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# Development of a Food Handling Gripper Considering an Appetizing Presentation*

Gen Endo[1] and Nobuhiro Otomo[2]

*Abstract*— **In recent years, industrial robots have been applied to food production because of its huge potential market. Although cooking large amount of foods are done by specially designed cooking machines, dishing up the cooked foods remains as a labor-intensive task. To solve this problem, this paper proposes a new food handling gripper which is suitable for lunch box setout considering appetizing shape of presentation. A two degree-of-freedom multi-fingered gripper with a sliding push part was developed, and evaluated by grasping experiments with noodles and simmered foods. The gripper could put the food with a circular cone shape and control the amount of grasped food.**

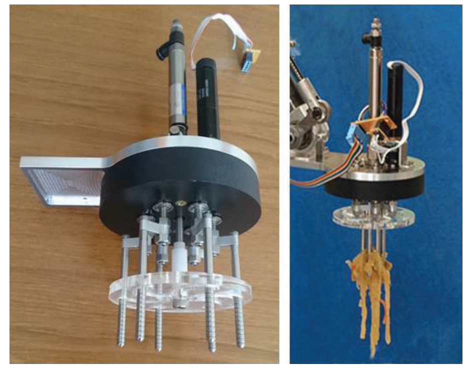

Fig. 1. Overview of the proposed food handling gripper named ”Tsummori-Hand (TMH)”

Fig. 2. Typical lunch box ”Makunouchi” of Japanese cuisine


Fig. 3. Line production in a lunch box factory placing foods in a serving dish.

## I. INTRODUCTION

Industrial robots have been improved mostly based on requirements of automotive industry. In recent years, new applications of the industrial robots have been pioneered especially in pharmaceutical production, cosmetic production and food production. A delta type parallel robot developed by ABB is applied to a high speed pick-and-place task combined with visual tracking for pancake stacking [1]. A serial link 5/6 degree-of-freedom (D.O.F.) manipulator which secure the cleanness of the robot has been developed by FANUC, targeting food, medical supplies and cosmetics [2].

In this paper, we focus on a food handling task for making a lunch box and propose a new gripper named ”Tsummori Hand” (Fig.1). Final goal of this development is to make a typical lunch box in Japanese cuisine ”Makunouchi” shown in Fig. 2. One of the largest lunch box company, which supplies to the most major convenience stores in Japan, can produce six million lunch boxes a day at maximum [3]. However, it is said that net profit of an individual lunch box is estimated around only 1.8% whereas personnel expenses are more than 11%. Figure 3 shows a typical line production to layout the foods into the boxes, and indicate that dishing up task is indeed labor-intensive. Therefore, automation is highly demanded in order to increase net profit.

There are several related works for food handling tasks. Based on the same motivation of ours, Sakamoto et al. discussed handling a visco-elastic object such as Sushi roll by two fingers gripper with stiffness control [4]. Pettersson et al. designed a force controlled two fingers grippers to handle easily damaged natural food products such as vegetables and fruits [5][6]. Vacuum suction pads are one of solutions to pick up fresh foods or packed food products [8], and already commercialized for sweet treat production, frozen food production and so on [7]. A gripper based on Bernoulli principle have been also proposed because the gripper does not directly touch the food, and demonstrated a pick-and-place task with sliced cucumbers and tomatoes [9]. Sakamoto et al. proposed a special device which has two needles and diagonally pierces to a grilled meat to pick it up [10].

However, to the best of our knowledge, almost all the

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previous works did not concern about the final shape of the placed food. We believe that delicious looking is one of the most important aspect for food products. Especially, lunch box layout largely affects to the customer's decision. Additionally, grasping foods of specified amount is also important in order to equalize quality of products. In case of lunch box production line, each foods are previously cooked and seasoned by specially designed cooking machines in large amount, and put in a food container tray nearby a factory worker. The worker picked the food and put it on a lunch box container. Thus, picking up foods with specified amount is very important functionality of this task. Moreover, huge variety of foods, which are difficult to handle by previously developed two fingered gripper, vacuum sucker, Bernoulli chuck and piercing, still exist such as pasta, simmered foods in soup, boiled beans, sticky foods and so on.

