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The use of the impedance measurements to distinguish between fresh and frozen–thawed chicken breast muscle

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ABSTRACT

An impedance system was built to differentiate fresh chicken breasts from those that had been frozen and thawed. Inserting needle electrode pairs of the detecting probe aligned with the longitudinal direction of muscle myofibers (PL) gave more satisfactory results. Learning vector quantization neural network (LVQNN) and partial least square-discriminant analysis (PLS-DA) were employed to acquire the prediction accuracy. The results demonstrated that the model using LVQNN achieved a satisfactory prediction accuracy, with a discrimination accuracy for fresh breasts of 100%. Additionally, the recognition results for a single frozen–thawed cycle were greater than 90%, and for two cycles were greater than 88%. The values obtained from PLS-DA were somewhat lower than for LVQNN, being 100% for fresh samples, in excess of 90% for single frozen–thawed cycle and more than 84% for those that had been multiple frozen–thawed. In conclusion, these results showed that the impedance system is a simple and effective application for the discrimination of fresh chicken breasts from frozen–thawed ones.

1. Introduction

Chicken meat plays a very important role in the daily life of many people, making a significant contribution to their overall nutrition. Because of its significant usage, there is concern regarding the meat quality and safety for consumers, regulatory authorities and retailers. Although freezing is an efficient method for extending the shelf life of chicken meat (Leygonie, Britz, & Hoffman, 2012), the content of many nutrients is lost during storage and thawing process (Soyer, Ozalp, Dalmis, & Bilgin, 2010). This results from structural damage to cell membrane caused by the formation of ice crystals and by various molecular changes (Ottavian, Fasolato, & Barolo, 2013). Currently, many consumers prefer to buy fresh meat rather than frozen–thawed one despite the higher cost of fresh meat as they are aware that the sensory and nutritional quality of the product as well as the shelf-life may be affected. Unfortunately, some retailers fraudulently mislabel their products, selling frozen–thawed meat as fresh one.

Many methods have been developed to evaluate the freshness of meat in order to differentiate fresh from frozen–thawed meat (Hansen, Høy, & Pettersen, 2009; Fan et al., 2009; Campus, Addis, & Cappuccinelli, 2010). For example, much attention has been paid to various biochemical technologies of which the β-hydroxyacyl-CoA-dehydrogenase (HADH) method is the most widely used to distinguish the fresh from the frozen–thawed meat (Gottesmann & Hamn, 1983). Methods based on DNA technology, including real-time polymerase chain reaction (RT-PCR) and neutral comet assay, have also been reported (Bellete, Flori, Hafid, Raberin, & Trans, 2003; O'Brien, Xu, & Patierno, 2001; Park et al., 2000). Meanwhile, methods based on spectroscopy, such as visible and near infrared spectroscopy (NIR) (Liu & Chen, 2000; Liu, Barton, Lyon, Windham, & Lyon, 2004) and nuclear magnetic resonance (NMR) (Evans, Nott, Kshirsagar, & Hall, 1998; Guiheneuf, Parker, Tessier, & Hall, 1997; Mortensen, Anderson, Engelsen, & Bertram, 2006), are used more frequently to evaluate the freshness. As a result of the formation of the ice crystals during frozen, the damage to the cell can be detected by bio-imaging, consisting of the light microscopy (Molina et al., 2004; Zhu, Bail, Ramaswamy, & Chapleau, 2004), and electron microscopy (Carroll, Cavanaugh, & Rorer, 1981). However, most of these techniques have significant drawbacks such as their time-consuming, high costs and being destructive to sample. There is clearly a need for an effective, rapid, portable, cost-effective and easy to use method to differentiate such products. Recently, the use of impedance technology has become of interest in the meat processing industry. The Fricke model (Fricke, 1925), a basic theory regarding the impedance phenomenon, illustrates that biological tissue components (cells, liquids, membranes, intracellular fluids (ICFs), extracellular fluids (ECFs)) with passive electrical elements (resistor, capacitor) were connected in series and in parallel. The impedance depends on the intracellular fluids (ICFs) and extracellular fluids (ECFs), because they work as electrolyte which would be influenced by the integrity of cellular membrane. This reinforces the use of electrical impedance within the cellular. Impedance technology has been applied in cured product studies as well as fresh and frozen–thawed meat detection. Salt levels in food products have been studied using the impedance technology

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(Masot et al., 2010). Guerrero et al. (2004) applied electrical impedance technology to measure the 'pastiness' of dry cured hams. Rizo et al. (Rizo et al., 2013) used an improved method to monitor the process of the salting–smoking of fish. The same method is also applied in the fresh and frozen–thawed fish detection (Vidacek, Medic, Botka-Petrak, Nezak, & Petrak, 2008; Fuentes et al., 2013). Membrane modifications in the extracellular medium caused by the frozen–thawed process are bound to affect electrical properties. However, to our knowledge, there are limited reports regarding the use of electrical impedance technology for the rapid discrimination of the fresh from frozen–thawed poultry meat.

In non-destructive detecting modeling of agricultural products, the neural network model has been widely used for nonlinear model systems. Learning vector quantization neural network (LVQNN) is one of the nearest-neighbor pattern classifiers based on competitive learning. Due to the simplicity of the network and better pattern classification of the learning vector quantization neural network (LVQNN), it has always been applied for pattern classification, identification and pattern recognition analysis.

