

# Study on shock loading pre-processing for freeze-drying

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## ABSTRACT

In the food industry, it is hoping high value-aided product and the increase in efficiency of food processing. On the other hand, we get an experimental result that the load of the shock wave improves an extraction of food, and soften food. We tried to examine the effectivity of the shock wave as pre-processing for freeze-drying from the result in permeation character seen in the radish and so on. In the case of freeze-drying, the object tends to be limited to the small or thin one with size, from the sublimability in processing, the performance in case of the restoration and the viewpoint of the cost performance ratio. We report the result that shock wave loading was done to various foods as pre-processing of freeze-drying.

## 1. INTRODUCTION

In the food-processing field, static pressure was mainly used for high pressure processing. For example, in the case of meat, experiments were carried out very much by Macfarlane in the 1970's [1]. They reported about the softening of the meat and the effect of the improvement of the water-holding by high pressure processing [2–4]. The following is reported about the meat fiber: High pressure processing makes the structure of the meat change and some of the proteins of that become solubilization. Effect of solubilization of the proteins proceeds as much as time is long as much as pressure is high [5–8].

On the other hand, These technique using shock waves from explosion of explosives or discharge of high current in water results in new industrial development as non-thermal food sterilization [9, 10]. Shock waves from explosion of explosives or discharge of high current in water can get high pressure comparatively easily though action time is short. When an underwater shock wave incidents into food and the structure, it is known to propagate as an incident wave and a reflected wave. An extraction and the softening of food are achieved by the incident wave, the reflected wave, and the difference of impedance in food. Shock wave processing has the possibility to bring the effect for which to be different from the pressure processing by the static pressure.

We tried to examine the effectivity of the shock wave as pre-processing for freeze-drying from the result in permeation character seen in the radish and so on. In the case of freeze-drying,

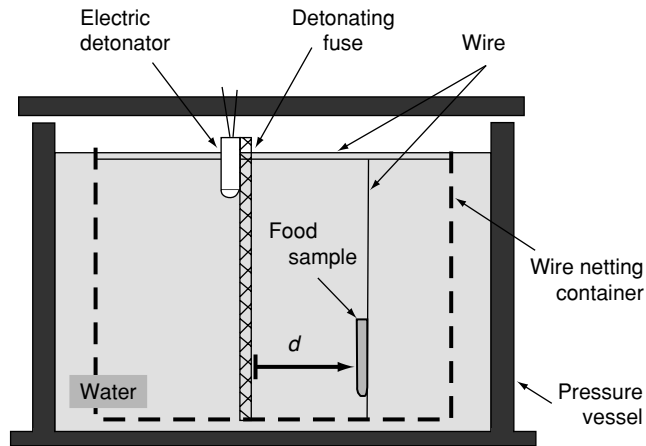


Figure 1 Outline of the shock loading experiment device.

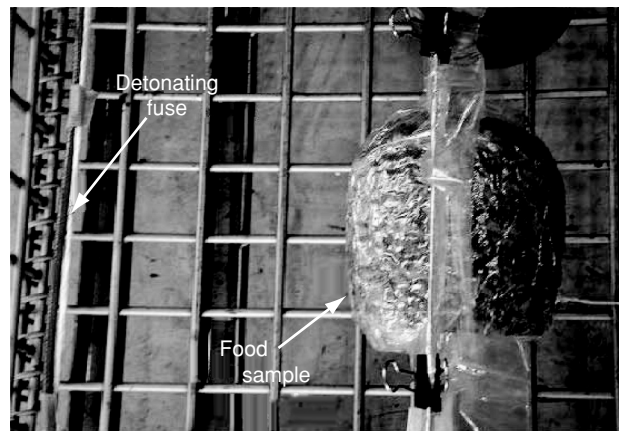


Figure 2 Photograph of experimental set up.

the object tends to be limited to the small or thin one with size, from the sublimability in processing, the performance in case of the restoration and the viewpoint of the cost performance ratio. Therefore, we used comparatively large beheaded shrimps and squids and attempted to review the effectivity of the shock wave processing about being freeze-drying.

