unit of this machine was fitted with the main frame of the machine. It helps control the sensor and all types of operation using certain programs and electric circuits. The flowing air pressure of the machine was controlled using a pressure regulator. The solenoid valve receives air pressure and serves this pressure to the air cylinder through a pipe. The extra pressure is exhausted through the silencer of the valve. Power is transmitted to each shaft using chains and gears. An induction motor (K9IP180FC) moves the Geneva gear, which transmits power to the main shaft. The main shaft transmits power to the driven shafts, which move the chain continuously. The plum holding and conveyer trays

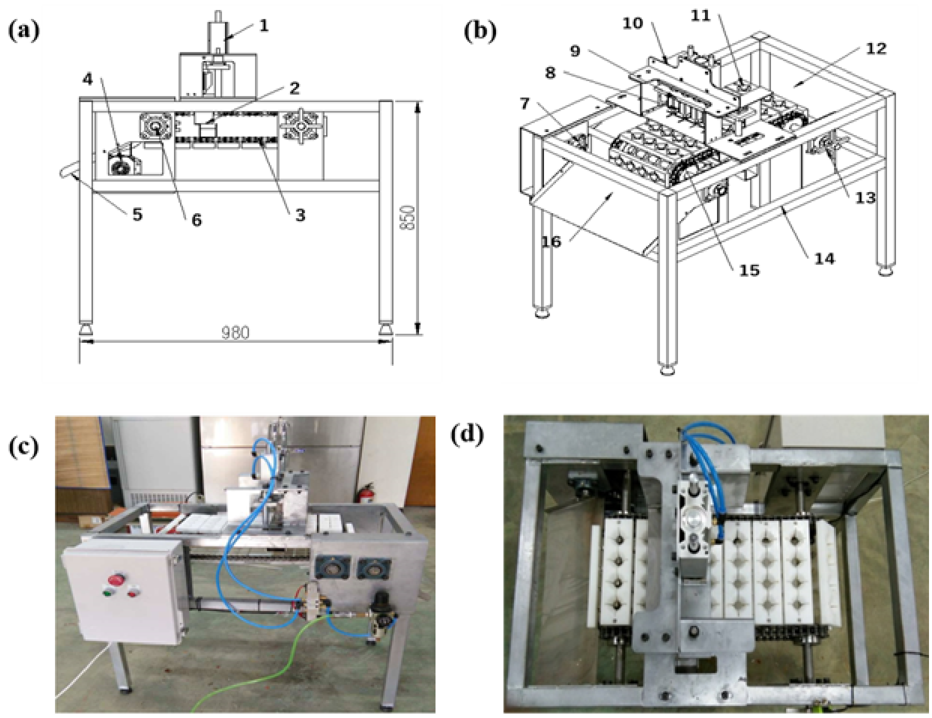

Figure 1. Design and appearance of PSR. (a, b) Schematics of PSR. The numbers indicate the main components of the machine: air cylinder (1), seed collector (2), transmitting chain (3), induction motor (4), flesh outlet plate (5), transmitting shaft (6), Geneva gear (7), cutter (8), cutter attachment plate (9), cylinder support (10), plum positioning hole (11), plum input portion (12), sensing plate (13), main frame (14), plum holding and conveyer tray (15), and flesh outlet (16). (c) Side view of the PSR. Programmable air pressure controlling components were attached to the side of the mainframe. (d) Top view of PSR showing the overall setup of the machine.

