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Development of a Metering Device for a Garlic Clove Planter

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Abstract: Objective of the study was to develop a garlic clove metering device. The metering device consisted of a drum, a bucket and a bucket cover. A garlic clove simulator was designed to simulate motions of garlic cloves in the metering device. Simulation was performed using a multibody dynamic analysis program, RecurDyn version 5.1. Physical properties of garlic cloves such as mass and center of gravity were determined using 3D CAD modeler, IDEAS version 10.0. In order to compare the results of the simulation with actual movement of a garlic, movement of garlic clove was photographed by a high speed camera. A prototype metering device was built and tested under various metering speeds and metering guide angles. At the 12 rpm metering speed, rate of single-clove-discharge was 90.0% and missing rate 1.3% at 5°.

Keywords: Garlic, Metering Device, Planter, Garlic Clove Planter

Introduction

Garlic, along with red peppers, is one of the major seasoning vegetables in Republic of Korea. Clove planting is one of the most laborious operations for Korean garlic production. The garlic planting, for requiring tremendous amounts of human labor, has been done manually, resulting in the increase of production cost. Because of the geometrical uniqueness and irregularity of garlic cloves, mechanization of garlic clove planting is very difficult. To overcome price competition against imported garlic, however, there has been need of development of a clove metering device for a garlic planter.

Overall objective of the study was to develop a garlic clove metering system. Computer simulation and laboratory tests were conducted to meet the following objectives:

1) Characterize geometries of garlic cloves produced in mild winter regions, Korea, and determine a garlic clove model based on the results. Then measure the shape of a selected garlic clove by a 3D scanner. The Scanned garlic was compared with the garlic clove model designed by a 3D CAD modeler.
2) Based on the modeled garlic clove, design a bucket and a metering device to develop a garlic clove metering system.
3) In order to investigate falling motion of garlic cloves from the metering device, computer simulation was conducted with a simulator. And, the result was compared with the photographed garlic clove motion.
4) Conduct laboratory tests the prototype under different drum rotation speeds and metering guide positions.

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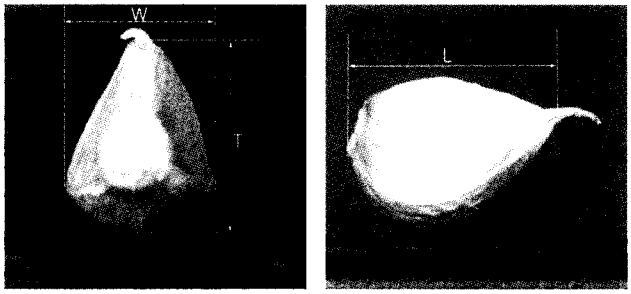
Materials and Methods

1. Measuring and modeling garlic cloves

Garlic feature circular cloves around woody remnants of a scape. Thus shape of garlic cloves is geometrically irregular. Cultivar of Namdo in mild cold areas, the major variety in Korea, was chosen as a sample garlic.

One representative garlic clove was chosen for four physical properties (length, width, thickness, and mass) of garlic cloves, and they were proposed as standard values for Namdo garlic. And the garlic clove was scanned, using a 3D laser scanner (Surveyor DS 2030, LDI, USA) to design



(a) Front view **(b) Side view**

Fig. 1 Geometrical notations of a garlic clove.

a garlic clove model.

A garlic clove model was designed with a 3D CAD modeler (IDEAS 10.0, EDS, USA) to simulate motions of garlic cloves in a metering device. And the garlic clove model was used to design a bucket and to simulate the metering device. The garlic model was evaluated by comparing the center of gravity and volume of actual garlic cloves and the garlic model.

2. Design of metering device

A garlic clove metering device was constructed with a mechanized drum-bucket assembly to pick up a single clove by each bucket. The device has six buckets fixed onto the drum, and the groove of the bucket was designed to contact with the bottom of a garlic clove. As each bucket passes through the seed hopper, it picks up a single garlic clove.

3. Analysis of motion

In the process of garlic clove design using a 3D CAD, weight and center of gravity can be obtained easily.

The analysis was performed using a multibody dynamic analysis program (Recur Dyn 5.1, FunctionBay, Korea). Physical properties of garlic cloves such as mass, center of mass and moment of inertia were determined with a 3D CAD modeler. In simulation of falling motion of garlic cloves, it is possible to obtain fundamental data for design of a metering system.

Simulations were conducted at different drum rotation speeds. The rotation speed levels were 10, 12 and 15 rpm.