## 2. EXPERIMENTAL APPARATUS AND METHOD

### 2.1. EXPERIMENTAL APPARATUS AND METHOD

The outline of the shock loading experiment device is shown in Fig.1. The food samples packed by polystyrene envelope and a detonating fuse (Japan Carlit Co. Ltd., The 2nd kind detonating fuse, principal ingredient: PENET, loading density:  $1200 \text{ kg/m}^3$ , outer diameter: 5.4mm, detonation velocity: 6308m/s) were fixed on the wire netting container (see in Fig.2). The wire netting container was put in the water-proof pressure vessel made by steel, and the

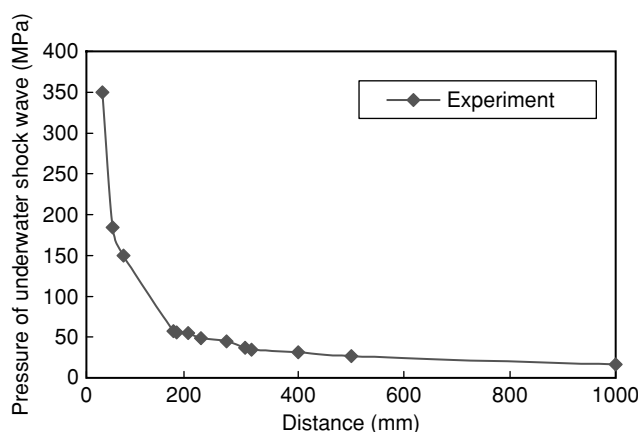


Figure 3 Relationship between pressure of underwater shock wave and distance.

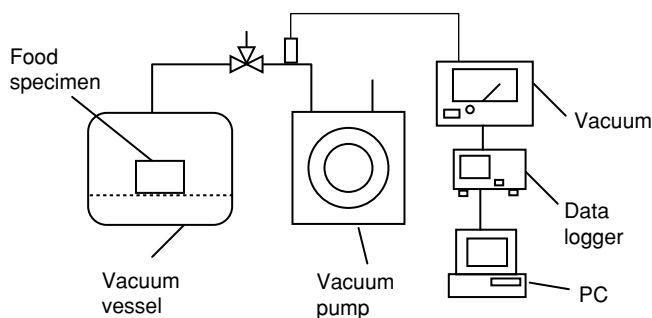


Figure 4 Schematic diagram of freeze-drying set up.

water-proof pressure vessel was filled with the water. The initiation is made by the No.6 electric detonator (Asahi Chemical Industry Co. Ltd., Japan).

The relation between the pressure value of underwater shock wave and the distance from the detonating fuse obtained by the pressure measurement is shown in Fig.3. The pressure measurement of underwater shock wave generated by the detonating fuse was performed at the point's 30 mm, 50 mm, 70 mm, 165 mm, 300 mm, 500 mm 1000 mm and others from the detonating fuse. The underwater shock wave generated from the detonating fuse attenuates gradually while propagating in water.

The shock-loaded specimens were frozen in a freezer and were set in the vacuum equipment to process freeze-drying. Freeze-drying process has been carried out without cold trap to monitor a sublimation condition by the vacuum pressure at this time. Also, it implemented freeze-drying processing by the only vacuum pump without overheating by the heater and so on to prevent from effect in heat-of-sublimation supply. The setup of the equipment to have used for freeze-drying processing is shown in Fig.4. The equipment for freeze-drying, it is simply composed of vacuum vessel, vacuum pump and vacuum gauge. The vacuum gauge connected with the PC through the data logger, and always monitored and recorded a vacuum pressure during freeze-drying.

