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Innovative food processing technology using ohmic heating and aseptic packaging for meat

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ABSTRACT

Since the Tohoku earthquake, there is much interest in processed foods, which can be stored for long periods at room temperature. Retort heating is one of the main technologies employed for producing it. We developed the innovative food processing technology, which supersede retort, using ohmic heating and aseptic packaging. Electrical heating involves the application of alternating voltage to food. Compared with retort heating, which uses a heat transfer medium, ohmic heating allows for high heating efficiency and rapid heating. In this paper we ohmically heated chicken breast samples and conducted various tests on the heated samples. The measurement results of water content, IMP, and glutamic acid suggest that the quality of the ohmically heated samples was similar or superior to that of the retort-heated samples. Furthermore, based on the monitoring of these samples, it was observed that sample quality did not deteriorate during storage.

1. Introduction

Currently, retort heating is one of the main technologies employed for producing processed foods, which can be stored for long periods at room temperature. There is a strong demand for retort food from consumers as emergency food because of their long shelf life and ease of consumption; furthermore, such foods are popular as everyday food. However, retort sterilization relies on external heating, using hot water or steam as a heat transfer medium; this results in poor heat transfer efficiency and, consequently, considerable energy loss.

Ohmic heating is an emerging thermal process technology and describes the process when an electrical current is passed directly through a food and the resistance imposed by the food leads to the generation of heat within the product. The basic principles as well as the main factors influencing ohmic cooking have been explained by Sastry (1992) and Ye, Ruan, Chen, and Doona (2004). Sastry and Palaniappan (1992) reported that ohmic heating can be used in a continuous flow mode to cook and sterilize liquid food and solid–liquid mixtures. Huixian et al. (2007) reported that the microbial counts and the calculated decimal reduction time resulting from ohmic heating were superior to those resulting from conventional heating, and there was no difference in the degree of protein denaturation between the two methods. Nowadays ohmic heating is viewed as an alternative heating system for pumpable foods and there are currently a number of commercial scale processing plants in various countries (UK, Italy, Mexico) producing fruit and/or vegetables in sauces and also pasteurized orange juice and liquid egg. Sarkis, Jaeschke, Tessaro, and Marczak (2013), Mercali, Jaeschke, Tessaro, and Marczak (2013), and Mercali, Jaeschke, Tessaro, and Marczak (2012), reported on the denaturation of anthocyanins and vitamin C in acerola and blueberry during ohmic heating compared to the denaturation of these during conventional heating. Moreno, Pizzaro, Parada, Pinilla, and Reyes (2012) reported that ohmic heating is the best dehydrating method. And the color and the hardness of osmotically dehydrated strawberry with ohmic heating and vacuum impregnation was superior to the conventional method. The effect of ohmic heating and vacuum impregnation changed the shelf-life from 12 days to 25 days. While a number of the early patents in ohmic heating were in the area of meat processing the amount of in depth research conducted to date has been quite limited in spite of the fact that ohmic heating has the potential to cook meat in a much shorter time than the conventional cooking procedures. Shirsat, Brunton, Lyng, and Mckenna (2004) and Piette et al. (2004) showed that it is possible to cook comminuted meat emulsions ohmically to a comparable quality of the conventional cooked samples. Dai et al. (2013) evaluated the color and sarcoplasmic protein of pork following water bath and ohmic cooking at 10 °C to 80 °C. Ohmic heating of fluids, which may also contain solid foods, has been thoroughly studied and reported in the literature. Bertlini and Romagnoli (2012) showed that the process-target-cost of vegetable soup was reduced with ohmic treatment and aseptic packaging.

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However, these products represent a relatively small proportion of total cooked meats and no results have yet been presented on the quality of ohmically cooked noncomminuted meats. The direct application of ohmic heating to solid food is limited (De Alwis & Fryer, 1992). There are no studies on the production technology for solid food with commercial-level sterility attained by heating at 100 °C or higher or by ohmic heating without the use of conductive liquids.

The ohmic method requires uniform conductivity values within the meat which means that a perfectly even distribution of injected salt or brine solutions must be achieved in the case of non-comminuted meats. A lot of research was done on electrical conductivity of foods (Palaniappan & Sastry, 1991) and on the changes in electrical conductivity of foods during ohmic heating (Halden, De Alwis, & Fryer, 1990). Sanjay, Sudhir, and Lynn (2008) published a paper about the change of electrical conductivity values over a special temperature range in a very small unit. This research team looked mainly into the electrical conductivity changes of fruits and also a few details about the behavior of different meat pieces were published but there is still a lack of research in the ohmic heating of full meat products.

A novel cooking method such as ohmic heating may offer a number of advantages, such as quicker cooking and less power consumption and safer product, however, the important considerations for a food product are its taste, quality, and customer satisfaction.