In this paper, we determine a circular cone shape as a target shape. It is generally known in Japanese cuisine that food on a dish should be placed three dimensionally for a good presentation. For example, a simmered food should be formed like a circular cone shape. To verify the efficacy, we made a questionnaire survey whether food shapes affect to human willingness to eat. Two photographs were shown to the 22 Japanese subjects and we asked that "Which one would you like to eat?" The amount of food and size of the dish were the same, and the only difference was the shapes of foods. Two types of foods were tested. One was a simmered shredded radish and the other was a noodle salad (Fig.4).

As we expected, the most of the subjects preferred to the circular cone shape regardless of the displaying order of the photographs. The subjects of 82% choose (a) whereas horizontal circular shape (b) was selected only by the subject of 18%. The same tendency was observed in case of (c) and (d).

Although this result could be dependent on cultural background, the result seems to be general because a pasta dish is often served with a circular cone shape in European and American cuisine. At least, a food formed a circular cone shape is more appetizing for Japanese people, indicating the potential added value for the food handling task.

In this paper, we propose a new 2 D.O.F multi-fingered gripper considering appetizing shape of foods. The proposed gripper can grasp cooked foods of specified amount by controlling the finger opening radius and insertion depth into foods in a large container. Additionally, a linearly moving push part releases the grasped food that is potentially capable of forming a desired shape of the placed food.

The rest of this paper is organized as follows. The Section II proposes a new food handling gripper with an appetizing food shaping function. The Section III describes mechanical design of the proposed gripper. Then, the Section IV reports experiments to verify the effectiveness of the gripper using a light duty manipulator. The last section concludes this paper and discuss future work.

## II. PROPOSED MECHANISM

Figure 5 shows basic mechanism of the proposed gripper. In order to achieve a simple operation and cost-effectiveness, we propose two D.O.F. hand. Multi-fingers arranged to form a circle can change the diameter of inscribed circle of the fingers by simultaneously rotating the planetary gears. The planetary gears can be driven by a single internal ring gear. Thus, multi-finger's opening/closing motion is one D.O.F. In this example, we show six fingered gripper. However, our proposal is not limited to six fingered. We can increase/decrease number of fingers depending on the property of the target food.

Additionally, the proposed gripper has a push part to place the grasping food without opening the fingers. This push part moves in a translational motion of one D.O.F. The push part can be changed depending on the desired shape of the food such as a circular cone and a half-sphere.

The grasping sequence is as follows. First open the multi-fingers with a specified radius, and insert fingers into foods stored in a large container tray. Then close the fingers, move the gripper upward, and position the foods to the target


Fig. 4. Willingness to eat changes depending on the food shape. Percentages of willingness to eat are (a)82%, (b)18%, (c)9% and (d)91%

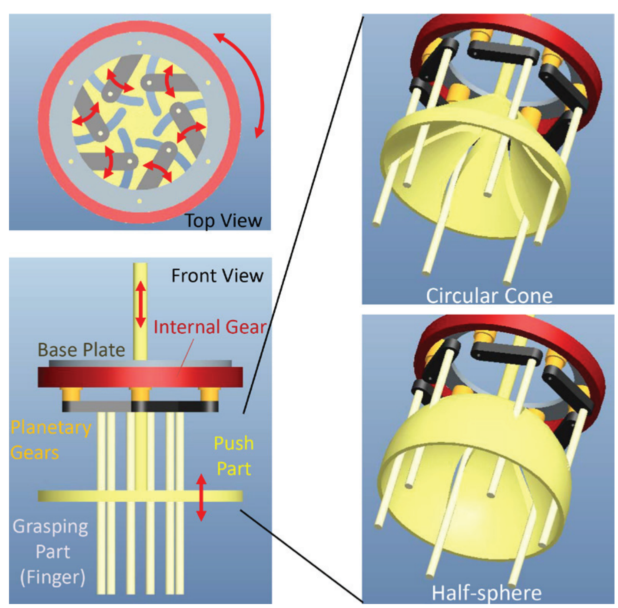



Fig. 5. Fundamental mechanism of the proposed gripper

location, and finally release the food. There are two methods for releasing the grasped food. One way is to open the fingers and the other is to push the food down by using the push part.

This gripper has several advantages. Since the fingers are arranged in a circle and changes its radius inward, the grasped food shape tends to be a circular cone. The amount of the grasping food can be adjusted by changing the opening radius and/or insertion depth to the food. Moreover, the gripper can put the food at the corner of a lunch box because all the fingers are thin and the gripper access to the target location from the top. Additionally, if the cooked food contains a liquid such as source and syrup, the gripper can squeeze the liquid, which is important for a lunch box not to mix the taste. In this case, force control for finger grasping movement will be required, which will be also effective to handle soft and unstable foods. The push part can adjust the final shape of the placed food by designing an appropriate shape of the push part. It can be also effective for releasing sticky foods.

