2-1 Developing Disinfection & Volume-reduction Technologies for the Composting of the Waste with High Moisture Content

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ABSTRACT

For developing a volume-reduction technology, dehydration process of a biomass with superheated steam (SHS) was investigated. The SHS at 140-190^oC decreased the weight of the model of substance with a high moisture content, asparagus. The dehydration rate depended on the temperature and 190 ^oC was the most effective temperature within the range tested. An alternative effective technology, exraction of valuable components from biomass, was investigated using subcritical water. Reducing sugar and protein were effectively extracted from a shell of nut, *Carya cathayensis sarg*, at 190 and 280^oC, respectively.

KEYWORDS

Superheated steam, volume reduction, subcritical water, biomasss

INTRODUCTION

In Asian and Pacific countries, all governments do not establish a garbage collection system. In such an area, even if it is a city area, there is the reality that a large amount of garbage is piled on the street. The high humidity and high temperature help various germs growing up in the pile. The pile of garbage is going to decay and release a bad smell. Such situation is a serious problem for human health and the environment. A first priority to solve the problem is to establish a garbage collection system, however, there is still the same problem in a dump where the garbage is collected. If a simple and easy technology to reduce quantity of the garbage immediately with sterilization is developed, the serious problem becomes better. The technology can be adopted not only for the garbage but also for biomass with high moisture content. After biomass is sterilized and its volume is reduced, it can be available for transporting and composting.

In order to develop such a technology, I focused on superheated steam (SHS). It is a dried gas which consists of only water-molecules heated over 100^oC. SHS has some properties different from a heated air (Suzuki 2005). One of the most important properties is a higher thermal conductivity caused by three reasons as follows. Firstly, the convectional heat transfer of SHS is higher than that of the heated air because the heat capacity of the water-molecule is higher than that of N_2 and O_2. Secondly, the molecule of water gives radiant heat but molecules of N_2 and O_2 do not. Thirdly, the molecule of water in the gas state condenses on a surface of a substance, the temperature of which is lower than 100°C. When the water condenses, the heat of condensation is transferred to the substance. From these reasons, the SHS has an advantage to heat the substance quickly. When the temperature of substance increases, liquid water in the substance easily changes into gaseous water, i. e. steam. The change introduces dehydration and weight-reduction of the substance. In this study, utilization of SHS for dehydration of biomass which contained a high amount of water was investigated.

The objective of the study at the beginning was to investigate the utility of SHS for volume-reduction of biomass as mentioned above. I added another objective to this project. It is to use water for collecting good materials from biomass, which is discarded. I used water which maintains its liquid state in a temperature range from 100 to 374°C under pressurized condition. The water is called as subcritical water and has two characteristics different from water at ambient temperature and pressure. One of the characteristics is a low relative dielectric constant. It is a reason why solubility of hydrophobic substances such as fatty acid to subcritical water was increased while temperature increased (Khuwijitjaru *et al.*, 2002). The other is a high ion product. It makes subcritical water to act as an acidic or basic catalyst. Using the two characteristics, subcritical water have been investigated as a tool for extracting valuable materials from various biomass (Adachi and Kimura). In this study, the subcritical water was investigated in order to extract valuable materials from shell of *Carya cathayensis sarg*, which is a nut produced in China. The amount of product is 7,000 ton a year. The shell is discarded.

MATERIALS AND METHODS

1. Dehydration of a substance with a high water-content by SHS

The apparatus as shown in Figure 1 was set for the experiment. Distilled water was supplied to a stainless tube (i. d. 0.8 mm x 20 m, sus316) by a pump. The water was heated in the preheated coin set in the oven and the water changed to the SHS, the temperature of which was the same of the air in the oven. The SHS was supplied into the stainless bucket at a constant flow rate, 1.0 L/min. The SHS was drained to the outside of oven. Asparagus was selected as a model of plant biomass with a high water-content. The asparagus was cut into some 3 cm-pieces. The piece was put on a stainless plate and it was weighed (w_0). Nine of the plates were

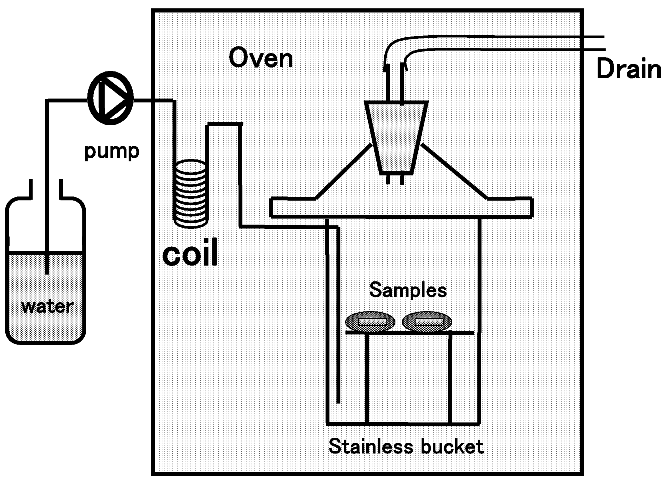

Fig. 1 Apparatus for the SHS experiment

put in the bucket which was preheated. Three of them were picked up at an appropriate time to weigh them (w_x). They were not put back but kept in another oven at 105 °C until their weigh reached to a constant value (w_e). The temperature of the oven for the SHS experiment was set at 140, 155, 170, or 185 °C. The content of remaining free water (w) was calculated as follows.