The garlic clove metering device that has been manufactured and used for laboratory tests was a type drum with 6 buckets, and each bucket contained a cover. A metered garlic clove can be fell out of the bucket when the bucket cover contacts with the metering guide. The falling motion of garlic cloves from the bucket was photographed with a high speed camera, and the falling trajectory of cloves were compared with the results from the multibody dynamic analysis program.

The high speed camera system consist of a high speed camera (MotionXtra HG-100K, Redlake, USA), image analyser (Image Express Motion Plus, SAI, USA), and light kits (1KW Halogen Lighting 2Ki).

Start from the moment when a clove fell from the bottom of the drum, 110 frame imagery (0.22 sec) was taken and analysed. Simulation results were compared with the actual garlic clove trajectories, the garlic clove metering device that with the simulation results were determined. The acquisition resolution rate was 500 frame per second.

In order to compare it with the results of the simulation, the actual trace of garlic clove was analysed. On these studies, garlic clove metering device was analysed to find one that would attend garlic clove metering simulator.

4. Test of metering system

The garlic clove metering system constructed and used for laboratory tests was a drum type with a bucket and bucket-cover.

Laboratory tests were conducted in the final development phase under various drum speeds and positions of metering guide. Tested drum speeds were 10, 12 and 15 rpm, and positions of metering guide were -10, -5, 0, 5, 10°.

Results and Discussion

1. Garlic clove modeling

Length, width, thickness of garlic cloves was ranged from 17.8 to 33.8 mm, 11.8 to 22.5 mm, and 13.5 to 24.4 mm, 1.9 to 6.1 g, respectively, as shown in table 1.

From the property measurements, a representative garlic clove was chosen. And Figure 2, 3 and 4 show the selected garlic and the designed garlic model.

Center of gravity of the garlic model were 0.3 mm less to right position of x direction and 0.9 mm lower to the y direction than the representative garlic. Volume of the selected garlic and the garlic model were 4076.0, 4044.5 mm^3.

Table 1 Physical properties of the experimental garlic cloves (N=105)

	Min	Max	Ave	S.D.
Length (mm)	17.8	33.8	28.5	2.8
Width (mm)	11.8	22.5	16.4	2.4
Thickness (mm)	13.5	24.4	19.6	2.0
Mass (g)	1.9	6.1	4.0	0.9

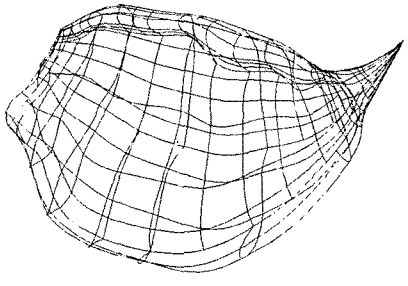


Fig. 2 Laser scanned representative garlic clove.

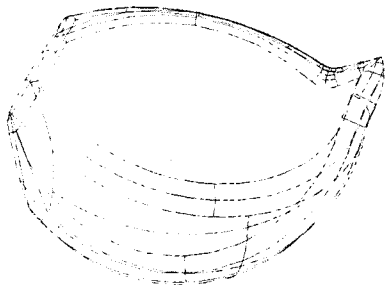
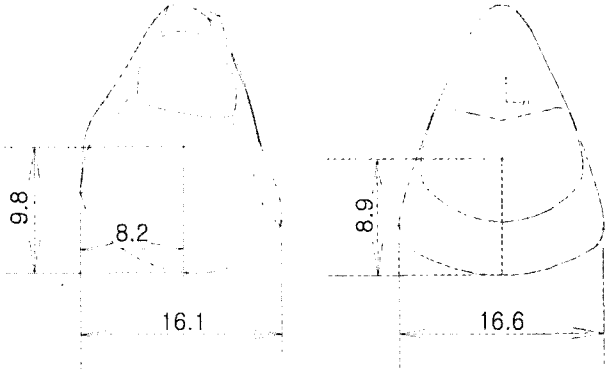


Fig. 3 Simplified garlic clove.



(a) Laser scanned representative garlic clove (b) Simplified garlic clove

Fig. 4 Locations of center of gravity for the laser scanned representative garlic clove (a) and a simplified garlic clove (b).

2. Design of metering device

As shown in figure 5, the prototype metering system consisted of a drum, a seed hopper, a bucket, and a bucket-cover. The bucket was designed and constructed to put the garlic clove into each bucket with a bucket-cover (fig. 6).