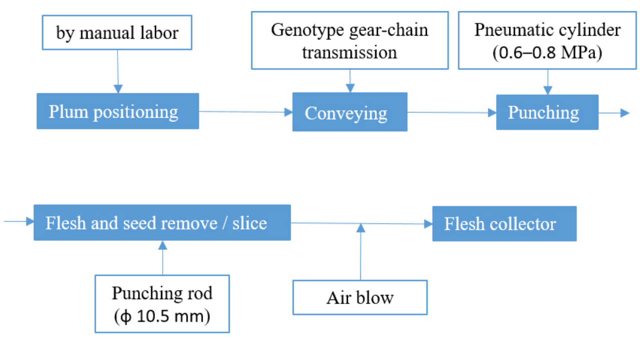

Figure 2. A diagram of the overall processes of the PSR. Plums were selected for the experiment, and after their preparation they were positioned on the conveyer tray manually. Through the help of a genotype gear-chain transmission system, the plum conveyer was moved randomly. On the other hand, the cutters moved up and down continuously using air pressure (0.6-0.8 MPa), and extruded the flesh and seeds of the plums following their slicing.

were attached with a chain. Using this process machine, all process can be run and controlled using a power on-off switch. A flow chart of the machine processing is shown in Figure 2.

Geometry and hardness measurement of plums

The plum samples used to evaluate the performance of the machine were collected from different plum fields in Jeollanamdo province in the Rep. of Korea. An electrical weighing balance and slide calipers were used for the weight, length, and width measurements. The hardness, particularly of three varieties, “Namgo,” “Chungo,” and “Aengsuk,” were determined using puncture methods with a texture analyzer (Stable Micro Systems, UK). Both four-blade and zero-blade cutters were used as a probe for measuring the plum hardness. The probe diameter was 10 mm and the load rate was 1 mm/s, which was determined using a texture analysis program. The maximum hardness of the plum, as well as its shape and size, showed significant differences among the varieties, and affected the performance of the plum seed remover. The hardness tests for the different varieties were divided into three stages according to the maturity. The first ripening stage was on May 29, and the second and third ripening stages were on June 10 and 25, respectively. A total of 160 plum samples were selected for various tests, and their geometric measurements were recorded prior to the hardness test. Finally, the force applied with respect to time for each test was recorded graphically, and the average and maximum forces required to remove the seeds were calculated.

Supplying and positioning of plums

Fresh plums were harvested for testing, and weighed easily with a balance; for the frozen plums, however, some additional time was required for the test. For this reason, the frozen plums were brought out from a refrigerator 20 to 30 min prior to starting the test. The tested plums were positioned at different angles on the plum holding tray, and generally maintained at 0°, 15°, 45°, 90°, and 180° angles by manually fixing their position. The desired cutting and punching pressures were stabled using a pressure regulator, and were supplied from an air compressor through an air conveying pipe. The machine was then ready to be operated. We generated a formula for quantitative measurements of the deseeding quality, and compared it using a statistical analysis. The formula used in this study is as follows:

Flesh recovery ratio

$$F_r = \frac{R_f \times 100}{I_w \times T_f} \tag{1}$$

where F_r is the flesh recovery ratio (%), R_f is the weight of the removed flesh (kg), I_w is the initial weight of the plum (kg), and T_f is the total percentage (%) of flesh.

Deseeding efficiency

$$\eta_d = \frac{N_p \times (N_b + N_u) \times 100}{N_p} \tag{2}$$

where η_d is the deseeding efficiency (%), N_p is the total number of plums, N_b is the numbers of broken seeds, and N_u is the number of partial and unshelled plums.

Machine cutting performance

$$C_p = \frac{N_p}{T} \tag{3}$$

where C_p is the machine cutting performance (kg/h), and T is the total time required for the operation.

Total seed amount

$$G_s = \frac{I_s \times 100}{I_w} \tag{4}$$

where G_s is the total seed amount (%), and I_s is the total weight of the seeds (kg).

Statistical analysis

All experiments were repeated three times at various plum positions, and all results were expressed as the mean ± standard deviation. Statistical significances were analyzed using a one-way ANOVA system (Tukey's multiple range test). The significance between items was verified at a level of 5%.

