Study on Application of Stirling Cooler to Food Processing

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Abstract

It is known that in some methods of food production, refrigeration and mixing are essential. For example, the process of butter production involves a considerable number of stages. Also in the Stirling cooler with colliding displacers (SCCD), the cylinder concusses regularly to produce cooling and churning actions. There is some comparability between the two processes. So the research objective of this study is the application of Stirling cooler to the production of butter.

In order to apply Stirling cooler to butte churning, an experimental Stirling cooler was introduced, which can be used as cooler, as well as produce butter.

There are many factors can affect the performance of the Stirling cycle cooler. In this study, three major effect parameters—the size of the displacer, the volume of the working fluid (air) and Oscillating frequency—were studied. The results showed that the size of the displacer has a significant impact on the performance of the cooler, the larger the size of displacer, the lower the temperature of the cooler and the higher the temperature falling rate; referring to the effect of the volume of working fluid, enhancement of the cooling effect is achieved with a large volume of working fluid or a high compression ratio. The oscilling frquency experiments showed that there was an optimum oscilling frquency which can obtain the lowest temperature and the time needed to reach the lowest temperatur was found to reduce when the oscillating frequency increased.

From the butter churning experiments with the Stirling cooler, it can be concluded that the butter cluster when the Stirling cooler was used formed earlier than that under the control method (no cooling effect) and also the butter cluster produced using the Stirling cooler showed a higher quality, which was lower in water content and higher in fat content than that produced using the control method.

However, the fat content of the butter cluster produced in chapter 3 was 68-69%, which was lower than that of the standard butter which is currently over 80%. The reason for this was that the cooling efficiency was probably not as high as expected. So that the displacer (regenerator) of the cooler was improved to enhance the cooling ability. Following this adjustment, the experimental FPSC was used for butter churning again to demonstrate the increase in the performance.

The original displacer was improved by stainless steel mesh layer. The mesh number and thickness of the mesh layer were chosen as the parameters and two-way ANOVA test was carried out to confirm the optimum parameter combination. The results were that the thickness of the mesh layer showed the statistically significant main effect on the cooling performance, however, the mesh number of mesh layer showed no statistically significant main effect on the cooling performance, and also no significant interaction effect was observed between thickness and type of mesh. And the cooling performance was improved by use of the modified displacer than that of the original displacer.

After the optimal combination of mesh number and thickness of the mesh layer was determined through the foregoing experiments, butter churning was carried out with the Stirling cooler. The results were that the butter cluster formed earlier and was of higher quality when the modified displacer was used than that of the original displacer was used. The results also included that there was an optimum value of initial fat content of the cream, under which the butter churning process could be completed more quickly.

The results showed that the water content of butter cluster obtained in this experiment has decreased and the fat content has increased to a certain extent than that of former experiments. This means that with the increase in cooling ability, the characteristics of the butter cluster have also increased. However, energy consumption ratio of this equipment is very low, after the suitability of application on butter churning was testified, improvements to the equipment are necessary in order to obtain butter of high quality with a high energy consumption ratio in the further study.