This finger opening/closing mechanism itself is not a novel mechanism because we can find many previous works such as [12][11]. However, this gripper has a novel linearly moving push part in order to customize a desired shape of the placed food. Moreover we also believe this is a new application and can provide a new functionality for food production task such as appetizing presentation and quantitativity of grasped food.

We designed a hardware prototype shown in Fig. 6. In this implementation, a DC motor with a rotary encoder rotates one planetary gear, and the other planetary gears are rotated via a bearing floated ring gear. A push part is driven by a pneumatic actuator with a solenoid valve. We choose a flat push part for initial prototyping and the different shape of the push part will be investigated in the near future.

The total weight of the gripper is $485g$ and the maximum finger radius is $28.5mm$, the stroke of the push part is $40mm$, which is the same length of the finger. The diameter of each finger is $4.0mm$ and there are ten grooves at the tip of each finger in order to increase friction between the finger and foods. Since this is an initial prototyping, we do not consider hygiene. However it is not so difficult to modify hygienical design because most of moving parts can be enclosed.

## III. EXPERIMENTS

In order to carry out experiments for verification. we installed the gripper at the tip of our light duty arm [13]. The arm was developed to work with human workers. Thanks to a gravity compensation mechanism with a non-circular pulley and a spring, the installed actuator power is only $20W$ for each joint while the arm has long reach of $985mm$, comparable with a human. Since the arm structure weights only $1kg$, it is safe compared with an ordinary industrial robot. The gripper is kept vertical due to the additional parallel linkage to the wrist pitch joint. Thus, the fingers are always inserted vertically to the grasping food. The arm is controlled by a position control from Windows PC via CAN communication.

We carried out pick-and-place experiments to evaluate the proposed food handling gripper. One of the most important functionality of the gripper we should test is to control the amount of grasped foods. We did 15 times pick-and-place experiments and measured the weight of the grasped foods each time. Averaged weight and standard deviation were calculated to discuss its performance. We investigated 1) number of fingers n, 2) finger opening radius R and 3) insertion depth d (where total depth of test foods is D). These definitions are visually shown in Fig.8-10. In each grasping phase, R was kept constant value of $7.5mm$ in order to generate sufficient grasping force. In releasing phase, R slightly increased and the foods naturally slipped down due to the gravity except for the last experiments. Additionally, we also evaluate the shape of the placed foods by using the flat push part.

