Study on the Quality Difference between Hainan Ruijin Black Pork and Ordinary Pork by MR Imaging

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Abstract. This study is based on low field nuclear magnetic resonance (LF-NMR) to detect water content, and discuss with the Hainan Ruijin Black Pork and common lean pork differences at the molecular level, which provided data support for Hainan Ruijin Black Pork as brand pork. From the ratio of peak apex time and peak area of combined water, non-flowable water and free water, the difference between the two kinds of pork can be seen. Hainan Ruijin black pork has a lower peak time than the free water T 23 of ordinary lean meat type pork, but the ratio of T 23 peak area is high, indicating that the cell gap between Hainan Ruijin black pork and water is tight and the water content is high.

1. Introduction

Hainan Ruijin Black Pig is a descendant of Hainan local black pig sow and the alien variety Duroc. It grows in Chengmai County, Hainan Province, which is rich in trace selenium. It adopts biological feed and ecological stocking. During this period, they did not undergo any cooling treatment. It is easily contaminated by bacteria, viruses, vehicles, packaging, etc. in the air during processing, transportation and sales. Because the meat is in a relatively high temperature environment, the bacteria will multiply and there are safety hazards [1-2]. Water accounts for more than 75% of meat, and physical and chemical changes in meat are related to water [3]. Therefore, the distribution of water and the change of state are important factors influencing the quality of meat. Nuclear magnetic resonance refers to the nuclear nuclear level splitting under the action of a static magnetic field. When an applied radio frequency electromagnetic wave that satisfies a certain energy condition acts on the nuclear system, the nucleus absorbs the incident electromagnetic wave energy and transitions from a low energy level to an adjacent high energy level. After the RF pulse is turned off, the time from the excited state to the equilibrium state of the hydrogen nuclei is related to the state of the hydrogen nuclei and the physical and chemical environment in which it is located [4-6]. Therefore, the transverse relaxation map can be used to reflect the nature, distribution and dynamic information of moisture in meat. Low-field NMR detection technology has the advantages of rapid detection, low requirements for operators, and lossless samples [7].

Hainan Ruijin Black Pork is a green organic pork, which is twice as expensive as ordinary pork. It monitors the breeding, slaughtering, transportation and sales of pigs, which is beneficial to ensure the quality and safety of pork food. However, the quality inspection department lacks effective means to
distinguish between green organic pork and ordinary pork, and suppliers also have difficulty in certification. In this paper, low field nuclear magnetic resonance (NMR) technique was used to detect the difference of water distribution and state of two kinds of pork, which provided data support for Hainan Ruijin black pork as brand pork.

2. Material and Analysis Method

The pig hind leg meat of Hainan Ruijin Black Pig is provided by Hainan Ruijin Investment Holdings Co., Ltd.; the common lean meat pig hind leg meat is provided by Haikou Agriculture, Industry and Trade Co., Ltd. Meso MR23-060H-I Nuclear Magnetic Resonance Imaging Analyzer: Suzhou Newmarket Analytical Instrument Co., Ltd. The CPMG (hard pulse echo) sequence is used to detect the transverse relaxation spectrum of meat. Because different sequence parameters are set, the signal intensity and signal-to-noise ratio of the sampled signal are greatly affected. Set the appropriate sequence parameters [8]. The signal with large amplitude and high signal-to-noise ratio is obtained, which is beneficial to improve the detection efficiency and ensure the accuracy, stability and repeatability of the sampled signal [9].

Therefore, it is necessary to explain the setting of the sequence parameters in this experiment.

(1) Meat quality

The higher the meat quality, the more the number of hydrogen nuclei contained. The greater the signal intensity of nuclear magnetic resonance, the diameter of the experimental instrument is 60mm. In order to obtain a strong sampling signal, the meat is placed in the magnetic resonance center position with good magnetic field uniformity, so we choose pork with a mass of 150.02 g.

(2) Temperature

When the magnet temperature is 32±0.02 °C, the magnetic field is stable and the uniformity is good. When the temperature is exceeded, the detected magnetic resonance signal is very poor.

