Effect of ultrasound pretreatment on hot air drying rate of scallop muscles

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Abstract. To improve the drying rate and to reduce the energy consumption of aquatic product, scallop muscles were treated by ultrasonic with different frequency, time and different temperature. The hot air drying rate of treated scallop muscles was determined, and, meanwhile, several quality parameters such as the shrinkage and rehydration rate of samples with pretreatment were determined to compare with those of untreated samples. The results indicated that the drying rate of scallop muscles can be improved by the ultrasonic pretreatment without affecting the quality. Under a 70 kHz for 30min at 25°C, the drying rate of pretreatments is 1.29 times higher compared with that of the control group.

1. Introduction
Scallop is a popular aquatic product available in China. Since 1980s, cultivation of scallops has developed rapidly. In recent years, the production of scallop has been in excess of 100,000 tons [1]. Scallop muscle contains many desirable flavor components. As an important marine product, dried scallop is also regarded as healthy food that is gaining popularity. Hot air drying is one of the most commonly used procedures in dried scallop muscle, with main disadvantages being prolonged duration and high energy consumption [2]. Therefore it is necessary to explore low power consumption processing for hot air drying.

Dry pretreatment technology is utilized to treat food through some physical methods before drying it. Pretreatment can not only improve the quality of dried food but also speed up its drying and thus reduce energy consumption. For example, during the process of drying and dehydration for fruits and vegetables, high pulse electric field pretreatment at certain intensity will enhance their drying rate and thus reduce the drying energy consumption [3-7].

Ultrasound has been used in the food industry for many purposes. Low-frequency, high-energy ultrasound has been applied to determine food properties. However, this technology in food industry is relatively new and it has not been explored in-depth until recently [8].

Studies in recent years have demonstrated that as a pre-processing step for fruits and vegetables in the drying process, a ultrasound is able to cause reversible membrane perforation, and it is hoped that it will help to increase dryer efficiency, save energy, and enhance product quality [9-11]. For example, Nowacka et al. used ultrasound to pretreated apples, and found the ultrasound treatment caused reduction of the drying time by 31% in comparison to untreated tissue. The ultrasound treated apples exhibited between 9% and 11% higher shrinkage, 6-20% lower density, and porosity of 9-14% higher than untreated samples [12].
At present, there are only few reports on drying seafood products using ultrasound pretreatment. In this paper, scallop muscle, as a representative of seafood products, were treated in an ultrasound system, in different frequency, time and different temperature. The hot air drying rate of treated scallop muscle was determined and, meanwhile, several quality parameters such as the shrinkage and rehydration rate of samples with pretreatment were determined to compare with those of untreated samples.

2. Experimental procedure

2.1. Experimental equipment

The ultrasound pretreatment system shown in figure 1 was developed by the authors. Its main components are an ultrasonic generator and a constant temperature water bath. The range of frequency of which can be adjusted from 50 to 100 kHz by a controller.

![Figure 1. Schematic of the ultrasound pretreatment system](image)

2.2. Preparation and drying of scallop muscles

Fresh scallops were procured from the local market near Dalian Ocean University, China. Before drying, scallops were washed with tap water and blanched in boiling water. The scallops were quickly taken out as soon as their shells opened; they were then cooled in tap water. The scallop muscles were cut and rinsed. After rinsing, the scallop muscles were dipped in NaCl solution at 90–95 °C for 10 min. They were then taken out and drained. The initial moisture content of scallop muscle was 71±1%. The samples were divided into 28 groups with similar weights. One was the control group and the others were experimental groups. The experimental groups were subjected to ultrasound pretreatment with different time (15, 30, 45 min), different ultrasonic frequency (50, 70, 100 Hz) and different temperature (15, 25, 35 °C), respectively. Then, all samples were dried by hot air (60°C) until they reached the final moisture content (15±1%).

2.3. Shrinkage measurement

Shrinkage determination was made by manually measuring the sizes (average diameter and average thickness) of the fresh scallop muscle and the dried scallop samples obtained from different drying processes using a vernier caliper. The equivalent column volume of each sample was then determined and compared. Ten samples were measured under each experimental condition. Percentage of shrinkage was calculated using the following equation:
Percentage shrinkage = $(Z_0 - Z_f)Z_0^{-1} \times 100$ \hspace{1cm} (1)

Where $Z_0$ (cm$^3$) and $Z_f$ (cm$^3$) are the volume of each group of scallop muscle at the beginning and at the end of each drying experiment, respectively.

2.4. Rehydration ratio measurement

Rehydration ratio was determined by soaking dried scallop muscle in hot water at 100°C. The soaked scallop muscles were blotted with a paper towel of good quality to remove excess water. They were then weighed and placed back into the soaking water. Rehydration ratio value was expressed in percentage and calculated as mass of water absorbed per 100 g of dried scallop muscle using the following formula.

Percentage rehydration ratio = $(m_g - m_0)m_0^{-1} \times 100$ \hspace{1cm} (2)

Where $m_0$ (g) and $m_g$ (g) are weights of the samples before and after rehydration, respectively.

3. Results and discussion

3.1. Influence of different ultrasonic frequency and pretreatment time for different temperature on drying rate

The influence of ultrasonic frequency and pretreatment time for different temperature on drying rate was shown in Figure 2-4. It can be seen from the graphs that the drying rate of ultrasonic pretreatment scallop muscle was higher than that of the control. Under a 70 kHz for 30min at 25°C, the drying rate of pretreatments is 1.29 times higher compared with that of the control group.

![Figure 3. Effect of ultrasonic frequency and pretreatment time on average drying rate of scallop muscle at 25°C.](image_url)
3.2. **Influence of ultrasonic pretreatments on shrinkage and rehydration ratio of scallop muscle**

The influence of ultrasonic frequency and pretreatment time for different temperature on shrinkage and rehydration ratio of scallop muscle was shown in Table 1. It can be seen from the table that the shrinkage of ultrasonic pretreatment scallop muscle was lower than that of the control. But, rehydration ratio results showed that the pretreatment improves rehydration capability of scallop muscle.

**Table 1. Three Scheme comparing.**

| Pretreatment group (70 kHz for 30min at 25°C) | Shrinkage | Rehydration ratio |
|---------------------------------------------|-----------|-------------------|
| control group                              | 71.1      | 125.7             |
| Pretreatment group (70 kHz for 30min at 25°C) | 71.3      | 122.2             |

4. **Conclusion**

The drying rate and quality of scallop muscle can be improved by ultrasonic pretreatment, and while ultrasonic pretreatment was applied by 70 kHz for 30min at 25°C, the drying rate could be increased approximately 29%.

**Acknowledgments**

This work was supported by the Scientific Research Fund of Liaoning Provincial Education Department under contract No (L2013273)

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