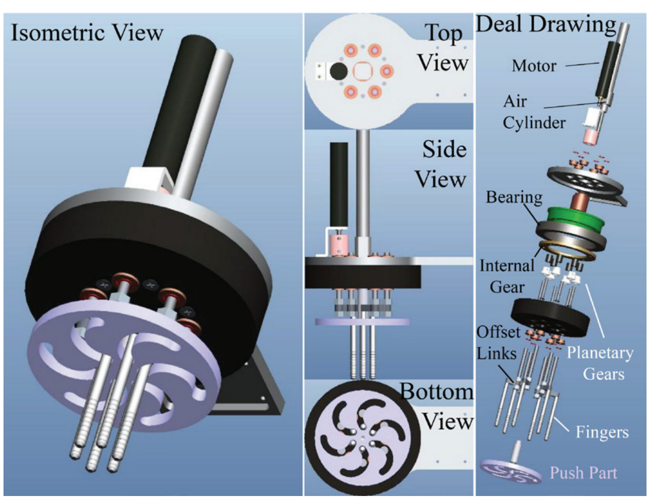



Fig. 6. Hardware prototyping of the proposed gripper

Fig. 7. Light duty arm equipped with the proposed gripper

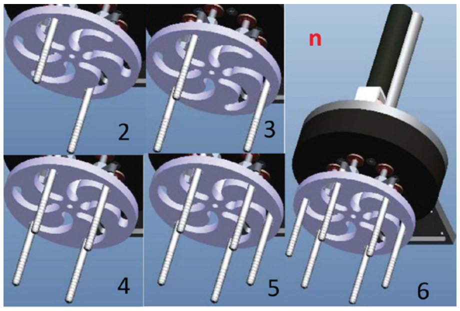



Fig. 8. Deferent number of fingers n

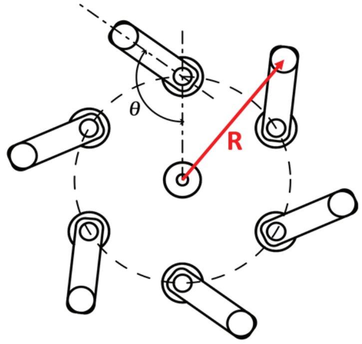



Fig. 9. Definition of finger radius R

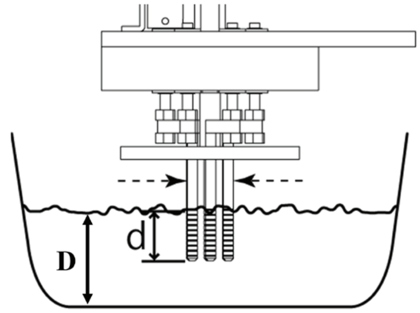



Fig. 10. Definition of insertion depth d

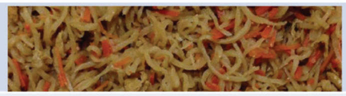
| | Noodles | Simmered Dried Radish | Simmered Hijiki Seaweed |
|---|---|---|---|
| Photos |  |  |  |
| Ingredients | Noodles Made from Konjac Flour | Dried Radish, Carrot<br>Deep-fried Tofu | Hijiki Seaweed, Carrot<br>Deep-fried Tofu |
| Length | 10 cm | Dried Radish : Average 8 cm<br>Others : Average 3 cm | Hijiki Seaweed : Average 2 cm<br>Others : Average 3 cm |
| Cross-sectional Shape | Circle of a diameter 1—3 mm | Dried Radish : Indeterminate 2 mm in width<br>Carrot : 5x2 $mm^2$ Rectangle<br>Fried Tofu: 3.5x1 $mm^2$ Rectangle | Hijiki : 2x1 $mm^2$ Elliptic<br>Carrot : 5x2 $mm^2$ Rectangle<br>Fried Tofu: 3.5x1 $mm^2$ Rectangle |
| Mean Density | 0.81 $g/cm^3$ | 0.66 $g/cm^3$ | 0.72 $g/cm^3$ (Without Liquid) |
| Feature | Slippery<br>Easy to get twisted up | Ease to get twisted up each other because of long dried radish. | It is soaked in soup, and shorter than other two foods |

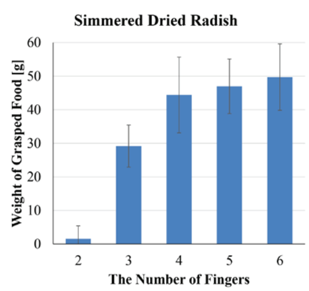
Fig. 11. Properties of foods used for experiments

### A. Test foods

Three kinds of foods were selected and the properties of the test foods are summarized in Fig.11. These foods are not tractable for previously developed grippers because ingredients are shredded in liquid source, and difficult for two fingers gripper to pinch, while a vacuum sucker does not work at all. [1] Noodle made from konjac flour was selected as a representative of noodles since konjac noodle does not absorb too much water during experiments. Other two foods are very common in traditional Japanese cuisine which are often served in "Makunouchi" lunch box as one of a side dish. These foods were kept in a rectangular container which was sufficiently large, and made flat every time before each grasping experiment.

### B. Number of fingers

It is obvious that large number of fingers increases the amount of grasped food and performs stable food handling. However, large number of fingers makes the hand mechanism complicated and increases parts count. Thus, we have to make trade-off between grasping stability and number of fingers. We tested different number of fingers where other parameters were set to $R = 28.5mm$, $d = 20\,mm$, $D = 35mm$ . The results are shown in Fig.12. As we expected, two fingers could hardly grasp the foods. As the number of finger increases, the averaged grasped weight increases because of increase of the volume surrounded by the fingers. Figure 12 also indicates that the standard deviation of simmered dried radish is larger than Hijiki seaweed. This is because the length of dried radish is much larger than Hijiki seaweed, and dried radish tends to tangle. This result suggests that four fingered gripper is sufficient for dried radish.