(3) P1, P2

Place the meat in a constant temperature water bath to 32 °C (so that the meat and magnet temperature are the same) and place it in the magnetic field center of the NMR analyzer. After searching for the center frequency, use the FID sequence to find the appropriate 90° pulse width P1 and 180° pulse. Wide P2. The measurement yielded P1(μs) = 16, and P2(μs) = 34.

(3) RG1, DRG1, PRG

Since the signal of the nuclear magnetic resonance itself is small, it is necessary to amplify the signal by hardware, and the signal amplification is too large, which causes the signal to be distorted. Therefore, set RG1 (dB) = 20, DRG1 = 3, and PRG = 1.

(4) RFD

The RF delay RFD, which is the sampling start time, is used to control the sampling time of the first sampling point by delaying the application time of the 90° pulse. Since the time of signal reception is fixed, the receiver sampling time can be controlled by setting an appropriate RFD. If the RFD is too large, the 90° pulse is applied before the receiver begins to acquire the signal, and the sampled signal will include a signal that has not undergone nuclear magnetic resonance. If the RFD is too small, the signal that the receiver starts to sample includes the 90° pulse signal and the zero-sigma signal. Usually we choose the first highest amplitude point that is not subject to zero-sound interference at the end of 90° zero-slope as the starting point. Set RFD=0.01.

(5) TW

TW is the repetitive sampling waiting time. After the previous sampling is finished, it waits for a certain period of time, and the longitudinal magnetization of the hydrogen nuclei can return to equilibrium. The waiting time is long enough, the longitudinal magnetization completely recovers to the maximum magnetization vector M0; if the waiting time is short and the longitudinal magnetization does not return to M0, the amplitude of the signal obtained by the next sampling will decrease. TW is long, the more complete the longitudinal relaxation recovery, the stronger the signal and the larger the signal-to-noise ratio, but the longer the sampling time, which affects the detection efficiency. The TW is short, the longitudinal relaxation is not fully recovered, and the amplitude of the sampled signal is small.
general, TW is greater than or equal to 5 times the longitudinal relaxation time T1. Therefore, set TW=4500ms.

(6) TE

The echo time TE not only affects the maximum amplitude of the CPMG sequence echo, but also affects the total relaxation time of the signal. The longer the echo time, the stronger the self-diffusion of the hydrogen nuclei and the longer the relaxation time. The shorter the TE, the less obvious the attenuation of the transverse magnetization, the stronger the signal, and the better the signal-to-noise ratio. The system requires an echo time TE greater than 6 times the P1 value. Therefore, set TE=0.22ms.

(7) SW

If the sampling frequency SW is too small, it is likely to lose valid information in the sample. The larger the SW, the shorter the sampling time, and the larger sample frequency is beneficial for obtaining complete sample information. The shorter the relaxation time of the sample, the larger the SW that needs to be set. SW = 100 KHz.

(8) NECH

As the number of echoes NECH increases, the transverse relaxation interval of the CPMG echo curve becomes larger. In general, the number of echoes should be set large enough to completely attenuate the signal. However, if the number of echoes is too large, the measurement time will be prolonged, the experimental detection efficiency will be lowered, and the signal-to-noise ratio of the sampled signal will be reduced. If it is too small, the effective information in the sample will be lost. In theory, the number of echoes is the minimum number of echoes that relax the sample, as shown in Figure 1, which makes the signal occupy 1/3 of the window. Set NECH=5000.

Figure 1. Sampled data of pork.
3. Results and analysis

3.1. Low-Field Nuclear Magnetic Resonance Analysis of Hainan Ruijin Black Pork and Common Lean Meat Pork

![Figure 2. Distribution of transverse relaxation time $T_2$ in Hainan Ruijin black pork](image1)

![Figure 3. Distribution of transverse relaxation time $T_2$ in common lean pork](image2)

$T_{21}$ represents a layer of water molecules in which polar groups on the surface of protein molecules are tightly bound to water molecules; $T_{22}$ represents water that is not easily flowing between muscle fibrils, myofibrils and membranes, and is susceptible to changes in protein structure and charge. $T_{23}$ indicates that water that is free to flow in the extracellular space is maintained by capillary force [10-12]. It can be seen from the figure that the peak area of $T_{21}$ does not change much with time, the $T_{22}$ peak and the $T_{23}$ peak gradually shift to the left, the peak area of $T_{22}$ gradually decreases, and the peak area of $T_{23}$ gradually increases. This is because as the storage time prolongs, the muscle fibers in the meat gradually become loose and tight, and cannot absorb more water. The hard-flowing water existing between the myofibrils and the membranes in the meat flows to the extracellular space, converted to free water, so that less easy to flow water, free water increased. The total peak area is gradually reduced because the growth of microorganisms in the meat consumes part of the water over time, resulting in a decrease in the total moisture content of the pork [13].

