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Comparison of Processing Effects by Spalling Phenomena Caused using Underwater Shock Waves in Food Processing

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Abstract

We applied the shockwave technology to food processing and developed a processing machine. Shock wave technology is used in mechanical engineering for welding, rolling and powder metallurgy. However, it is not statistically known what kind of foods is processed using shock waves, and to what extent. We have been researching shock wave technology for food processing in anticipation of its specific effects on specific foods. However, it is not statistically known what kind of foods is processed using shock waves, and to what extent. The purpose of this study is to obtain basic measurement results to predict the spalling fracture characteristics caused by shock waves. We selected carrots as the test food to obtain comparative measurement results for drying speed, fiber tensile strength, and softening degree with and without shock wave treatment. The results revealed differences depending on the presence or absence of shock waves. It can be said that carrots are easily dried by shock waves, their fibers are cut, and they become soft.

1. INTRODUCTION

The global population is increasing continuously and will exceed 8 billion by 2022[1]. It is expected to reach approximately 10 billion by 2050. However, the food self-sufficiency rate is expected to decline further. Food prices are rising continuously, making it difficult for low-income households to secure food[2]. Therefore. There is a need for improved production technologies for more efficient and terrestrial food products. New and unprecedented technologies have been developed for food processing[3]. Obata et al. suggested some clues on the mechanism to enhance EPS production using Moderate pulsed electric field treatment technology[4]. Feng Liang Chen et al. used twin-screw extruder technology to process soybeans and develop foods with a texture similar to meat[5]. K. Shiby Varghese et al. showed that ohmic heating is suitable for processing particulate and protein-rich foods[6]. We applied the shockwave technology to food processing and developed a processing machine. Shock wave technology is used in mechanical engineering for welding, rolling and powder metallurgy. There are very few studies shock wave technology to food processing being applied in food processing. Shock waves destroy the internal tissues of food (vegetables), which have air, fiver and water structures. When a shock wave propagates, it is divided into transmitted and reflected waves at the interface of the density difference inside the food. The destruction occurs because of the tensile forces of both waves. This destruction is called the spalling phenomenon and has the effect of softening foods and improving their extractability. We have been researching shock wave technology for food processing in anticipation of its specific effects on specific foods. Rice flour is used as a substitute for wheat in Japan and is processed into breads, cookies, etc. The heating during milling flour damages the starch and deteriorates its quality of powder. It is possible to mill high-quality rice flour using shock wave processing without heating[7]. However, it is not statistically known what kind of foods is processed using shock waves, and to what extent. If we can obtain data that can predict the spalling phenomenon characteristics, we can use shock wave technology to solve difficult problems in food processing. The purpose of this study is to obtain basic measurement results to predict the spalling fracture characteristics caused by shock waves. We selected carrots as the test food to obtain comparative measurement results for drying speed, fiber tensile strength, and softening degree with and without shock wave treatment. We confirmed the differences in the measurement results with and without shock wave processing.

2. Food processing machine using shock waves

Figure 1 shows an overview of the food processing device that generates underwater shock waves. Electric energy is charged with the hi-charging device (TDK Lambda: 152A) from a switchboard (200V, 20A). The pressure vessel for food processing is filled with water. The charged electric energy is supplied to an electrode in the pressure vessel by the gap switch with the air cylinder. A thin aluminum wire is installed between electrodes, and it is evaporated by thermite reaction induced by instantaneously applied high voltage, resulting in shock wave generation. The generated shock wave propagates in the water in the pressure vessel. The food to be softened is packed with silicone or resin.