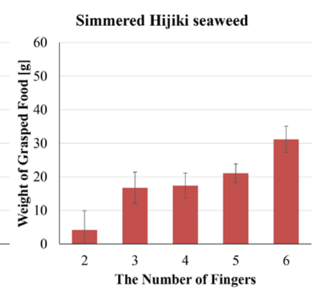




Fig. 12. Multi-fingers increase amount of grasped foods

[1]In our preliminary experiments, we installed chop sticks, tongs and a spoon and a fork at the end of two fingered gripper, and tried to grip above foods. However, these conventional instruments could not perform steady handling by simple vertical access to the food, suggesting dexterous movement of these instruments by a human workers for serving.

### C. Finger radius

We investigated the relation between finger opening radius R and the averaged grasped weight where $n = 6, d = 20mm, D = 35\ mm$. The results is shown in Fig.13. Since R is precisely controlled by the actuator with a rotary encoder, we can accurately control the weight of the foods with the resolution of less than $10g$, suggesting a suitable ability for food production. Figure 14 shows the difference of the amount of the grasped foods. The shapes of the placed foods are similar to circular cones.

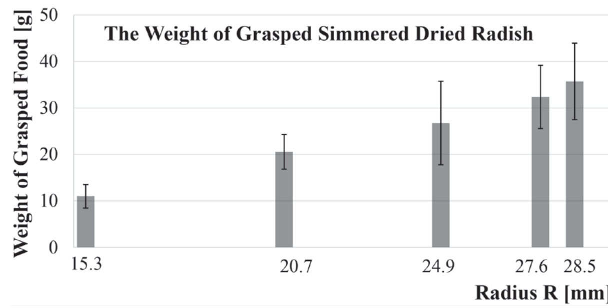


Fig. 13. Relationship between R and grasped weight of food

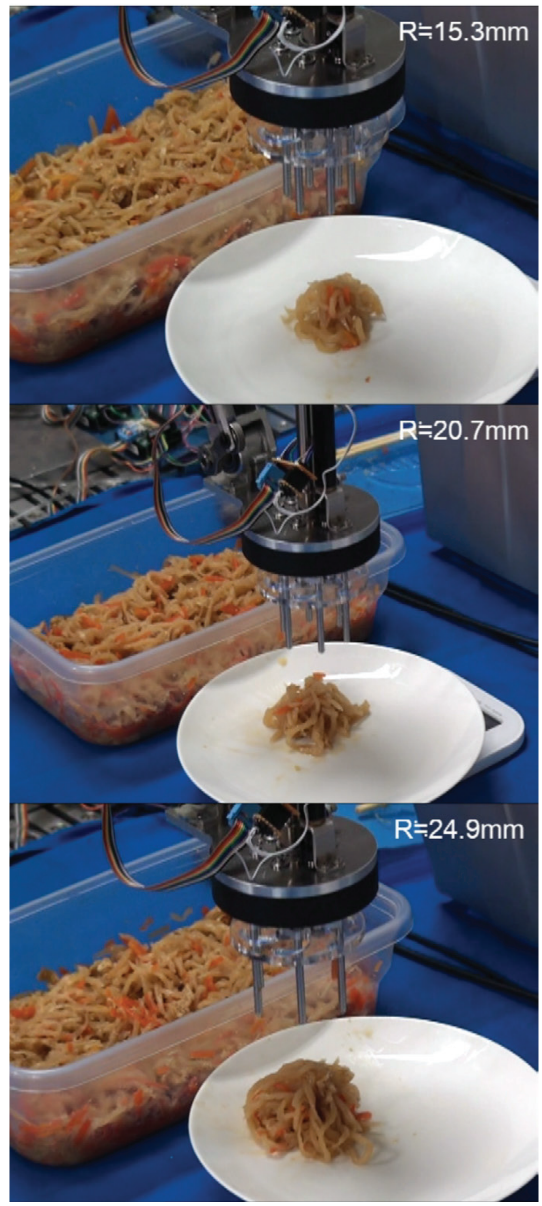


Fig. 14. The grasped amount is controlled by the finger radius R

### D. Insertion depth

The grasped weight can be also controlled by insertion depth d, which increases the volume in the vertical direction. Figure 15 shows the relationship between d and the averaged grasped weight where $R = 28.5mm, n = 6, D = 45\ mm$ (noodles), $35mm$ (dried radish). The grasped weight increases in proportional to the insertion depth. In the case of $d = 30\ mm$ with Konjac noodles, grasped weight is not so high compared with the $25mm$. This is due to the low friction of noodles and noodles easily slipped down to the container, suggesting the requirement of improvement of finger shape for slippery foods. Figure 16 shows a demonstration of serving on a dish with three different amounts by controlling d. Overall food shapes become circular cones.

