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Research Note

Determining the drying degree and quality of chicken jerky by LF-NMR

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ABSTRACT

The objective is to characterize the changes in water mobility in drying process of chicken breast using ^{1}H low-field nuclear magnetic resonance (LF-NMR). Chicken breast was dried at different temperatures, i.e. 50 °C, 55 °C, 60 °C, 65 °C, 70 °C and 75 °C, respectively. Indicators related to water mobility were gained by LF-NMR and the shear force, the main relevant quality indicator, was also measured. The total water content measured by the conventional determination method-oven drying method were recorded and analyzed. The results showed that the total water content, the transverse relaxation time of immobilized water (T_{21}) and the signal per mass of the immobilized water (A_2) and the total water content (A) decreased significantly but the shear force value (SFV) increased with the drying time increasing at each drying temperature. A_2 and A had extremely significant correlations with the total moisture content, whose correlation coefficients were 0.983 and 0.992 for 50 °C, 0.928 and 0.901 for 55 °C, 0.975 and 0.970 for 60 °C, 0.920 and 0.938 for 65 °C, 0.821 and 0.798 for 70 °C, 0.911 and 0.906 for 75 °C. So, the immobilized water of the dried chicken breast determined the changes of the total moisture content at the same drying time. A_2 and A can be on behalf of the total moisture content in this respect of change rule. A_2 and A also had extremely significant correlations with the shear force. Therefore, the LF-NMR was able to evaluate the drying degree and the quality of chicken jerky.

1. Introduction

Jerky is an important part of the snack food with characteristics of low water content, endurable storage, small size and convenience for transportation, etc. Chicken breast rich in protein, vitamins and minerals is good material for jerky's processing. The main problem in this type of food is how to control the moisture content that plays an important role in the inhibition of microbial growth, increasing the storage time and the formation of good taste (Trout, 1988). The moisture content has influence on the tenderness of jerky that is one of the most important quality indicators and quantified by the shear force value (SFV). The development of rapid method and technique to determine the moisture content is necessary to guarantee the quality of jerky. The current methods used in determination of moisture content of chicken jerky are sensory measurements and oven drying method which is the conventional determination method. Different studies have focused on the development of methods to evaluate the drying degree of chicken jerky. However, some of the methods are tedious, expensive and time-consuming and require skilled personnel, so it is of interest to develop rapid non-destructive moisture content control techniques, which can be applied at any stage of the supply chain.

Being sensitive, fast and non-invasive, the low-field nuclear magnetic resonance (LF-NMR) has been widely adopted as an analytical technique for the characterization of water mobility and distribution in food (Agudelo-Laverde et al., 2014; Troutman et al., 2001; Haiduc and van Duynhoven, 2005). In recent years, NMR has been successfully applied to quantify the changes in water distribution and mobility during the conversion of muscle to meat, during ageing and during the process of freezing and cooking (Siciliano et al., 2013; Reid et al., 2006; Bertram et al., 2002). This technique has been suggested as an alternative method for the conventional determination of water-holding capacity (WHC), such as the Honikel's bag, the press methods and the centrifugation method in other development (Ruiz-Cabrera et al., 2004; Farag et al., 2009).

In this study, water mobility of chicken breast dried at different temperatures was measured using LF-NMR. At the same time the shear force, one of the most relevant quality parameter, was also measured. Correlation analysis about transverse relaxation time, the signal per mass and the shear force of dried chicken breast was determined to evaluate the drying degree, and try to monitor the quality variation of chicken jerky in drying process on line.

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2. Materials and methods

2.1. Sample preparation

Chicken breast, twenty-four hours post-mortem, was obtained from a local commercial meat plant in Henan Province and transported to the laboratory in a cooling box.

Upon arrival to the laboratory, chicken breast block shaped, complete and fresh was selected. After removing its fat, fascia and skin, chicken breast rinsed with water was put into the pot and boiled for 10–15 min until showing no significant red. Then meat samples were cut along the fiber direction and trimmed with a scalpel (3 × 1.5 × 1.5 cm) after cooling. The water of last step was filtered and weighed 20–40% of the weight of meat to dissolve or soak ingredients (Ingredients bag includes salt 30 g, ginger 30 g, sugar 25 g, white wine 10 g, star anise 7 g, licorice 3 g, resurrection lily rhizome 2 g, fructus tsaoko 2 g, cinnamon 1.5 g, fennel 1 g, monosodium glutamate 1 g and cloves 0.5 g) with being heated to boil. Next, the water and the cut meat was boiled for thirty minutes in the pot, and then simmered gently for 1–2 h until the water in the pot dried up.

The meat was dried at 50 °C and 55 °C for 2.5 h; dried at 60 °C for 2.0 h; and dried at 65 °C, 70 °C and 75 °C for 1.5 h in the oven. All determinations were done every 30 min.

As we know, drying conditions could be influenced by the circulation and the humidity of air besides the temperature. These factors will affect the mass transfer in drying process of chicken breast. A lot of preliminary experiments had been done to explore the optimal drying condition that was used over the course of this study.