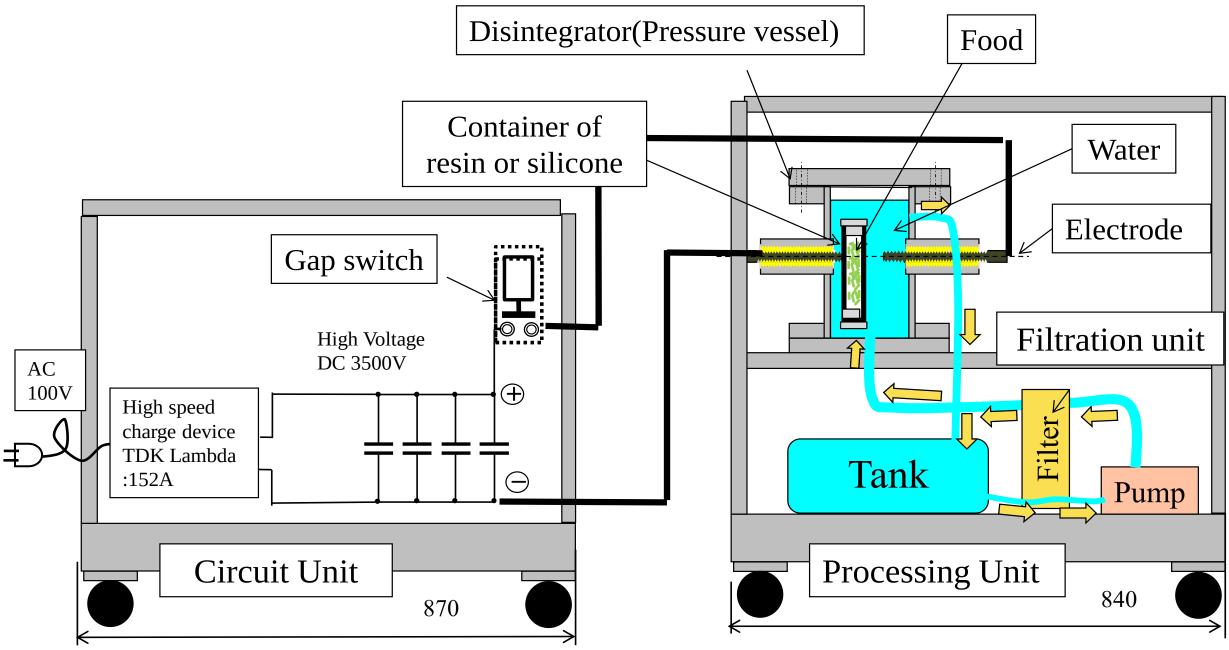

Fig.1 Figure of food processing machine for test processing

3. Experimental materials and processing experiment conditions

We selected carrots for the experiment because carrots are easily available regardless of the season. It cleared that carrots can be made highly functional using shock wave processing[8]. The dimension ware 10, 10, and 50 mm. This shape was uniformly cut using a grid knife. It was processed once and twice using a machine that use shock waves. Figure 2 shows the image of carrots after shock wave processing. Conditions other than the number of machining steps were maintained as similar as possible. The shock wave generation energy was 4.9 KJ. The distance between the shock wave generation points and the carrot and the material and size of the wire used to cause the thermite reaction ware always constant.

Unprocessed One time Two times

Fig.2 Image of processing by shock waves

4. Measurement of the drying rate

Dried foods are consumed world[9]. Dry foods, including freeze-dried foods, are lightweight and can be stored for long periods. These foods are commonly sold and used as lightweight foods for hiking, travel, and emergencies caused by disasters. In our experience, the destructive effect of shock waves on the internal structures contributes to an increase in the drying rate of food products. To quantify the drying speed, food was dried using a commercially available food dehydrator. The mass was measured every hour, and the mass loss wad considered as the drying rate. Figure 3 shows a graph of the mass loss caused by processing the shock waves.

The horizontal axis presents the drying time, whereas the vertical axis presents the mass loss rate. Here, unprocessed suggests not processed by the shock waves. The plot representation the average mass of 8 carrot pieces. It was difficult to compare the drying rates because the shock wave caused the surface to peel (Fig.2), creating a difference in the initial mass upon drying. The mass reduction rate was calculated using an initial mass

