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Meat quality and cooking attributes of thawed pork with different low field NMR T_{21}

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ABSTRACT

A relationship of low field NMR T_2 components to meat quality and cooking attributes of pork was investigated. *Longissimus muscle* was removed from 23 pig carcasses at 24 h postmortem for meat quality measurements and cooking test. Frozen samples were classified into three groups by LF-NMR T_{21} of thawed samples: A (<40 ms), B (40–44 ms) and C (>44 ms). There were significant differences ($P<0.05$) in pH, lightness (L* value) and pressing loss among the three groups. Cooking time to attain 70 °C was slightly lower in group C than the other groups. Shear force value of cooked samples was not affected by T_{21}. The component T_{21} correlated ($P<0.05$) with L* value, muscle pH and pressing loss, while L* value correlated ($P<0.05$) with thawing loss and muscle pH. Therefore, combined LF-NMR and color measurements could be a good way to differentiate water holding capacity of pork.

1. Introduction

In the past 10 years, Bertram and her co-workers have successfully applied low field (LF) NMR and other technologies to evaluate pork quality, especially of water holding capacity (WHC) (Bertram et al., 2001; Bertram, Purslow, & Andersen, 2002). In LF-NMR analysis, transverse relaxation components of myowater (T_2) within muscle or meat can be separated into two to three populations representing the water concentration in different compartments, which are characterized by two to three relaxation times (T_{2s}). Normally, the fastest relaxation population with a time constant of 0–10 ms (T_{2b}) is referred to as water tightly associated with macromolecules, and the intermediate population with a time constant of 30–50 ms (T_{21}) represents water located within highly organized protein structures, e.g. water in tertiary and quaternary protein structures with high myofibrillar protein densities including actin and myosin filament structures (intra-myofibrillar), and finally the slowest population with a time constant of 100–250 ms (T_{22}) represents the water located outside the myofibrillar network (extra-myofibrillar) (Bertram & Andersen, 2004). The LF-NMR transverse relaxometry (T_2) reflects myowater distribution and mobility and corresponding structural features in meat which directly affect WHC and drip (Bertram, Schafer, Rosenvold, & Andersen, 2004; Bertram et al., 2003, 2002; Pearce, Rosenvold, Andersen, & Hopkins, 2011), and sensory quality of cooked pork (Bertram, Aaslyng, & Andersen, 2005; Pearce et al., 2011). All these findings are extremely important to understand water distribution and mobility in muscle tissue at different conditions. However, few studies have related LF-NMR data to other quality attributes (e.g., meat color, shear force) and cooking attributes of meat.

The objective of the present study was to compare meat quality and cooking attributes among three groups of pork classified by LF-NMR T_{21} of thawed samples.

2. Material and methods

2.1. Sampling

A total of 23 cold pig carcasses (average and standard deviation of carcass weight were 62.4 kg and 10.8 kg) were randomly selected from animals, which were reared in the same farm, at 24 h postmortem in a local slaughterhouse. *Longissimus dorsi* muscle between the last three lumbar vertebrae was removed from the left side and meat color of cutting surface was measured. Due to long distance between the slaughterhouse and the laboratory (approximately 400 km), the samples for measurements of pH, water holding capacity (thawing loss, cooking loss and pressing loss), LF-NMR, cooking and shearing were vacuum packed and frozen at −20 °C, and then transported to the laboratory on dry ice.

2.2. Color measurement

After removing from carcasses, cutting surface of samples was bloomed in the air for approximately 20 min. Five measurements were performed on each sample. Color parameters were determined

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using a Minolta colorimeter (CR-300; Minolta Camera Co., Osaka, Japan) with illuminant D65, a 0° viewing angle and an 8 mm port/viewing area. Before measurement, the colorimeter was calibrated with a white tile (mod CR-A43). Color coordinates (L*, a*, b*) were recorded.

2.3. pH measurement

Muscle pH was measured according to the method of McGeehin, Sheridan, and Butler (2001). Briefly, 1 g of frozen sample was homogenized (Ultra Turrax T25, IKA, Germany) at 6000 rpm for 2 × 15 s with a 5 s break in 10 ml of ice-cold buffer containing sodium iodoacetate (5 mM) and potassium chloride (150 mM), pH 7.0. The pH of the homogenate was recorded with a Hanna 211 pH meter (Hanna, Italy).

2.4. Thawing and cooking

Frozen samples were thawed at +4 °C for 16 h. Thawing loss was calculated as a percentage of weight loss before and after thawing. Thawed samples were cut into two pieces (one was 2.5 cm thick and the other was 1.0 cm thick) perpendicular to muscle direction. The 2.5 cm thick piece was used for cooking test and the 1.0 cm thick piece was used for pressing test and NMR measurement.