2.2. NMR transverse relaxation measurements

The stripes were placed into a cylindrical glass tube (18 mm in diameter). The relaxation measurements were performed on a Niumag Pulsed NMR analyzer (PO001, Niumag Corporation, Shanghai, China) with a resonance frequency for protons of 22.7 MHz at 32 °C. Transverse relaxation was measured using the Carr-Purcell-Meiboom-Gill sequence (CPMG) (Bertram, 2004), with a τ-value (time between 90° pulse and 180° pulse) of 100 μs, and the lengths of the pulses were 19.0 and 38.0 μs, respectively. The repetition time between two scans was 3 s. Data from 4000 echoes were acquired as 4 scan repetitions and analyzed by a multi-exponential model under the program of the MultiExp Inv Analysis (Version 4.08, Niumag Corporation, and Shanghai, China).

2.3. Determination of the total moisture content

Meat samples were analyzed for moisture according to AOAC Official Method 950.46 with minor modifications, in which sampling weight was about 10.0 g (accurate to 0.001 g) instead of the weight from 5 g to 8 g and the first drying time of every sample was prolonged to 3 h. The mass of sample was measured before and after drying to constant weight in an oven maintained at 105 °C, and the moisture content was calculated as the percentage of weight loss.

2.4. Determination of the Warner–Bratzler shear force

The samples of dried chicken breast were trimmed along the fiber direction with a scalpel (2 × 0.7 × 0.7 cm). Then the chilled trimmed samples were placed on the equipment for shearing force (Warner–Bratzler Meat Shear SALTER Brecknell MODEL 235 6X of G-R Manufacturing Co., Manhattan, Kansas, USA) and ensured the fiber direction was perpendicular to the shearing blade. The measurements were conducted using a crosshead speed of 10 mm/min and a straight shearing blade which was 1.5 mm in thickness at room temperature. Samples of different drying time and temperature were divided into different groups. Test repetitions were for five times and the shear force was calculated as kg.

2.5. Statistical data analysis

Data are reported as mean ± standard deviation. Statistical treatment of the data was performed using the Statistical Package for the Social Sciences 12.0 (SPSS Inc., Chicago, IL, USA). An analysis of variance (one-way ANOVA) was conducted for each evaluation indicator to test whether there were significant differences.

In order to assess the feasibility of the LF-NMR discriminating the drying degree and the quality variation of chicken jerky, correlation analysis among the indicators was conducted.

3. Results and discussions

3.1. NMR transverse relaxation measurements of chicken breast dried at different temperatures

Four peaks were shown in Fig. 1. Two connected ones in the range of 0–10 ms (T_{2b}) stood for the bound water which integrated closely with polar groups on the surface of muscle protein molecules. And the largest peak whose signal reached above 90% of the whole in the range of 10–100 ms (T_{21}) stood for the immobilized water entrapped within the myofibril (Pearce et al., 2011). The last one in the range of 100–1000 ms (T_{22}) stood for the bulk water in the myofibril lattice. The phenomenon that the T_2 data of the transverse relaxation time in this study was different from those of relevant researches might be explained by the variability in breed, the testing conditions of NMR, the inversion algorithm and the analysis methods of the transverse relaxation data (Takemori et al., 2007; Gudjónsdóttir et al., 2011; Pearce et al., 2011).

According to Fig. 2, the signal of the water contained in the chicken breast dried at 50 °C changed gradually as the drying proceeded. Fig. 2 clearly showed that with the extension of the drying time, the transverse relaxation time of the immobilized water and the bulk water of chicken breast decreased significantly, suggesting that their mobility declined gradually. The variation trend of immobilized water was more evident than that of the bound water and the bulk water. And the mobility of bound water did not change significantly. It reflected the stability of that combined closely with the muscle protein (Damez and Clerjon, 2008; Brøndum et al., 2000; Møller et al., 2011; Puolanne and Halonen, 2010).

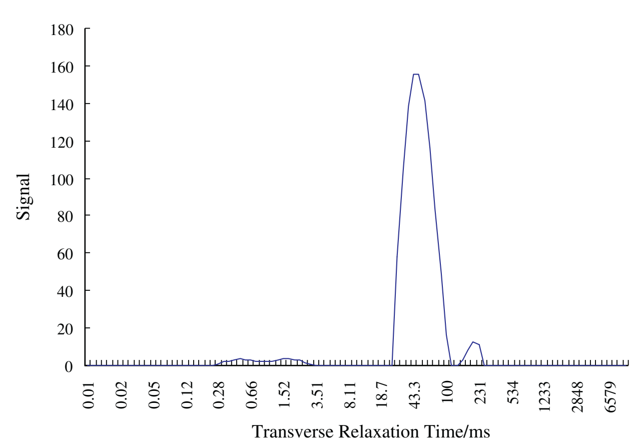

Fig. 1. Typical distribution of the transverse relaxation of the chicken breast.