Results and Discussion

Physical and geometrical plum properties

The plums used in this study were harvested from three regions (Namgo, Chungo, and Aengsuk in Jeollanamdo province) and during three periods (premature, mature, and overmature). The lengths, widths, and weights of the plums varied depending on the region and degree of maturity (Table 1). During the immature stages, the average lengths were from 25.26 ± 0.84 mm (Namgo) to 29.48 ± 3.45 mm (Chungo), and the average widths were from 22.52 ± 0.86 mm to 26.88±3.61 mm, respectively. During the mature stage, the average lengths were from 29.77 ± 1.55 mm (Namgo) to 35.21 ± 3.8 mm (Chungo), and the average widths were from 29.21 ± 1.74 mm to 33.90 ± 3.86 mm, respectively. During the overmatured stage, the average length and width were 37.59 ± 5.60 mm and 37.42 ± 4.67 mm, respectively, although there was no statistical difference among the varieties. The weights of the plums were recorded as 7.15 ± 1.2 g (Namgo) to 25.00 ± 1.63 g (Aengsuk). Omitting Aengsuk, the average weight of every mature plum was below 20 g. Among the three regions, the plums harvested in Chungo were bigger in size than those in other regions, and the plums of Aengsuk were heavier than those of the other regions.

Design and characterization of plum cutters

Plum flesh requires various shapes based on its usage, such as juices, wines, candy, and pickles. The capability of

Table 1. Length, width, and weight of the plums during three different harvesting periods for three plum varieties. The harvesting date of the immature plums was May 29, that of mature plums June 10, and that of the overmature plums was June 25. The plums were collected from the three different locations, Numgo, Chung, and Aengsuk, and the number of samples per group was 160. The mean values with the different letters are significantly different based on Tukey's multiple range test ($p \leq 0.05$)

Variety	Harvesting stages	Mean size (mm)		Mean weight (g)
		Length	Width	
Namgo	Immature	25.26±0.84^{e}	22.52±0.86^{e}	7.15±1.2^{f}
	Mature	29.77±1.55^{cd}	29.21±1.74^{c}	13.39±1.98^{d}
	Overmature	37.59±5.60^{a}	37.42±4.67^{a}	17.54±1.90^{c}
Chungo	Immature	29.48±3.45^{cd}	26.88±3.61^{cd}	11.39±3.95^{de}
	Mature	35.21±3.80^{ab}	33.90±3.86^{b}	21.15±5.40^{abc}
	Overmature	35.11±3.91^{ab}	34.23±3.11^{ab}	22.23±5.70^{ab}
Aengsuk	Immature	27.38±1.76^{de}	25.12±1.22^{de}	9.08±1.55^{ef}
	Mature	33.31±1.99^{bc}	33.37±1.67^{b}	19.38±2.76^{bc}
	Overmature	36.34±1.90^{ab}	36.30±1.53^{ab}	25.00±1.63^{a}