Table 1 Results of shrimp reconstituted by hot water in the case of shrimp

Run No.	Shock condition	Freezed mass(g)	Dried mass(g)	Reconstituted mass(g)	Rehydration ratio(%)	Reconstitution ratio(%)	Average of rehydration ratio(%)	Average of reconstitution ratio(%)
Control_1	Control	7.43	2.50	5.11	52.9	68.8		
Control_2	(Un-shocked)	8.25	2.66	4.47	32.4	54.2	35.3	56.8
Control_3		6.34	2.13	3.00	20.7	47.3		
1_1	70 MPa	10.56	3.20	9.18	81.3	86.9		
1_2		8.14	2.66	6.64	72.6	81.6	73.9	82.2
1_3		10.01	3.17	7.81	67.8	78.0		
2_1	50 MPa	10.38	3.37	7.33	56.5	70.6		
2_2		8.26	2.66	5.20	45.4	63.0	47.4	64.5
2_3		9.20	3.00	5.51	40.5	59.9		
3_1	35 MPa	8.01	2.46	5.23	49.9	65.3		
3_2		8.40	2.78	5.86	54.8	69.8	50.6	66.2
3_3		8.25	2.56	5.24	47.1	63.5		

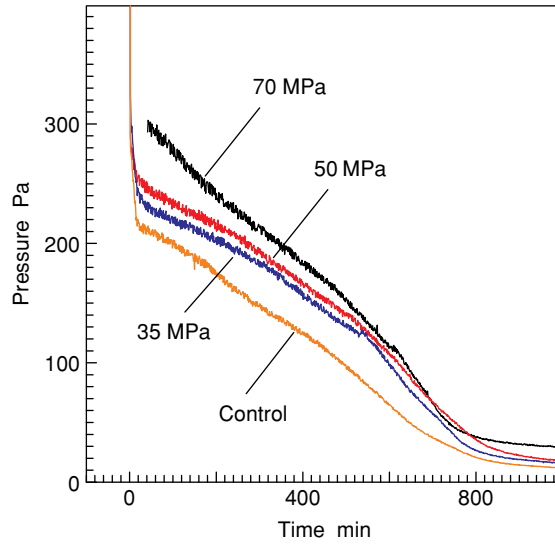


Figure 5 Pressure-time histories in the case of shrimp.

### 3. RESULTS AND DISCUSSIONS

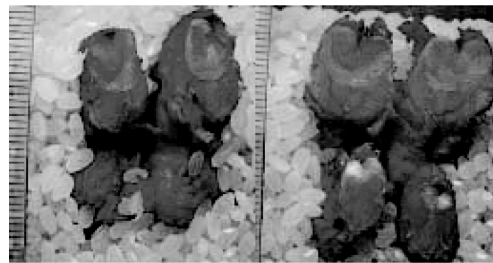
#### 3.1. IN THE CASE OF SHRIMP

We divided the scalded beheaded shrimp of 12 tails into four groups; ① 70 MPa shock loaded, ②50 MPa shock loaded, ③35 MPa shock loaded and ④control (un-shock loaded) for comparison respectively, as shown in Table1 and experimented.

Pressure-time histories in the vacuum vessel are shown in Fig.5. The pressure value reaches to equal or less than about 600 Pa of sublimation conditions within about 1minute without using a cold trap after the frozen specimen set in the vacuum vessel. From this result, the pressure of the specimen to have strong shocked processing is changing in the high condition and it shows that sublimation speed is fast. This is one of the problem which it should review, being detailed in the future with the possibility that the freeze-drying operation time can be abridged by the shock wave processing shown.



(a) Control (un-shocked)



(b) 70MPa shock loaded



(c) 50MPa shock loaded



(d) 35MPa shock loaded

Figure 6 Photographs of shrimp after reconstitution by hot water in the case of shrimp.

These shrimps processed freeze-drying were attempt to reconstitute using boiling hot water with 1minute. To understand the state of the penetration of the case, hot water was colored with the food red. The representative example of each group is shown in Fig.6. The photograph shows a section of the division into the two equal parts in central and the section when quartering more. In case of control (un-shocked), the reconstitution by hot water is only the surface neighborhood and reconstitution of core part is nothing. In the case

