

On the destruction of the cell wall of plants and its mechanism by the shock wave

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ABSTRACT

The shock wave transmitted at the speed that exceeds speed of sound generates the expansion wave by the density difference. The expansion wave causes negative pressure on the density difference side. And it causes the high-speed destruction phenomenon that is called "the spalling destruction". This phenomenon is caused also on the surface of the cell wall of the plant. The cell of the plant has the cell wall to maintain the shape. This is a big difference between the animal cell and the plant cell. That is, the plant has all big density differences in the cell structure. Therefore, the spalling destruction on the surface of the cell wall can spread to the entire cell tissue of the plant by the shock wave. It is possible to apply it to the extraction of the cytoplasm etc. by the cell wall destruction by using this phenomenon. The mechanism to which walls of the plant cells are destroyed by the shock wave is described in the experiment and the comparison with the scanning electron microscope photograph in this research.

Keywords: Underwater shock wave; Plant cell; Extraction

INTRODUCTION

Authors have researched non-heating sterilization technology using the underwater shock wave loading [1]. In that's research, the underwater shock wave of approximately 350MPa sterilized the fermented *Saccharomyces cerevisiae* (yeast) by almost 100%. The sterilization rate is 97% on the average in fermented and high pressure. The sterilization rate is 86% on the average in fermented and low pressure. The sterilization rate is 63% on the average in non-fermented and high pressure. That is, fermentation influences the sterilization rate.

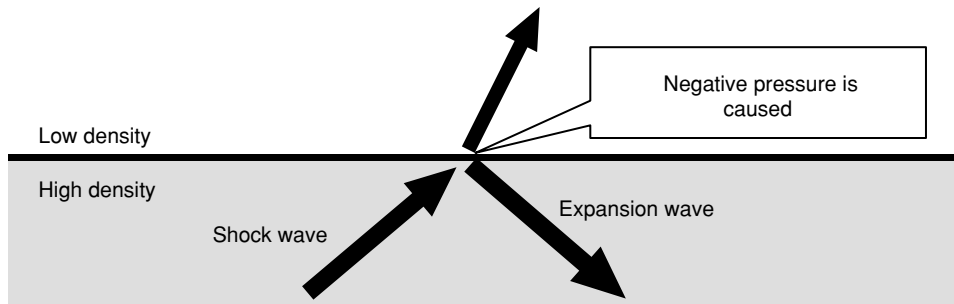


Figure 1 Propagation of the shock wave at the change side of materials.

The sterilization effect has decreased at non-fermented *S.cerevisiae*. It is thought that there was a density difference by the bubble caused by fermentation in the inside of the body of *S.cerevisiae*. It is thought that this density difference causes the spalling destruction, and the body cell of *S.cerevisiae* was destroyed.

In the plant system, we have researched the reforming of wood [2]. The reforming is the improvement of dryness and fireproofing by the chemicals injection through the water road. The loading of the underwater shock wave to the Japanese cedar, a kind of the conifer, brings dryness and the improvement of permeability. The Japanese cedar trunk is composed of the passage of water that is called the tracheid, by the connection of short tubes, and carries the water sucked up from the root to the leaf. The tube connects with the other tube by the pit membrane to pass the water. As for the heartwood of the Japanese cedar, water doesn't pass because the pit membrane has shut, dryness is bad, and the injection of the chemicals is also difficult. Then, the pit membrane is destroyed by the shock wave. As a result, Japanese cedar is made to easy to dry. The reason for these effects is that the firm cell wall defended by lignin is selectively destroyed by the underwater shock wave. It is to obtain the water road. This is due to the spalling destruction caused in the density difference between the cell wall and the cytoplasm.

CELL STRUCURE

Between the animal cell and the plant cell, there is a feature constructional difference. It is existence of the cell wall. The animal cell doesn't have the cell wall. The cytoplasm is covered with a soft cell membrane, and enables animal's smooth motion. The plant cell has the cell wall. The cytoplasm is covered with the cell membrane as well as the animal cell. In the plant cell, the cytoplasm is covered with the cell wall. The cell wall maintains the shape of the plant. That is, the plant cell comes to cause the spalling destruction by the density difference easily.

SPALLING DESTRUCTION

The shock wave transmits in the material at the speed that exceeds speed of sound. The shock wave divides into the penetration wave and the reflected wave on the change side of the density difference (Figure 1). The expansion wave is a speed below speed of sound. The reflected wave caused on a high density side brings the pull stress from negative pressure. And, the pull stress causes exfoliation effect, that is, spalling on the surface of the density difference. This high-speed destruction phenomenon is called spalling destruction.