There have been no studies on ohmic heating combined with aseptic packaging for meat nor on meat measured for one year as shelf-stable food of meat. In this study, we developed novel food processing technology, which supersedes retort processing, using ohmic heating and aseptic packaging. Chicken cooked by combined ohmic heating and aseptic packaging was tested and compared with chicken heated by retort heating. We examined the temperature history, electrical conductivity data and lethal rate during current application. Additionally, we assess quality and sensory tests on the sterilized packaged food heated by those two methods.

2. Materials and methods

2.1. Material

Chicken meat was purchased from Miyagawa Shokucho Keiran and stored in a freezer at −80 °C until experimentation.

2.2. Equipment

We used a high-frequency power unit (HJU3000-HF-30, Hano Manufacturing). The output voltage was 10–100 V, output frequency was 20 kHz, and maximum power output was 3 kW. A polyphenylsulfone (PPSU) container with an internal diameter of 3 cm and a length of 10 cm (Sunny) was used as the heating cell. Titanium foils (30-μm thick) were used as electrodes.

2.3. Preparation of samples

The stored meat was removed from the freezer and thawed in a refrigerator at 5 °C. Then, the meat was shaped into a cylindrical form (approximately 30 mm × 100 mm, 70 g ± 0.5 g) so that it could fit into the heating cell, and was wrapped with polyvinylidene chloride film. Wrapping the sample with the film made it easier to clean the cell and prepare it for the next test.

The meat was inserted into the heating cell. Thereafter, silicone rings and stainless caps, in that order, were attached to the cell, and the cell was fixed using a stainless steel retainer. A type T thermocouple covered with an insulator was inserted into the cell through a hole in one of the stainless steel caps and fixed in place. Given that the pressure inside the cell increases during heating, the cell was retained securely to prevent steam leakage during heating. The electrodes of the high-frequency power unit were connected to the stainless steel caps and an electric current was then applied to the heating cell. The voltage was set at the maximum, 100 V. The current was set to 5 A because the maximum effective current is around 1.5 A for chicken breast when the measured temperature is between 10 °C and 140 °C.

The current application was stopped when the temperature of the cold point exceeded 121 °C for four continuous minutes. When the temperature decreased to below 100 °C, the sample was placed aseptically in a sterilized retort pouch and was sealed using a heat sealer (Ishizaki Electric MFG). Following cooling for 20 min under flowing water, the sterilization-test sample was stored in an incubator at 35 °C for 14 days; the quality-test sample, at 25 °C for 2, 14, 28, 56, 84, 112, 168, 224, 280, or 365 days; and the sensory-test sample, at 25 °C for 14 days.

In this study, the ohmically heated sample was compared with a retort-heated sample in the quality and sensory tests. The retort-heating sample was shaped into a cylindrical form with the same size and weight as the ohmic-heating sample, frozen at −80 °C, and sent to Nihon Senshoku, Fukuoka Prefecture (shipping temperature −20 °C), where it was retort heated. The retort-heated sample was stored for 2, 14, 28, 56, 84, 112, 168, 224, 280, or 365 days. Furthermore, prior to retort heating, we ensured that the sample was stored at the same temperature as the ohmically heated sample.

2.4. Temperature measurement at different locations

Every point was measured three times. The heating cell and the locations of thermocouples placed on the cell for temperature measurement are shown in Fig. 1. The thermocouples were placed at five locations (A–E) (see Fig. 1) and temperature changes until 121 °C were recorded.

2.5. Electrical conductivity calculation

Measurement was made five times. The distance between the electrodes d [m], electrode contact area A [m^2], applied voltage V [V], and measured current I [A] were substituted in Eq. (1) below. This equation was derived from Ohm's law, the relational expression between electrical resistance and electrical resistivity, and the relational expression between electrical resistivity and electrical conductivity, to

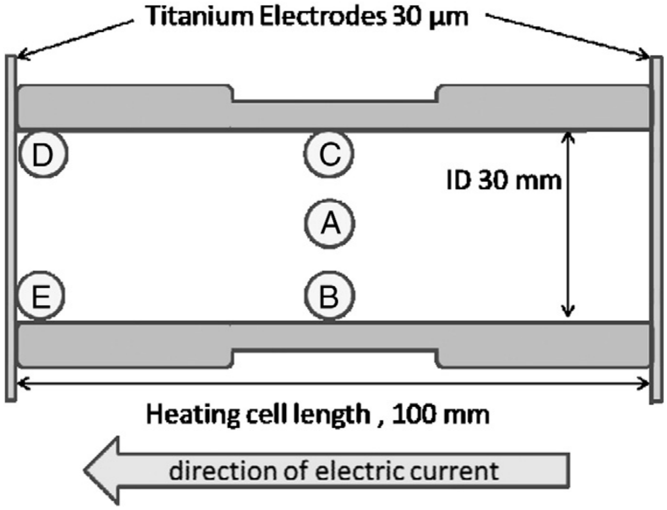

Fig. 1. Five locations of thermocouples for evaluation of temperature distribution during heating. A: Center of the cell. B: Bottom center of the cell. C: Upper center of the cell. D: Upper part of the cell near the electrode. E: Lower part of the cell near the electrode.