Thawed samples (152.9 ± 15.7 g of weight) were individually cooked in 80 °C water bath till central temperature reached 70 °C. During cooking, central temperature of samples was tracked with a Testo probe (Pt 100, Testo AG, Germany) connected with a Testo thermometer (Testo 735–2, Testo AG, Germany). Temperature recordings at a 1 s interval were exported and standardized with average weight and then cooking time to 70 °C was calculated. The cooked samples were chilled to room temperature. Cooking loss was calculated as a percentage of weight loss before and after cooking.

2.5. Shearing

Six to eight 1.27-cm-diameter cylindrical cores were removed from each cooked sample parallel to the muscle fiber direction. Cores were sheared by a Warner–Bratzler shearing machine (Salter 235, Manhattan Kansas, USA) and an average shear force (WBSF) was calculated for each sample.

2.6. Pressing test

Two 2.5 cm in diameter and 1.0 cm thick samples were removed from each thawed sample using a cylinder sampler (inner diameter, 2.50 cm). Then samples were wrapped with 16 layers of tissue papers and pressed under a force of 343 N for 5 min using a compression machine (YYW-2, Nanjing Soil Instrument, China). Pressing loss was calculated as a percentage of weight loss before and after compression.

2.7. NMR transverse relaxation (T_2) measurements

NMR relaxation measurements were performed according to the method of Bertram, Andersen, and Andersen (2007) with minor modification. Briefly, three 3.5 × 1 × 1 cm strips were removed along the fiber direction from each thawed sample. The strips were individually wrapped in parafilm membrane, placed a cylindrical glass tube (18 mm in diameter) and then inserted into the probe of a Niumag Pulsed NMR analyzer (PQ001, Niumag Corporation, Shanghai, China). The analyzer was operated at a resonance frequency of 22.4 MHz at 32 °C. Transverse relaxation (T_2) was measured using the CPMG sequence with a τ-value of 200 μs. Samples were repeatedly scanned for 20 times at a 1 s interval. A total of 3000 echoes were acquired and fitted with a multi-exponential model under the program MultiExp Inv Analysis (Niumag Corporation, Shanghai, China). Three relaxation times (T_{2b}, T_{21} and T_{22}) and their corresponding water population (P_{2b}, P_{21} and P_{22}) were recorded.

2.8. Statistical analysis

Principle component analysis (PCA) was performed with the program Unscrambler X (version 10.1, CAMO software AS, Oslo, Norway, 2010) to show the differences in the measured variables among all the samples. All the variables were standardized by multiplying by 1/SD. On scores plot, samples were grouped by variables one by one.

After grouping, the differences in measured variables among groups were evaluated by one-way analysis of variance. Least squares means were compared by the Bonferroni's method (Abdi, 2007). In addition, correlation coefficients between variables were calculated. The analyses were done with the program SAS 9.12 (SAS Institute Inc., Cary, NC, USA, 2003).

3. Results

3.1. PCA and sample grouping

Principle component analysis showed that the first two principle components (PCs) explained 49% of variation in all measured variables. Scores plot gave a preview on the similarity between samples (Fig. 1). When each measured variable was individually used for sample grouping, only T_{21} gave a relatively good separation. Samples in Group A (average 38.68 ms) were well separated from those in Groups B (average 42.32 ms) and C (average 44.53 ms) (Fig. 2). Based on this grouping, other measured variables were further statistically analyzed.

3.2. Carcass weight, pH and meat color

Average carcass weight of Group A was much lower ($P<0.05$, Table 1) than those of Groups B and C. Samples in Group C had higher ($P<0.05$, Table 1) pH values than the other two groups. Lightness (L* value) of muscle samples in Group A was higher ($P<0.05$, Table 1) than the other two groups. There was no significant difference ($P>0.05$) in a* and b* values between any two groups.

3.3. Water holding capacity and shearing

There was no significant difference in either thawing loss or cooking loss among the three groups ($P>0.05$, Table 1). However, pressing loss of thawed samples in Group A was lower ($P<0.05$) than those of the other two groups. No significant difference existed between Groups B and C ($P>0.05$). There was no significant difference ($P>0.05$, Table 1) in shear force value between any two groups.

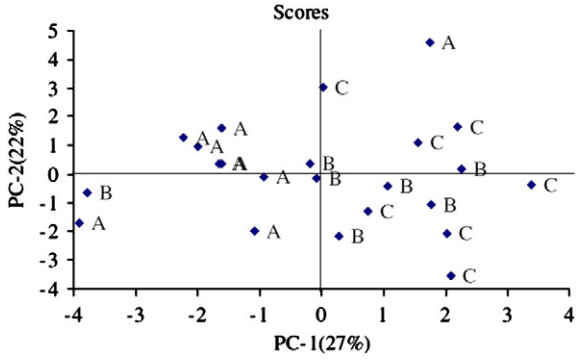

Fig. 1. Principle component analysis (scores plot).On scores plot, samples were grouped by T_{21}, where A is lower than 40 ms, B is 40–44 ms and C is greater than 44 ms.