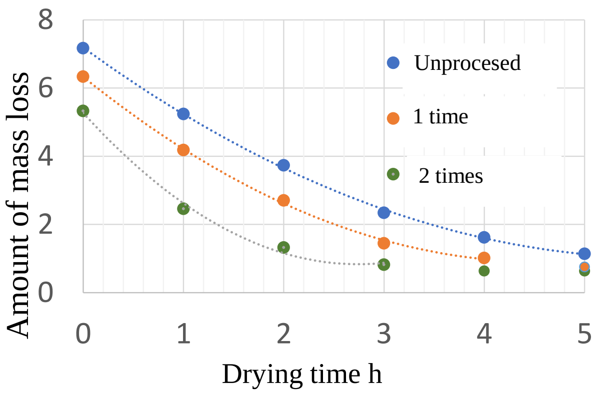

Fig. 3 Measurement of mass per hour

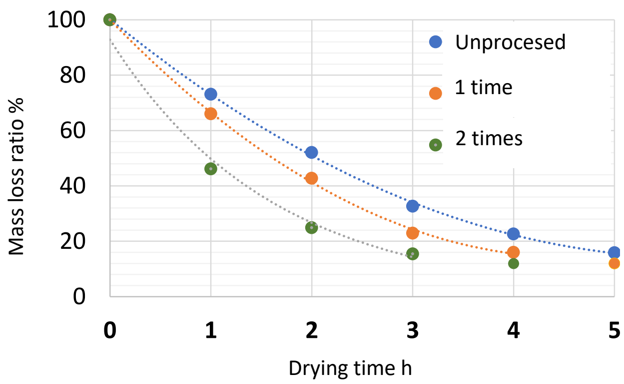

Fig. 4 Mass loss rate per hour

of 100%. Figure 4 shows the mass drying rate. The period after five hours from the start of drying was omitted because there was almost no change in the mass. A quadratic curve was approximated to the point at which the mass reached 15%. Shock wave processing promotes weight reduction, which is believed to improve the drying speed. This is assumed because the internal structure (cell walls) is destroyed by shock waves, thus promoting the expulsion of water from inside the carrot to the outside. Figure 5 shows a photograph of the carrots three hours after drying. It is believed that the shock wave causes the surface to peel off, there increasing the surface area and improving the drying rate.

Unprocesed One time Two times

Fig.5 Image of 3 hours after processing

5.Result of tensile test

Dietary fiber has a significant effect on food texture. The absorption of nutrients through digestion is also assumed to be improved by the reduction in dietary fiber. Food chewability is typically measured using a creep meter[10]. In mechanical engineering, the breaking strength is measured through a tensile strength testing apparatus to evaluate the physical properties of various materials. We used this technique to measure the fiber strength of carrots. Figure 6 shows an image of the tensile testing machine. A tensile tester was used to measure the breaking strength by fixing and pulling the object to be measured with a chuck. Carrots are soft when dried, therefore it is difficult to hold them in place with a mechanical vise chuck during experiments. The specimen was completely dried using a commercially available food dehydrator, and both ends of the specimen were fixed with resin. Both hardened ends were chucked and the tensile strength was measured. The cross-sectional area was calculated by measuring the diameter using calipers after chucking. Figure 5 shows a photograph of a carrot with both ends hardened and set in a tensile tester. The tensile speed was set at 20 mm/min. Figure 7 shows the results of the tensile strength with and without shock wave processing before drying. The fiber strength was measured five times for each shock wave processing number. The graph shows the average values of the five measurement results, and the error bars

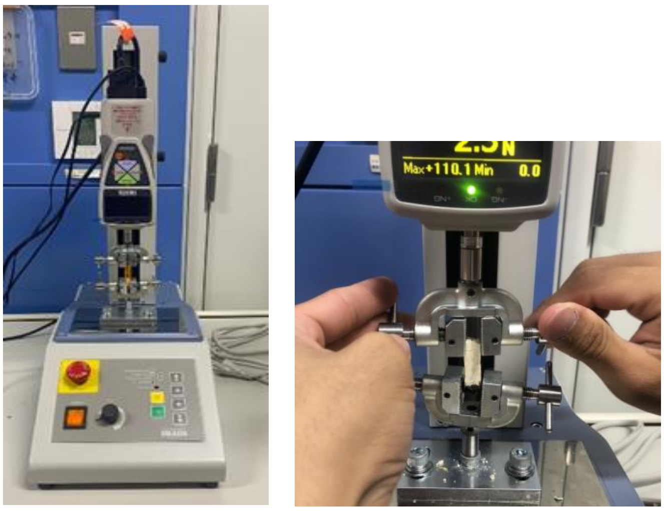

Fig. 6 Tensile testing machine and chuck mechanism

represent the maximum and minimum values. It is believed that the shock waves destroyed the carrot fibers, creating a difference in the tensile strength values. The error in the results is large.