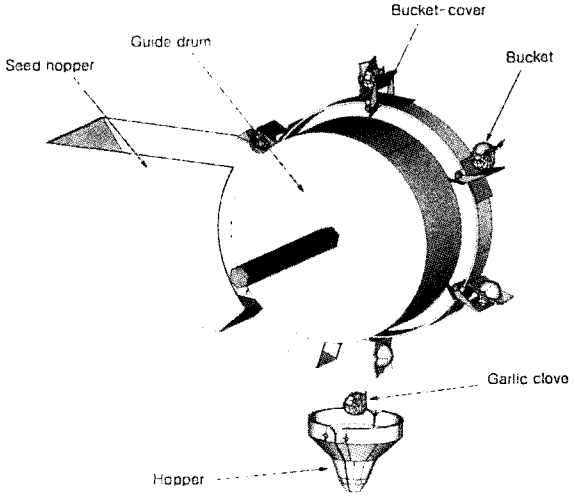


Fig. 5 Modeled garlic metering device.

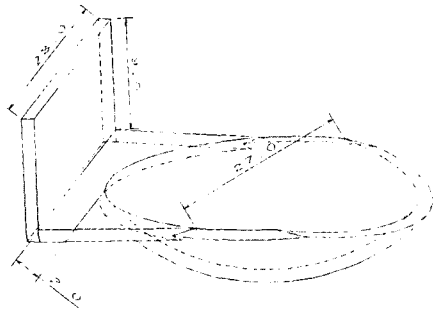


Fig. 6 Schematic diagram of the designed bucket.

3. Motion analysis

Simulation times with the garlic clove showed that the trajectories for a garlic clove to fall out of the bucket was 0.22 sec. Figures 7 and 8 show the trajectories of the representative garlic model simulated and photographed.

From the results of the simulations, it was found that positions of a garlic clove in x direction after 0.22 sec at 10 rpm was 2.2 mm lower than that of the computed results. And at the rotation speeds of 12, 15 rpm, the distances between two tests were 3.0, 6.0 mm. The rotation speeds were 10, 12, and 15 rpm, and distances in the y directions were 22.6, 32.5, and 34.4 mm.

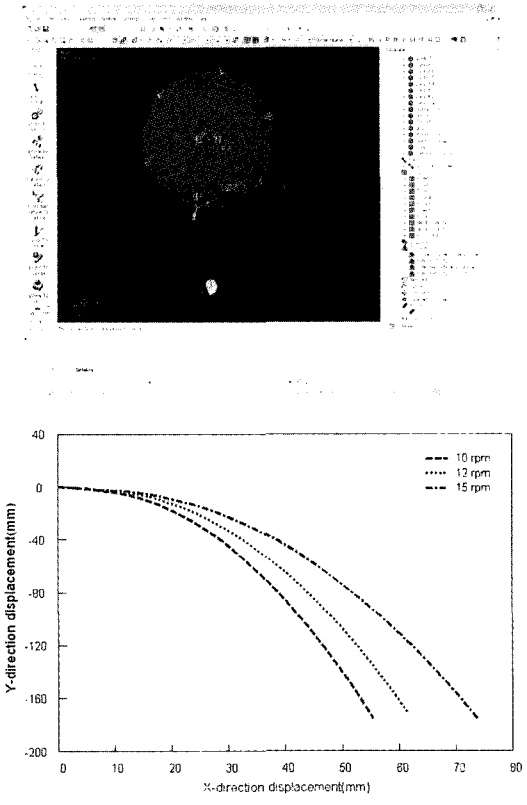


Fig. 7 Simulation of falling motion of the garlic model.