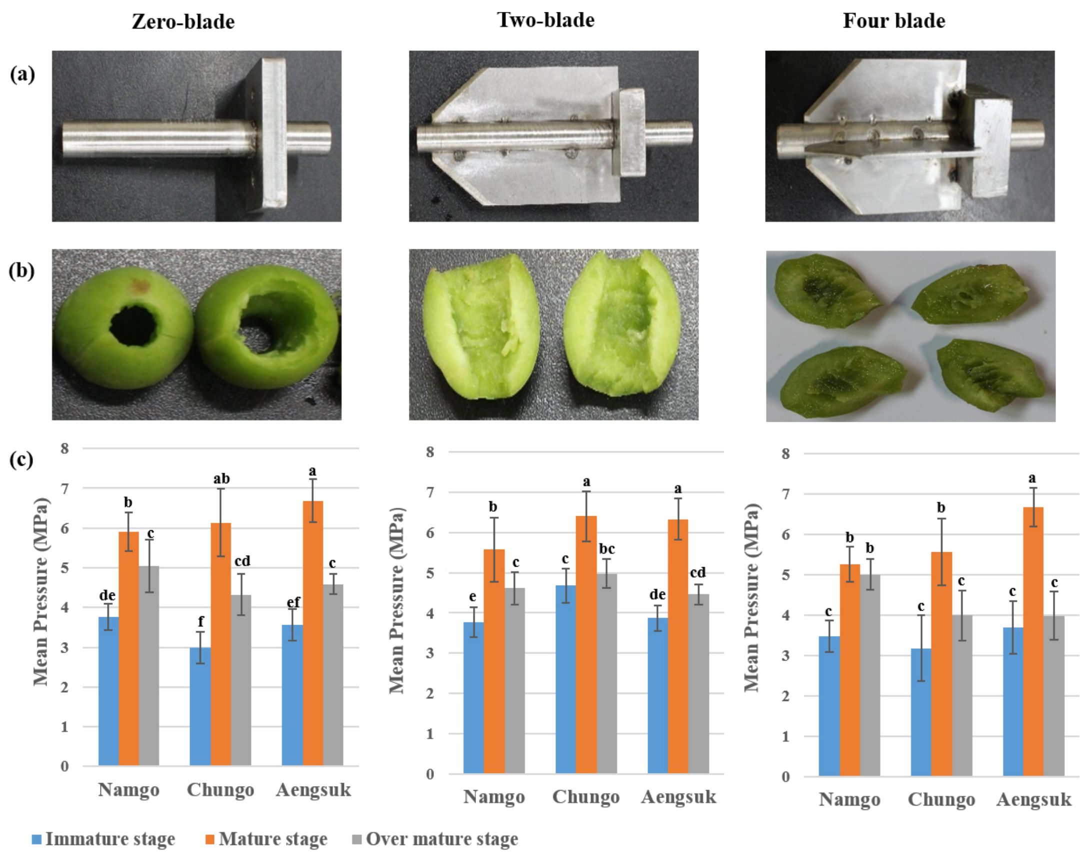

Figure 3. Features of developed cutters and their required pressure for cutting. (a-b) Images of zero-blade, two-blade, and four-blade cutters and their cutting of plum flesh. Using these three cutters, the plum flesh could be easily recovered as one, two, and four pieces, respectively. (c) The required pressures for the deseeding of plums using zero-, two-, and four-blade cutters, respectively. Plums during the full maturation period required the maximum pressure for plum deseeding. Error bars of (c) represent the standard deviation. The different letters on the bars represent the significant differences based on the Tukey's multiple range test ($p \leq 0.05$).

the various types of plum flesh is very important for the plum industry. However, a conventional manual machine and the Japanese machine has only one type of cutter, an O-shape cutter. For an appropriate use of plums, labor is needed for post processing of the plum flesh. The development of various types of cutters according to the use of the plums is a prerequisite. Therefore, we developed various types of cutters including a zero-blade cutter, which is the same as a conventional O-shape cutter, a two-blade cutter for cutting the plums in half, and a four-blade cutter to cut the plums into quarters (Fig. 3a). Furthermore, the minimum pressures required for a successful cutting of the plums depending on the harvesting regions, maturation stages, and shapes of the cutters were investigated using a texture analyzer (Figs. 3b-d). As a result, in all regions, plums during the mature stage required greater pressure than during the other maturation stages. In particular, mature plums harvested from Aengsuk required more pressure, up to 6.68 MPa, than those from other regions. There is no significant difference regarding the shape of the cutters (data not shown). As the number of blades increased, the mean pressure tentatively decreased.

For the successful development of the PSR, its multiple use should be guaranteed. For this reason, the punching pressure of the PSR should be over the minimum required pressure for cutting. Therefore, we designed the mean punching pressure of the PSR to be over 6.68 MPa. At first, we used a Φ40-diameter air cylinder. At that time, the mean cutting pressure was calculated as 4.01 MPa. As a result, the deseeding of four plums concurrently failed on occasion. Therefore, we replaced the Φ 40-diameter air cylinder with a Φ63-diameter air cylinder. As a result, the mean pressure estimated for the plum cutting changed to 9.95 MPa, which is higher than the required punching pressure. Regarding this result, the mean pressure of our developed machine was proven to be appropriate for the three different regions. However, the relevance of the cutting pressure to plums of other regions was not evaluated. To calculate the appropriate cutting pressure, users can measure the mean cutting pressures of plums harvested from other regions, and modulate the air pressure value accordingly. This process will facilitate the variable use of the PSR.