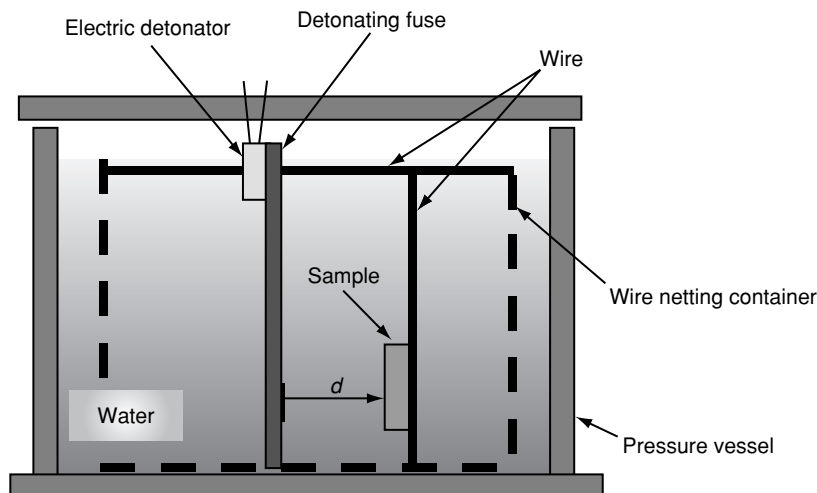


Figure 2 Experimental Set-Up to treat using the underwater shock wave.

The spalling destruction has been researched as a destruction phenomenon. For example, its purpose is to investigate strength and resistance characteristics against the shock wave of a concrete structure [3, 4]. In those researches, the techniques of the experiment and the numerical analysis, etc. were used.

On the other hand, the research of the spalling destruction in the microindentation as for the plant cell has not been completed. The softening effect of plants cell was clarified by our experiment by using the underwater shock wave loading to apples [5]. It is thought that the effect of softening is caused because the cell wall is destroyed by the density difference between the cell wall and the cytoplasm when the shock wave passes the plant cell. Authors report on the result of the observation of the image of the plant cell that receives the spalling destruction by the shock wave this time.

SAMPLES AND EXPERIMENTAL SET-UP

The coffee bean on the market and Japanese cedar were prepared as a sample for the experiment. The detonating fuse (made of The Japan Carlit Co., Ltd., detonation speed 6308m/s) and the SEP (made of Asahi-Kasei Industrial Co., Ltd., explosion velocity 6970m/s, density 1310kg/m³,) were used for the shock wave source, and the electric detonator (made of Asahi-Kasei Industrial Co., Ltd., No.6) was used for detonation. Samples were treated by the underwater shock wave loading in the pressure vessel (Figure 2).

PREPROCESSING FOR OBSERVATION

It is necessary to give some processing to observe the living thing sample such as the plants by the scanning electron microscope (SEM). The water contained in the sample generates the gas, and causes the disorder of the image by scattering the electron beam. That means the living thing sample loses the electroconductive by dehydration though it is necessary to dehydrate from the sample. So, the electroconductive is added to the sample by the Au coating. The processing procedure is as follows.

The sample dehydrated by six stages with the ethanol from 50 to 100%. 5 minutes in each density of 50%, 70%, 80%, 90%, 95%, and twice in 100% ten minutes. The sample had been

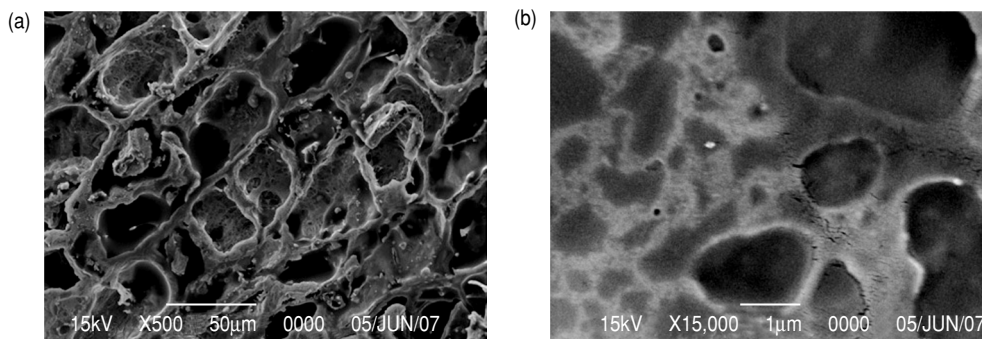


Figure 4 The SEM photographs of the coffee bean's cell tissue untreated by the underwater shock wave loading (control sample). (b) is a macro photography of (a) in a central part.

coated by Au before taking a photograph. The ionization current is direct current 10mA. The coating of the thickness of 300 angstroms was given by the electrical discharge of four minutes.

SCANNING ELECTRON MICROSCOPE (SEM) OBSERVATION

The rough vacuum scanning electron microscope was used for taking a photograph, and the accelerating voltage was 15-20kV.