$$w = \frac{w_0 - w_x}{w_0 - w_e} \times 100 \quad [\%]$$

2. Extraction of valuable substances from biomass by subcritical water

A shell of nut, *Carya cathayensis sarg*, which was produced in China, was chosen as a biomass in this study. The shell was ground into the powders with a mortar. Ten milligrams of the powder were put with 7 mL of distilled water in a withstand pressure vessel (10 mL, sus316). The vessel was put in an oil bath, the temperature of which was controlled at 130 to 190 °C. Alternatively, the vessel was rounded by a mantle heater with a thermo controller. The temperature of the vessel was kept at 200-280 °C. The reaction time was from 15 to 240 min. In order to stop the reaction, the vessel was put in ice. After the temperature of the vessel became the ambient one, the reaction solution was taken out from the vessel and filtered with a paper filter. The concentrations of reducing sugar and protein in the filtrate were measured by phenol-sulfuric acid method (Dubois *et al.*, 1956) and Lowly-Folin assay (Lowly *et al.*, 1951).

RESULTS AND DISCUSSION

1. Dehydration of a substance with a high water-content by SHS

Figure 2 shows the photos of the pieces of asparagus which were treated with the SHS at 170 °C. The samples at 20 min still kept their green color. The content of remaining free water was 70% at that time. At 40 min, the color was changed to yellow green and the content was 30%. At 120 min, the color was turned to brown and the content was 0%. The weight of the piece at that time decreased to 3% of that of the piece before treated. The pieces of the asparagus which were treated at 140 °C kept yellow color until 80 min (data not shown).

Figure 3 shows the time course of change of remaining free water contents. The contents decreased quickly. The decreasing rate depended on the

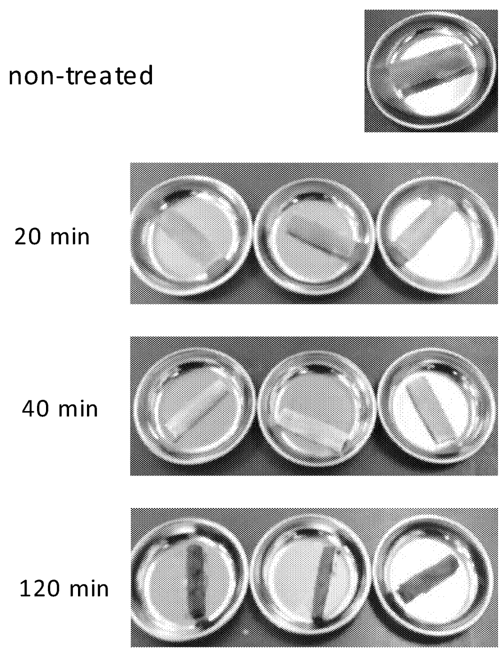

Fig. 2 Apparatuses which were treated by SHS at 170°C

temperature of the SHS. The higher temperature gave the faster rate. The times when the contents reached to 50% were 46, 36, 28, and 21 min at 140, 155, 170, and 185 °C, respectively. This result shows that the SHS can be used for the volume-reduction of a substance with a high water contents. The apparatus for this experiment is very small. The scale-up should be is the next issue.

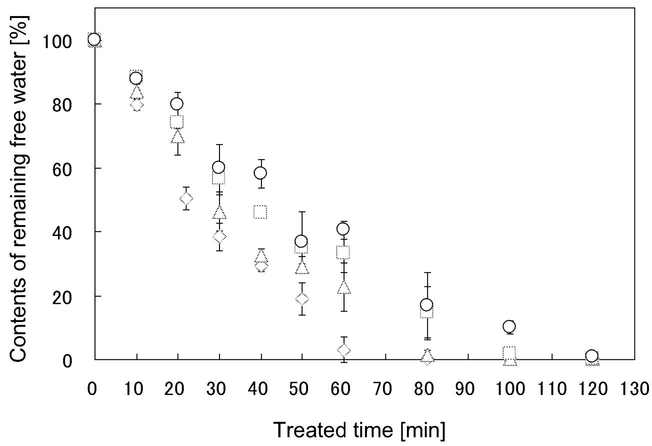

Fig. 3 Time courses of changes of remaining free water contents by the SHS treatment.