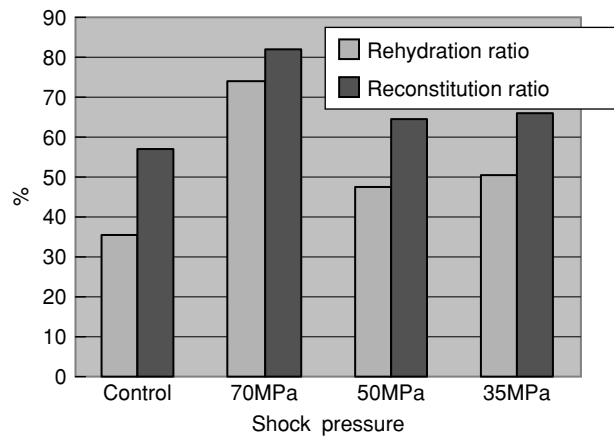


Figure 7 The improvement of the rehydration ratio and reconstitution ratio by the shock wave loading in the case of shrimp.

of 70 MPa shocked, reconstitution is approximately sufficient by hot water, body collapse is seen, too. In case of shock wave processing of 50 MPa, reconstitution is sufficient in part from head to center, but reconstitution of the tail part is not enough. There are few body collapses. In case of shock wave processing of 35 MPa, reconstitution is not sufficient overall, body collapse cannot be seen absolutely. A restoration result in case of the shrimp is shown in Table 1. The change of the rehydration-ratio and reconstitution-ratio by the shock wave processing is shown in Fig.7. When attempting to see about the result including Table 1, there is each sample individual difference, too, and its fluctuation is big, too. The result of rehydration-ratio and reconstitution-ratio shows that the restore quality of specimen using hot water improves by shock wave pre-processing, when catching broadly. In the future, we add the evaluation of the food sense and so on, too, and proceed with the reviewing such as the best value of shock pressure to each food, the best way to load.

### 3.2. IN THE CASE OF THE SQUID

About the effect of the shock wave processing about the freeze-drying in case of the squid, the time change of the pressure during the freeze-drying of the squid that processed a shock wave is shown in Fig.8 with the un-shocked squid (control). The pressure in the early stages is high and it shows that sublimation speed of shocked shrimp is fast. After that, the pressure in the case of shocked shrimp reaches a high vacuum earlier than that in the case of un-shocked shrimp and it let us understand that processing ending of freeze-drying is early, too.

We attempted to reconstitute the squid that processed freeze-drying using hot water with 3 minute. To understand the state of the penetration like the shrimp, reconstitutions were carried out using the hot water colored by food red. The representative photograph of each group is shown in Fig.9. In the same way the case of the shrimp, in case of control (un-shocked), the reconstitution by hot water is only the surface neighborhood and reconstitution of core part is nothing. In case of shock wave processing of 100 MPa, a body collapse can be seen, too, but it is found that reconstitution by hot water is improving by leaps and bounds. A restoration result in case of the squid is shown in Table 2. The change of the rehydration-ratio and reconstitution-ratio by the shock wave processing is shown in Fig.10. The result of rehydration-ratio and reconstitution-ratio shows that the restore quality of specimen using hot water improves by shock wave pre-processing in the same way the shrimp in case of the squid, too.

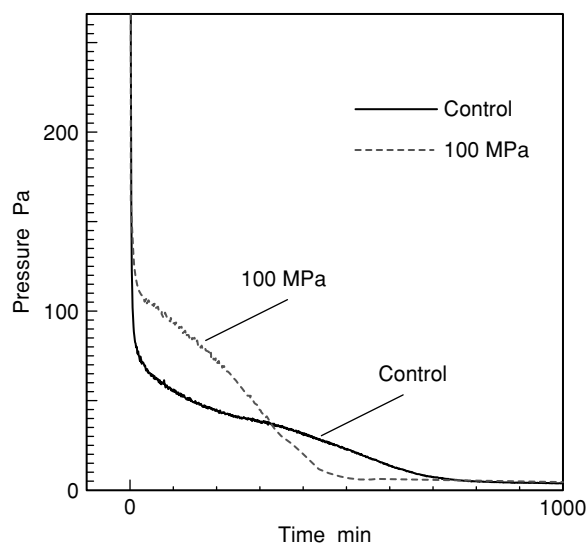
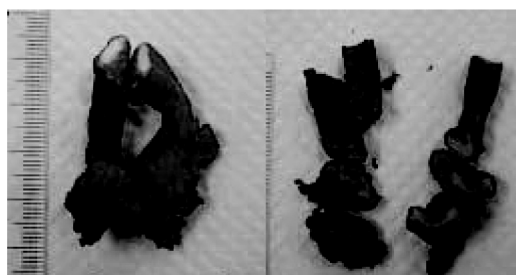


Figure 8 Pressure-time histories in the case of squid.