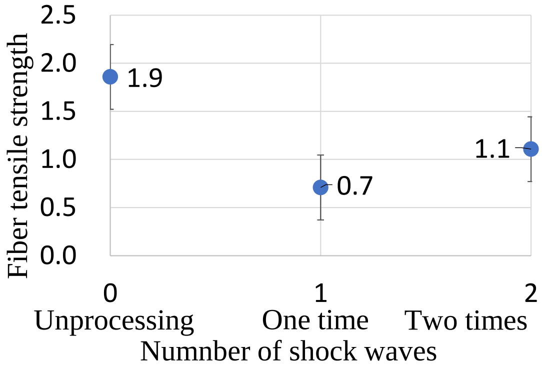

Fig.7 Result of tensile strength of Callot

Figure 8 shows the fiber tensile strength results of dried after processing with one shock wave. Several peaks can be seen in the graph. The fiber strength of vegetables such as carrots comes from the breaking down of several strong fibers inside. If fiber breaks occur simultaneously, the fracture strength increases, and if fiber breaks occur separately, the stress-strain diagram will have multiple peaks. As a result, it is thought that the breaking strength becomes a small value. I think that it necessary to increase the number of measurements and obtain an average value.

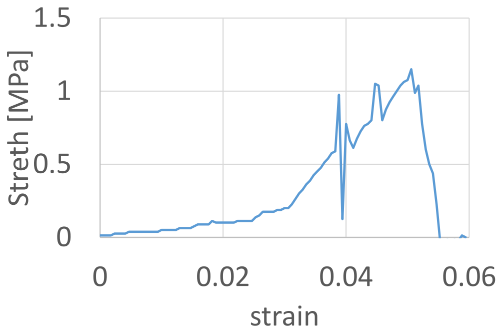

Fig.8 Stress strain diagram of one shock wave processing

6.Experiment of measurement of softening value

Food softness is sometimes measured using a creep meter, but in this study, it was measured using a durometer[11]. The measurement method followed the example of the meat tenderization experiment[12]. A carrot was cut in half and the inside of the cross section was measured using a durometer. The durometer type is A and the manufacturer is Teclock. When measured with a durometer, the measurement point is depressed by the push needle. The distance between measurement points was set to 1 mm or more to avoid affecting adjacent measurements. Figure 9 shows a graph of softening values. The vertical axis is the durometer hardness, and the horizontal axis is the number of shock wave occurrences. The plot points are the average values of 30 measurement points. Error bars indicate maximum and minimum values. It is thought that the difference in softening values was caused by the destruction of the internal tissues of carrots by the shock waves.

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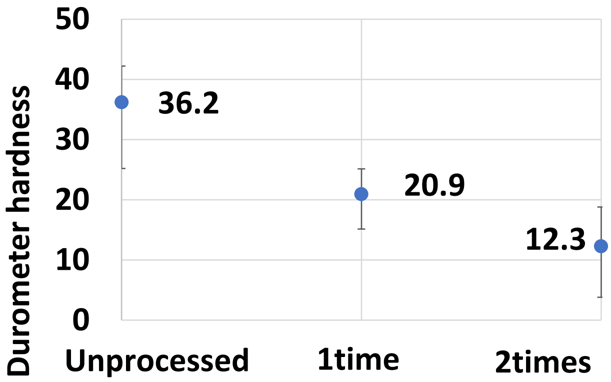

Fig.9 Softening of Callot by shock waves

7. CONCLUSION

There are very few research of food processing using shock waves. It is not known to what extent it is processed by shock waves. We experimentally demonstrated the measurement of food processing with and without shock wave processing, and showed the values of drying rate, fiber tensile strength, and softening. The results revealed differences depending on the presence or absence of shock waves. The carrot became approximately 20% softer by shock wave using durometer. The fiber strength decreased by approximately 37%. The difference in drying time is approximately 2 hours until the mass loss reached 15%. It can be said that carrots are easily dried by shock waves, their fibers are cut, and they become soft.

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