The SEM photographs of coffee bean's cell tissue untreated by the underwater shock wave loading (control sample) are shown in Figure 4. Innumerable pores are confirmed on the side of the cell wall. Such a minute crack was not observed in the cell wall of non-heating sample such as apples. Therefore, it is thought that pores were caused by roasting. In the case of roasted coffee beans untreated by the underwater shock wave, cracks caused only by roasting on the side of the cell wall are about 0.3μm or less.

The SEM photographs of coffee bean's cell tissue treated by the underwater shock wave loading are shown in Figure 5. Innumerable pores are confirmed on the side of the cell wall as same as the case of untreated. It is thought that pores were caused by roasting as same as the control sample. In the case of roasted coffee beans treated by the underwater shock wave, cracks caused by the underwater shock wave on the side of the cell wall are about 3μm. The length of the crack is about 10 times of the control sample.

The SEM photographs of Japanese cedar are shown in Figure 6. These are sets of the tracheid, and circles seen on the surface are pit membranes. The white round object seen in Figure 6(A) that shows the untreated Japanese cedar is a usual pit membrane. It shows that the pit membrane has been blockaded. The small black hole seen in Figure 6(B) is a destroyed pit membrane. The destruction effect of the pit membrane caused by the shock wave is remarkably confirmed with comparing Figure 6(A) and Figure 6(B).

RESULTS AND CONCLUSION

This time, we searched for evidences of the spalling destruction caused by the shock wave by the SEM observation.

As for the roasted coffee bean, the cell wall is hard because of heat. A minute crack by the heat of roast was confirmed by the SEM observation regardless of the shock wave

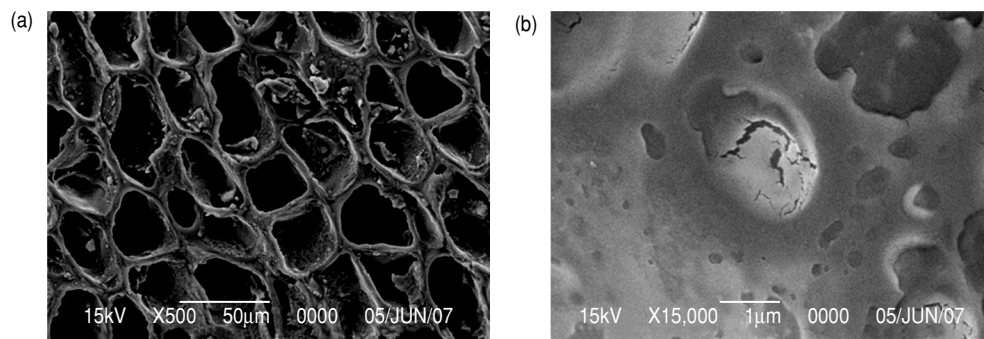


Figure 5 The SEM photographs of the coffee bean's cell tissue treated by the underwater shock wave loading. (b) is a macro photography of (a) in a central part.

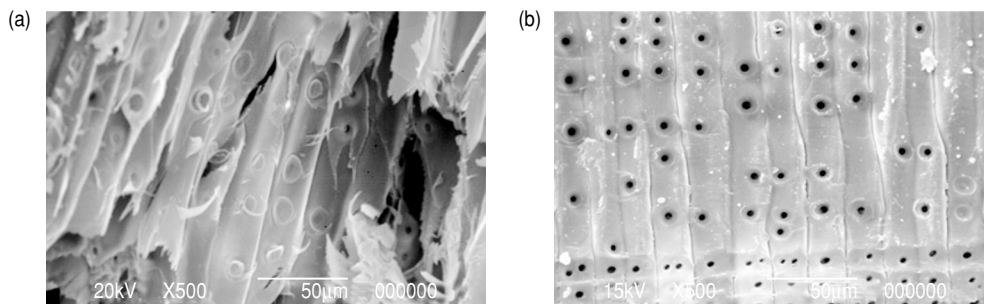


Figure 6 The SEM photographs of Japanese cedar. (a) Untreated (control sample) (b) Treated by the underwater shock wave loading.

processing. The crack by the spalling destruction was confirmed by the size about ten times the crack by roast. It is known to obtain the extract of more weights from the shock wave load coffee bean, by other research of authors [6]. The crack caused by the spalling destruction expands the surface area of the coffee bean, and, besides, improves the permeability of the hot water to the inside. As a result, it is thought that the effect of the extraction rises.

In the Japanese cedar that consisted of the hard cellulose including lignin, the destruction of the pit membrane of the tracheid by the spalling destruction was confirmed. The destruction of the pit membrane brings the Japanese cedar the improvement of the water pass. As a result, dryness and the chemicals injection efficiency improves, the reforming of the fireproofing and so on becomes possible [2].

Thus, minute spalling destruction in the cell wall of the plant brings various effects. The application of this research is expected to the reforming of the wood, the food processing and the other useful component extraction. It will be necessary to do these image analysis more in detail, and to clarify a detailed mechanism of spalling destruction in the future.

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