3.2. Comparison of transverse relaxation between Hainan Ruijin black pork and common lean pork

Figure 4 shows the comparison of the transverse relaxation $T_2$ inversion results of Hainan Ruijin black pork and common lean pork of the same quality at the same time. It can be seen from the figure that the two kinds of pork of the same quality, Hainan Ruijin Black Pork The area of $T_{22}$ peak is larger than that of ordinary pork $T_{22}$, indicating that Hainan Ruijin black pork has more non-flowing water between myofibrils and membrane, so the meat is tenderer. The peak areas of $T_{21}$ and $T_{23}$ of Hainan Ruijin black pork and ordinary lean meat type pork are small, but the peak time of $T_{23}$ peak of Hainan Ruijin black pork is smaller than that of ordinary pork $T_{23}$ peak. The shorter the relaxation time, the water and the tighter the substrate is combined, the longer the relaxation time is, and the freer the water is [14]. The free water of the ordinary lean meat type has a looser combination with the substrate, and the free water has a slightly larger fluidity.
Figure 4. Comparison of transverse relaxation time $T_2$ between Hainan Ruijin black pork and common lean pork

Figure 5. The change of $T_{21}$ peak time in common lean pork and Hainan Ruijin Black Pork

Fig. 5, Fig. 6 and Fig. 7 respectively show the peak apex time of ordinary lean meat type pork and Hainan Ruijin black pork $T_{21}$, $T_{22}$ and $T_{23}$ with time. From the figure, we can see the peak of Hainan Ruijin black pork. The apex time $T_{21}$ is lower than that of ordinary lean meat type pork, indicating that the combination of macromolecular protein and water in Hainan Ruijin black pork is tighter. As time goes by, the peak apex time of $T_{21}$ gradually increases, and water and macromolecules the combination is gradually loose. The peak apex time of $T_{22}$ and $T_{23}$ changes stepwise with time, because the content of free water and non-flowable water becomes less, the number of hydrogen nuclei decreases, and the time required from the excited state to the equilibrium state is short. The relaxation time becomes shorter.

Figure 6. The change of $T_{22}$ peak time in common lean pork and Hainan Ruijin Black Pork

Figure 7. The change of $T_{23}$ peak time in common lean pork and Hainan Ruijin Black Pork
Fig. 8 and Fig. 9 respectively show the peak area ratios of ordinary lean meat type pork and Hainan Ruijin black pork T22 and T23 with time. It can be seen from the figure that the proportion of non-flowable water is high. More than 80%, followed by free water and combined water. With the prolongation of storage time, the proportion of T23 peak area of Hainan Ruijin black pork and common lean meat type pork gradually increased with time, and the proportion of T22 peak area gradually decreased with time. Small, because it is difficult to flow water into free water. Hainan Ruijin black pork has a higher ratio of T23 peak area than ordinary lean meat type pork, indicating that it has more free water content, but its combination with substrate is tight.

4. Conclusion
From the ratio of peak apex time and peak area of combined water, non-flowable water and free water, the difference between the two kinds of pork can be seen. Compared with ordinary lean pork, Hainan Ruijin black pork has higher non-flowable water content, so the meat quality more tender. As the storage time is extended, the conversion of the non-flowable water into free water causes the content of the non-flowable water to decrease and the content of the free water to increase. Hainan Ruijin black pork has a lower peak time than the free water T23 of ordinary lean meat type pork, but the ratio of T23 peak area is high, indicating that the cell gap between Hainan Ruijin black pork and water is tight and the water content is high. Low-field nuclear magnetic resonance technology can be used to distinguish between Hainan Ruijin black pork and ordinary lean pork.

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