140(○), 155(□), 170(△), and 185 °C(◇)

2. Extraction of valuable substances from biomass by subcritical water

Figure 4 shows the contents of reducing sugar extracted by subcritical water (130-190°C). Almost no sugar was extracted by water at the ambient temperature but sugar (10% of the sample) was extracted even at 130 °C. The higher temperature increased the contents. The highest content was given at 190 °C and 60 min. The major components in this filtrate would be oligocellulose and glucose which are produced by decomposition of cellulose. The longer treatment time decreased the value of content. The decrease would be due to the degradation of sugar to some acid or other compound as shown in the case of other biomass (Hata *et al.*, 2008).

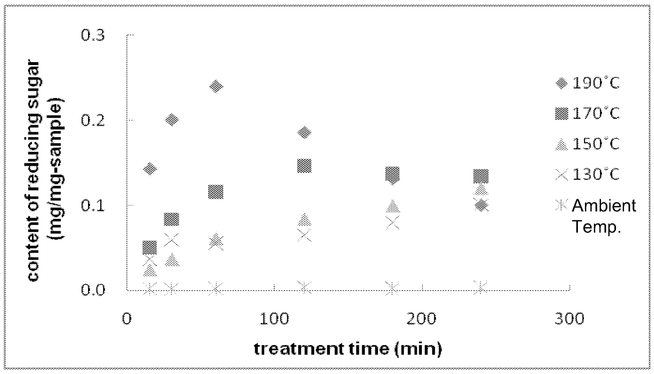

Fig. 4 Contents of reducing sugar extracted by subcritical water with various treatment time at various temperature, 130-190°C.

Figure 5 shows contents of protein in the filtrate when the biomass was treated at 130-190°C. The higher temperature increased

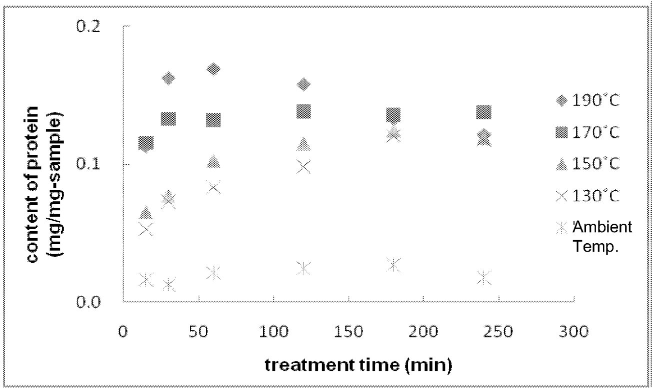

Fig. 5 Contents of protein by subcritical water with various treatment time at various temperature, 130-190°C.

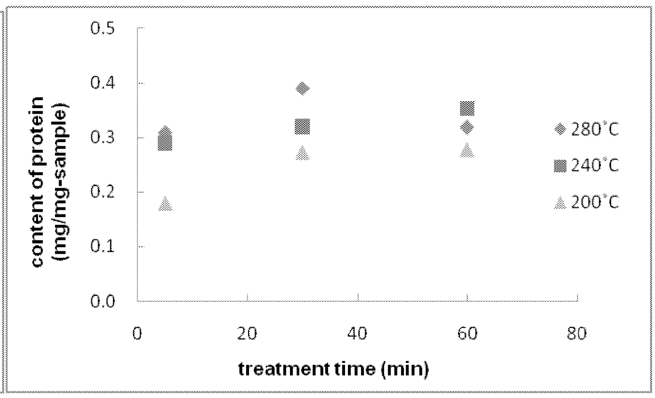

Fig. 6 Contents of proteinr extracted by subcritical water with various treatment time at various temperature, 200-280°C.

the content. The highest content was given at 190 ^{o}C and 60 min within these temperature ranage. The contents slightly decreased during the longer treatment time at 190^{o}C. In these treatment times, protein would be decomposed to some amino acids because the Lowry-Folin assay can detect native protein, denatured protein, and peptide but not detect amino acid except tyrosine and tryptophane. The temperature higher than 190 ^{o}C gave the higher contents (Fig. 6). The maxmam value of the content was 0.4 at 280^{o}C. The high temperature and short treatment time is available for the extraction of protein from this biomass.

The subcritical water is a good tool for the extraction of valuable components from biomass. In the further study, other components which exist in the filtrate should be detected by other assay such as radical scavenging assay (Hata et al., 2008).

CONCLUSIONS AND PERSPECTIVES

The SHS was available for the volume-reduction of a substance with high moisture content. The most effective temperature was 190^{o}C. Subcritical water effectively extracted valuable component, glucose and protein. The filtrate could be used as a broth for yeast to produce bioethanol. However, the scale of apparatus in this study is small. The scale up is the next issue for the application.

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