### E. Shape of the placed food

We measured the hight and the maximum breadth of the placed foods by taking photographs, where $R = 28.5mm, n = 6, d = 20\ mm, D = 35\ mm$. Number of trials were ten in this experiment, and averaged weight of the grasped food was $27g$. We tested the effectiveness with or without using the push part. Without moving the push part, the grasped food was released by slightly opening the fingers. With the push part, the grasped food was pushed down to the dish while the fingers were kept closed Figure 17 shows the results, and the height and the maximum breadth are slightly smaller by using the push part. The height became smaller because the push part directly pushed the foods downward. The maximum breadth became also smaller because the fingers were kept closed. However the difference between with or without the push part is not so significant maybe due to the flat shape of the push part. If we test with much stickier foods which easily stick to the fingers, the push part will be more effective.

## IV. DISCUSSION

In above verification experiments, we assumed that the position of the food container and height of the food is known and unchanged. And the arm was operated by completely open-loop control. Thus we needed to manually make the food flat in every experiment, which is not realistic for a practical application.

One solution is to install an additional tool like a spatula on the gripper, and change the gripper to the spatula by driving a wrist joint just like a usual industrial robot with multi-tools. The robot arm can make the food flat by using the spatula. Another solution is to measure the position where the food remaining in the food container. Visual information would be helpful to achieve the measurement.

We have to mention that we could not sufficiently handle source liquid of simmered hijiki seaweed. Source liquid dripped on the dish while moving the hand, which significantly impaired the food presentation. As we mentioned before, one solution would be squeezing grasped food to reduce source liquid by controlling grasping force using force control. The other solution is just increasing viscosity of liquid source, which is popular solution for lunch box foods.

Current hand-arm system does not have wrist yaw rotation around the center axis of the gripper. Twisting up motion will provide the food with a much higher circular cone shape, which is suitable for serving spaghetti dishes.

## V. CONCLUSIONS

This paper proposed a new food handling gripper which can grasp noodles and shredded foods. In order to apply lunch box production, the gripper can access the specified position from the top. Moreover the gripper can place the food with a circular cone shape considering an appetizing presentation. The hardware prototype model was developed and evaluated by the grasping experiments. The experimental results show that the proposed gripper can control the amount of the food by changing the opening radius of fingers or insertion depth to the foods in a container.

Reducing the standard deviation is one of the important future works. Optimization of finger shape depending on the target foods will decrease the standard deviation. Installation of a load cell to measure weight of the grasped food can be another solution for precise weighting. The investigation of the shape of the push part is also an important issue to enhance the attractive looking of the foods.

Moreover, comparisons between a human worker and the proposed robotic system should be discussed in terms of tact time, handling precision, labor cost and so on, to make the system practical in a food factory in the near future.

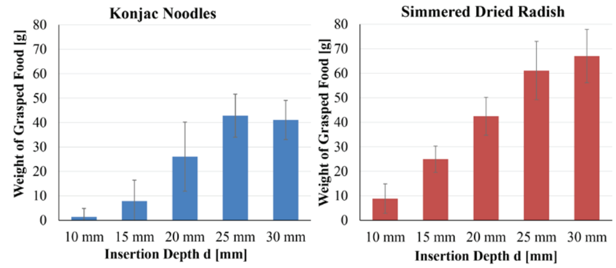



Fig. 15. Relationship between d and grasped weight of food

Fig. 16. Example of serving with three different amount of foods by changing insertion depth d

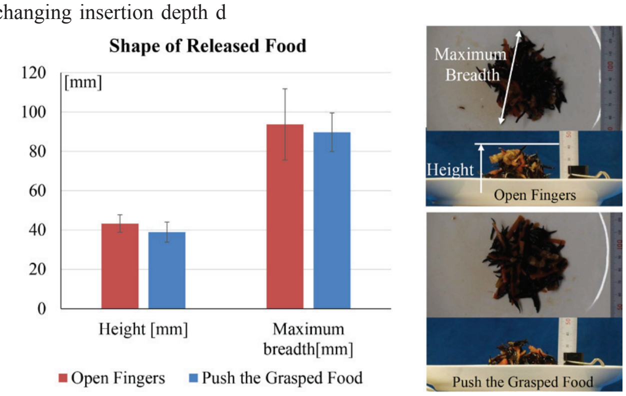



Fig. 17. Effect of using push part on the shape of served food

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