(a) Control (un-shocked)



(b) 100MPa shock loaded

Figure 9 Photographs of squid after reconstitution by hot water in the case of squid.

#### 4. CONCLUSIONS

We tried to examine the effectivity of the shock wave as pre-processing for freeze-drying using beheaded shrimp and a squid as specimen. The improvement of the sublimation speed was gotten from the result that the pressure change during freeze-drying processing and the improvement of the reconstitution was gotten from the result using hot water. It was expected

Table 2 Results of squid reconstituted by hot water in the case of squid

Run No.	Shock condition	Freezed mass(g)	Dried mass(g)	Reconstituted mass(g)	Rehydration ratio(%)	Reconstitution ratio(%)	Average of rehydration ratio(%)	Average of reconstitution ratio(%)
Control_1	Control	6.31	1.83	2.63	17.9	41.7		
Control_3 (Un-shocked)		5.09	1.48	2.01	14.7	39.5	15.9	41.5
Control_4		3.82	1.27	1.66	15.3	43.5		
2_1	100 MPa	8.00	2.26	6.12	67.2	76.5		
2_3		6.62	1.73	4.75	61.8	71.8	65.3	75.1
2_4		5.84	1.79	4.50	66.9	77.1		

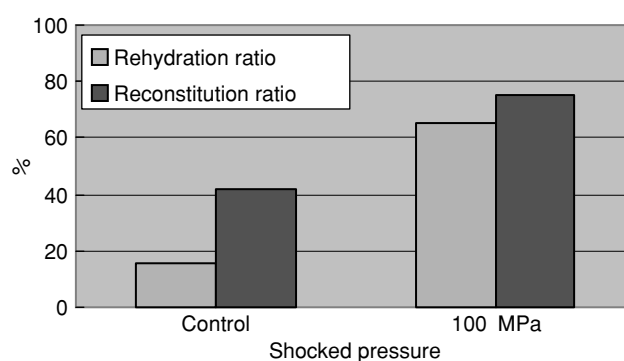


Figure 10 The improvement of the rehydration ratio and reconstitution ratio by the shock wave loading in the case of squid.

that the reconstitution of the freeze-dried food is improved and that a processing time is abridged, by shock wave loading as pre-processing for freeze-drying.

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## REFERENCES

- [1] J. J. Macfarlane, 1985, "Developments in Meat Science-3", Ed. R. Lawrie, Elsevier Applied Science Publishers, Barking.
- [2] J. J. Macfarlane, 1973, *J. Food Science*, 38, 294.
- [3] P. E. Bouton, P. V. Harris, J. J. Macfarlane and J. M. O'shea, 1977, *Meat Science*, 1, 307.
- [4] J. J. Macfarlane, I. J. Mckenzie, R. H. Turner and P. N. Jones, 1984, *Meat Science*, 10, 307.
- [5] J. J. Macfarlane, and D. J. Morton, 1978, *Meat Science*, 2, 281.
- [6] A. Suzuki, M. Watanabe, K. Iwamura, Y. Ikeuchi and M. Saito, 1990, *Agric. Biol. Chem.*, 54, 3085.
- [7] J. J. Macfarlane, 1974, *Food Science*, 39, 543.



- [8] A. Suzuki, N. Suzuki, Y. Ikeuchi and M. Saito, 1991, *Agric. Biol. Chem.*, 55, 2467.
- [9] Achim M. Loske, Ulises M. Alvarez, Claudia Hernandez-Garcia, Eduardo Catano-Tostado, and Fernando E. Prieto, *Innovative Food Science & Emerging Technologies* 3, 2002, pp.321–327.
- [10] Ulises M. Alvarez, Achim M. Loske, Eduardo Castano-Tostado, and Fernando E. Prieto, *Innovative Food Science and Emerging Technologies* 5, 2004, pp.459–463.