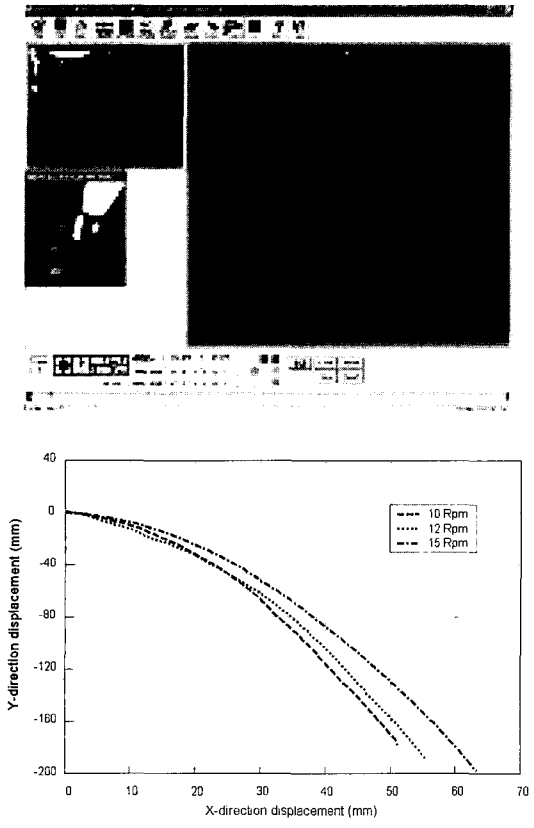
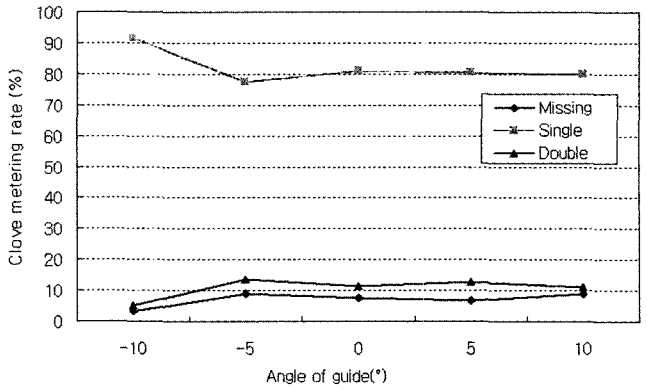
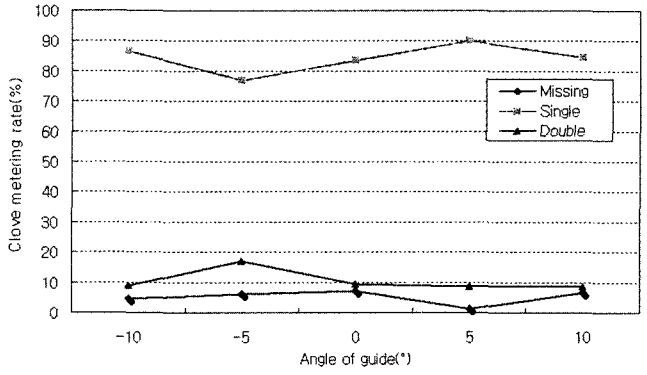


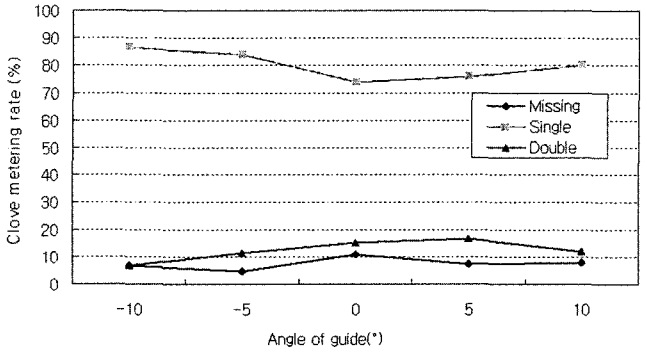
Fig. 8 Analysis of falling motion of the selected representative garlic clove.



(a) 10 rpm



(b) 12 rpm



(c) 15 rpm

Fig. 9 Result of the metering tests showing seed metering rate with respect to metering guide positions (-10～10°) for three drum rotation speeds (10, 12, and 15 rpm).

4. Metering test

Test results with garlic cloves showed that metering rates at the rotation speeds of 10, 12, and 15 rpm and metering guide angle -10～10°. Figure 9 shows the results of the metering tests.

Based on the results, the average overall rates were determined. Rates of single clove discharge and missing were 77.5～91.6% and 3.2～9.0% at the 10 rpm. And the rates of single clove was 83.5～90.0%, except the case of -5° at the 12 rpm.

Best results were obtained at 5° of metering guide angle, single clove discharge settings. Rate of single-clove-discharge was 90.0% and missing rate 1.3% at 5°.

At the 15 rpm metering speed, single clove discharge rate was 74.0～86.6%, and double clove-discharge was 6.7～16.7%.

Conclusions

Geometries of a Korean garlic clove were measured. And average shape and characteristics of the cloves were determined. A scanned garlic clove was compared with a representative garlic clove model. From the results of simulation, positions in x, y directions after 0.22 sec at 10～15 rpm showed 2.2～6.0 mm distance differences compared with those garlic clove motions. In y direction, they were in range of 22.6～34.4 mm.

Test results of a metering device showed the single clove metering rates at rotation speed of 12 rpm. And metering guide angle of 5°, the most good result was obtained, and the rate of the single clove discharge was 90.0% and missing rate was 1.3%.

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