Performance of psr based on cutter shapes

After the evaluation and calculation, we applied the developed cutters and modified the PSR suitable for plum cutting. The PSR was then applied to mature plums, and the results were collected based on the flesh recovery ratio, flesh loss ratio, seed condition and seed recovery ratio, machine capacity, and total loss during the operation, which are important values for the performance evaluation of the PSR. Tables 2 through 4 show the results of the performance test according to the various plum angles, e.g., 0°, 15°, 45°, 90°, and 180°. In all angles, the

Table 2. Deseeding results of fresh plums using zero-blade cutter. The mean values with the different letters are significantly different based on Tukey's multiple range test ($p \leq 0.05$)

Plum type	Setting angle	Deseeding efficiency (%)	Flesh recovery (%)	Seed amount (%)	Seed breakage (%)	Machine capacity (kg/h)
Fresh	0°	100	79.22±2.16[a]	14.28±0.59[a]	10	80
	15°	100	79.78±1.30[a]	13.65±1.13[a]		
	45°	100	78.13±1.28[a]	13.81±0.90[a]		
	90°	100	77.36±2.64[a]	15.35±1.09[a]		
	180°	100	80.70±1.37[a]	13.94±0.73[a]		
Average		100	79.04±1.32	14.21±0.68		

Table 3. Deseeding results of fresh plums using two-blade cutter. The mean values with the different letters are significantly different based on Tukey's multiple range test ($p \leq 0.05$)

Plum type	Setting angle	Deseeding efficiency (%)	Flesh recovery (%)	Seed amount (%)	Seed breakage (%)	Machine capacity (kg/h)
Fresh	0°	100	79.47±1.11[a]	13.84±0.31[a]	5	80
	15°	100	80.15±0.82[a]	13.19±1.73[a]		
	45°	100	77.24±1.09[a]	14.64±1.32[a]		
	90°	100	77.68±1.37[a]	13.87±0.91[a]		
	180°	100	80.23±1.8[a]	13.68±0.75[a]		
Average		100	78.95±1.40	13.84±0.52		

Table 4. Deseeding results of fresh plums using four-blade cutter. Among all positions, a cutting angle of 180° exhibited the maximum flesh recovery. On the other hand, a cutting angle of 90° recorded the minimum flesh recovery. The maximum flesh loss and seed breakage also occurred during this stage. The mean values with the different letters were significantly different based on Tukey's multiple range test ($p \leq 0.05$)

Plum type	Setting angle	Deseeding efficiency (%)	Flesh recovery (%)	Seed amount (%)	Seed breakage (%)	Machine capacity (kg/h)
	0°	100	79.14±1.7[abc]	13.31±0.5[a]		
	15°	100	79.44±0.9[ab]	12.75±1.0[a]		
Fresh	45°	100	77.39±0.6[bc]	12.12±0.8[a]	4±1.8	80
	90°	100	76.22±1.0[c]	12.97±0.7[a]		
	180°	100	81.04±1.3[a]	12.90±0.6[a]		
Average		100	78.65±1.88	12.81±0.44		