In order to explore the feasibility of impedance technology used for the differentiation of the fresh meat from the frozen–thawed meat, the present research undertook (1) the selection of the best setting for the capture of the impedance data; (2) the employment of learning vector quantization neural network (LVQNN) and partial least square-discriminate analysis (PLS-DA) models to investigate the feasibility of impedance technology for detecting fresh meat from the frozen–thawed meat; and (3) a comparison of the accuracy of the LVQNN and the PLS-DA based on magnitude, phase and the mixture effects of the two parameters.

2. Materials and methods

2.1. Chicken breast meat preparation

Chicken breast meat (*chicken pectoralis major* muscle) was obtained from a local poultry processing plant (New Hope Liuhe Co., Ltd. Shandong, China). The meat was from the same batch of chickens from the same breed and raised under similar management conditions. Visible fat and skin tissue were removed from each breast. The samples were initially stored at 4 °C in an insulated container and then transported (3 h) directly to laboratory with solid CO_2. A total of 750 breasts were randomly divided into three groups (250 samples per group). Each breast was about 250 g on average with almost same shape $13 \times 6 \times 4$ cm^3. The first group (G1) samples were used as fresh or unfrozen samples. The second group (G2) was used for meat stored at −20 °C for 30 days. The third group (G3) samples were processed as for G2, but were thawed once at 4 °C on the fifteenth day for 12 h then refrozen during the 30-day period of frozen storage. All G2 and G3 samples were placed into the plastic bags to prevent drying of the surface during cold storage. On the 30th day, the G2 and G3 were thawed at 4 °C for 12 h. Before being measured for impedance, all samples were allowed to equilibrate to 25 °C. Of the 250 samples from each group, 160 were randomly selected to build the prediction set while the remaining 90 samples were used to create the validation set. The detailed process used is shown in Fig. 1. In the rest of the research, the breast samples were classified using neural network.

2.2. Impedance data analysis system

The schematic diagram of impedance is shown in Fig. 2 according to Fricke model (Fricke, 1925). A set of impedance equipment was shown in Fig. 3. This system consisted of a computer (CPU E5800, 3.2 GHz, Memory 2 G, Dell, USA), the impedance instrument (T2827-A, Tonghui, Changzhou, China), a sample holder station and two different probes. The impedance magnitude and phase angle were measured at fifteen frequencies from 50 to 200 kHz (0.05, 0.06, 0.08, 0.1, 0.12, 0.15, 0.2, 0.25, 0.3, 0.4, 1, 1.2, 50, 100, 200 kHz) and all of these frequencies were selected referring to not only the ideal model for α-dispersion and β-dispersion described by Gheorghiu (1993) but also the range ability of the instrument.

2.3. Selection of the methods and the data acquisition

In order to acquire accurate and most appropriate data, detailed parameters of the equipment were selected. Because of the sensitivity of the impedance machine, the parameters were determined as: testing voltage of 500 mV, the testing temperature was adjusted to 25 °C (Chen, Zhao, & Vittayapadung, 2008) and the fixed insertion depth was 1 cm (Pliquett, Altman, Pliquett, & Schoberlein, 2003). However, the arrangement of the copper needles as well as the arraying direction of the probe and the myofibers (transversally and longitudinally) was important because of anisotropy (Damez & Clerjon, 2008a; Zhao, Wang, & Yao, 2015).

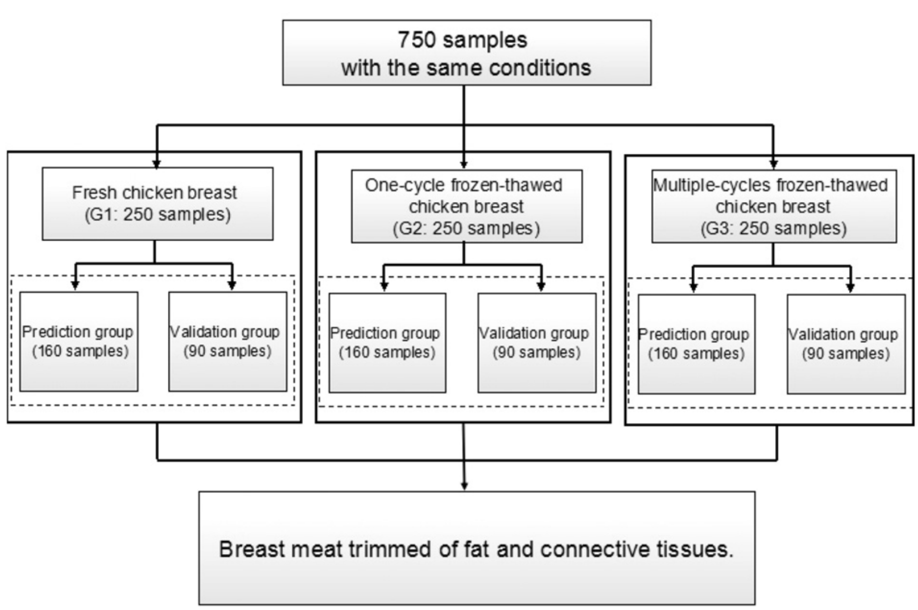

Fig. 1. Outline of pre-treatment used in this study.