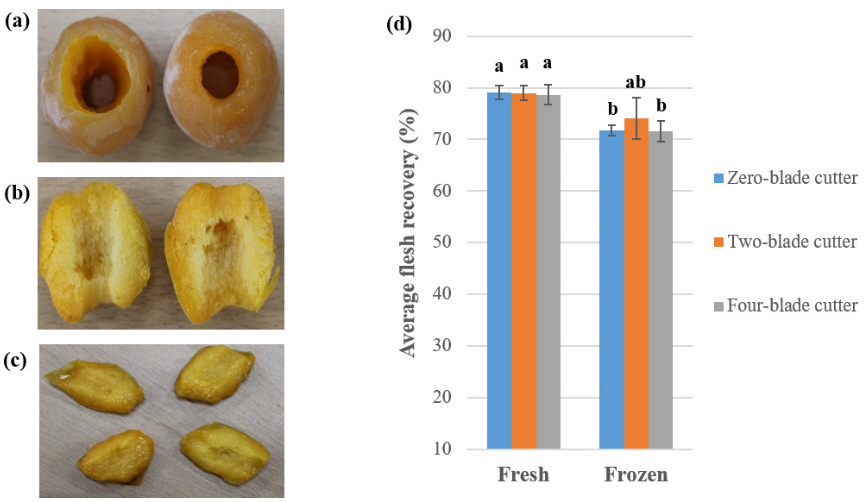

Figure 4. Frozen plum results. (a–c) Representative images of frozen plums treated using (a) zero-, (b) two-, and (c) four-blade cutters. The pieces of the recovered flesh were smooth. Comparison of average flesh recovery ratio for both fresh and frozen plums using three different cutters (d). No significant difference is shown between fresh and frozen plums, and all cutters showed statistically equal results. Error bars represent the standard deviation. The different letters on the bars represent significant differences based on Tukey's multiple range test ($p \leq 0.05$).

PSR with zero-, two-, and four-blade cutters showed 100% deseeding efficiencies, indicating that our developed machine provides sufficient cutting pressure regardless of the angles and cutter shapes used. Furthermore, no additional labor is required to divide the plum flesh. Consequently, the developed machine will be expected to significantly decrease the extra labor required for the dividing of the plum flesh. On the other hand, unlike the cases of zero and two-blade cutters, the four-blade cutter resulted in a significantly different flesh recovery ratio regarding the angles applied (Table 4). An angle of 180° showed the best flesh recovery ratio, whereas angles of 45° and 90° resulted in the worst results. At these angles, the maximum flesh loss and seed breakage also occurred. These results are thought to be deeply related with the structural factors. The shapes of the plums and plum seed are oval. Therefore, the alignments of the plums largely affect the geometrical distribution of forces, resulting in irregular cutting. For the best results, the workers should check the angles of the plums manually. To solve this problem, an alignment device enabling the angles of the plums to be automatically controlled will be required.

Performance of PSR on frozen plums

The plums are usually harvested from May through July. For their sustained use, freezing of the plums is necessary. Occasionally, frozen plums need to be treated. Thus, we assessed the performance of the PSR for frozen plums (Figs. 4a-c). All cutters including zero-blade (Table 5), two-blade (Table 6), and four-blade (Table 7) cutters were tested. As a result, whereas the average flesh recovery ratios of the fresh plums was ~80%, that of the

Table 5. Deseeding results of frozen plums using zero-blade cutter. The mean values with different letters are significantly different based on Tukey's multiple range test ($p \leq 0.05$)

Materials	Setting angle	Deseeding efficiency (%)	Flesh recovery (%)	Seed amount (%)	Seed breakage (%)	Machine capacity (kg/h)
Frozen	0°	100	70.90±2.79^{a}	15.05±0.12^{b}	0	80
	15°	100	71.80±1.38^{a}	15.98±0.16^{a}		
	45°	100	72.19±1.93^{a}	15.04±0.46^{b}		
	90°	100	70.62±0.80^{a}	15.41±0.12^{ab}		
	180°	100	73.24±0.64^{a}	15.82±0.33^{a}		
Average		100	71.75±1.05	15.46±0.43		

Table 6. Deseeding results of frozen plums using two-blade cutter. A 180° plum position showed the maximum flesh recovery compared with the other angles. Furthermore, the results of the two-blade cutter at 180° exhibited significantly better results than the other angles. The mean values with different letters are significantly different based on Tukey's multiple range test ($p \leq 0.05$)

Plum type	Setting angle	Deseeding efficiency (%)	Flesh recovery (%)	Seed amount (%)	Seed breakage (%)	Machine capacity (kg/h)
Frozen	0°	100	71.75±2.91^{bc}	15.09±0.41^{a}	0	80
	15°	100	73.04±0.97^{b}c	15.33±0.36^{a}		
	45°	100	70.02±1.44^{c}	14.78±0.46^{a}		
	90°	100	75.01±1.44^{b}	10.74±0.82^{b}		
	180°	100	80.42±0.94^{a}	11.50±0.10^{b}		
Average		100	74.05±4.00	13.49±2.19		

Table 7. Deseeding results of frozen plums using four-blade cutter. The mean values with different letters on the tables are significantly different based on Tukey's multiple range test ($p \leq 0.05$)

Plum type	Setting angle	Deseeding efficiency (%)	Flesh recovery (%)	Seed amount (%)	Seed breakage (%)	Machine capacity (kg/h)
Frozen	0°	100	70.59±1.50^{b}	14.69±0.15^{a}	0	80
	15°	100	69.78±0.61^{b}	15.37±0.60^{a}		
	45°	100	70.70±0.71^{b}	14.87±1.15^{a}		
	90°	100	72.04±1.58^{ab}	14.56±1.00^{a}		
	180°	100	74.69±2.18^{a}	15.91±0.89^{a}		
Average		100	71.56±1.93	15.08±0.56		

frozen plums was severely decreased: the flesh recovery ratios of zero-, two-, and four-blades were 71.75 ± 1.05, 74.05 ± 74.05, and 71.56 ± 1.93%, respectively, without a significant difference (Fig. 4d). These results are attributed to the alteration of the flesh conditions. When freezing, the inner structures of the plum flesh collapse because of the crystallization of freezing water. Thus, after a thawing of the plums, the mechanical properties of the flesh drastically decreased, resulting in a tearing of the flesh and a decrease in the flesh recovery. For the proper use of PSR on frozen plums, the development of storage techniques to reduce the water crystallization and maintain the mechanical properties of plum flesh is required.

Perspectives

We developed the PSR for multiple purpose plum treatment. In particular, various types of cutters were developed to reduce manual labor. Through the proper calculation of the punching pressure, the PSR successfully removed the plum seeds and divided the plum flesh into one, two, and four pieces. These results indicate that a proper positioning arrangement of the plum seed remover achieves good results. In addition, when a zero-blade cutter is used, the results were similar; however, for two- and four-blade cutters, the results showed a statistical variation, and thus it will be possible to increase the overall performance of the plum seed remover. Finally, the plum seed remover deseeding efficiency was 100% for all different stages, and for 0°, 15°, and 180° cutting and punching positions, no seed breakage occurred. However, for the relevant use of multi-purpose cutters, an alignment machine is required. When punching, a wobbling of the plums occurred, resulting in an incomplete cutting of the flesh and a decrease in the flesh recovery ratios. To solve this problem, pre-punching devices for tightly holding the plums are necessary. Furthermore, the overall flesh recovery ratio was approximately 80% for fresh plums, and 70% for frozen plums, and the machine capacity was 80 kg/h, which is two-times higher than that of the Japanese machine. However, the proposed machine still requires manual labor when installing plums into the device. Consequently, a follow-up study for plum seed removal should aim at the development of a fully automated PSR, namely, 1) the addition of pre-punching devices to hold the plums and increase the flesh recovery ratio, 2) the development of a plum-alignment device that is able to align the plums for proper cutting, and 3) the development of automatic plum-supplying devices facilitating the plum supply without manual labor. The development of a fully automatic PSR will reduce the costs related to manual labor, and eventually enhance the plum industry, as well as the agricultural economy.

Conclusions

A mechanical plum seed remover was constructed for the purpose of deseeding both fresh and frozen plums. The plum seed remover machine can use zero-, two-, and four-blade cutters. According to the plum size and shape, a positioning unit should be designed to obtain the desired plum position. Average flesh recovery was different for fresh and frozen plum because frozen plum deseeding time was too short around half an hour taken when it brought out from freeze to environment after this time the plum started to loss its flesh amount. More research on this machine will be helpful to obtain more feasible results as well as greater benefits for agricultural farmers and traders.

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