

Traceability of rigor mortis of muscle using a texture analyzer: a feasibility study

C. Li, P. Shi, X. Xu, C. Xu, X. Zhu & G. Zhou*

Key Lab of Meat Processing and Quality Control, MOE; Key Lab of Food Science and Quality Control, MOA, Nanjing Agricultural University, Nanjing, 210095, P R China.

*E-mail: ghzhou@njau.edu.cn.

Abstract

Rigor mortis is one of the most important changes of muscle at earlier time postmortem, which ultimately affects meat palatability. However, there seems no efficient way to track the whole process of rigor mortis continuously and automatically. This study is designed to explore a new method to realize the traceability of the onset and development of rigor mortis of muscles using a texture analyzer. A compression analysis was proven feasible to determine the changes of muscle within 48 h to 84 h postmortem at a 10 s interval. Chicken and duck breasts, obtained within 30 min postmortem, were immediately compressed under a 50 mm probe holding until 172800 s (48 h) at an acquisition rate of 0.10 point per second. The results showed that chicken and duck breasts reached the maximum rigor at different postmortem time. Environment temperature had a significant effect on the process of rigor mortis and its resolution. The approach in the present study would give us more accurate details on postmortem physicochemical changes in skeletal muscle.

Introduction

Rigor mortis is one of the most important physicochemical changes in skeletal muscles occurring at a relatively earlier period postmortem and then maintaining for a long period, which results in an increasing toughness of meat (Lawrie and Ledward, 2006). The rigor process usually includes two distinct phases: a delay period and a rapid phase (Bate Smith and Bendall, 1949).

Since 1930s, many authors have focused on the methods for determination of the onset and process of rigor mortis, including elasticity (Bate Smith, 1939), ultramicroscopic observation (Suzuki, 1976), tensile and adhesive properties (Currie and Wolfe, 1980), myotonometry (Vain et al., 1992), isometric tension (Hertzman et al., 1993), NMR and NIR (Tornberg et al., 2000) and sonoelasticity (Ayadi et al., 2007). These previous studies have given us a profound understanding on rigor mortis of skeletal muscles, especially of “red” muscles, and a technological guidance to control meat quality (Lawrie and Ledward, 2006). However, it is still difficult for us to give a more actual and accurate depiction of rigor mortis, in terms of a given muscle. The objective of the present study is to provide a feasible method that can track continuously and automatically the process of rigor mortis and the process of its resolution.

Material and methods

Broilers and ducks were killed by severing blood vessels, esophagus and trachea at the same time. The whole left breast muscle was obtained and wrapped in a plastic film to avoid evaporation. Meat samples were compressed by a 50mm-diameter probe using a texture analyzer (TAXT2i, Stable Micro Systems Ltd, Figure 1). Some parameters were set as follows: pre test speed, 2.0mm/s; test speed, 1.0mm/s; post test speed, 2.0mm/s; distance: 2.0mm; time, 172800s (48h); trigger force, 0.02N; acquisition rate, 0.10 pps (point per second). The environmental temperature was kept at ca. 4 °C or 15 °C throughout the experiment. The interval between bleeding and the beginning of compression was nearly half an hour. After 48h, a

rigor-resolution curve was obtained that showed both the processes of rigor mortis and rigor resolution. A total of 17280 data from the curve was exported to an excel file for further analysis. A regression analysis was performed between force and time where force was the dependent and time was the independent.



Figure 1. Diagram for determining rigor mortis of chicken breast.

This method was feasible on the basis of the following assumption: when a force of 0.02N perpendicular to muscle fiber axis be given to a pre-rigor muscle at a pressure distance of 2 mm, a elasticity from the muscle to the probe (N_1 , Figure 2a) would produce. During the process of rigor, muscle shrink, resulting in an increasing elasticity (N_2 , Figure 2b) till the maximum. After the maximum rigor, muscle would enter into the phase of resolution, concomitant with a decreasing elasticity (N_3 , Figure 2c) till a constant.

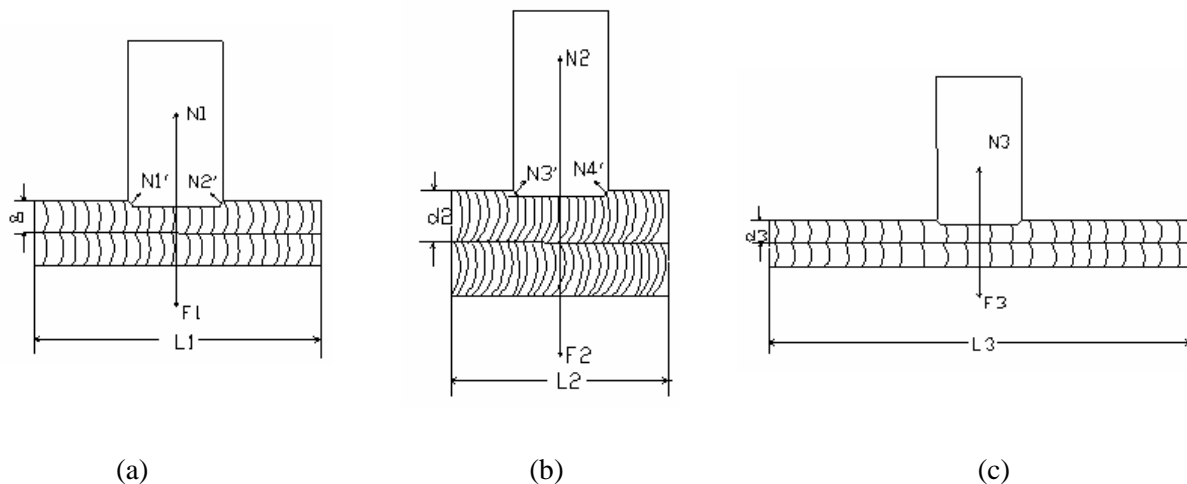


Figure 2. Mechanism for measurement of rigor mortis using a texture analyzer; (a) pre-rigor state, normal sarcomere length and fiber diameter, a relatively low force; (b) rigor state, shorter sarcomere length but larger fiber diameter and a higher force; (c) complete resolution state, extending sarcomere, decreasing fiber diameter and decreasing force.

Results and Discussion

According to 17280 data from each curve, we can find good exponent functions between elasticity force (N) and time (h), and calculate the time (h) of maximum rigor, the time (h) of resolution completion (Table 1).

For chicken breast, there was a distinct rigor phase with an increase in elasticity and also a significant resolution phase with a gradual decrease in elasticity within 48 h postmortem (Figure 3 a & b). The initial force and maximum force at 4 °C were significantly lower than those at 15 °C. It took a shorter time to reach the maximum rigor state at 4 °C than at 15 °C. However, the period of rigor resolution was longer at the low temperature than that at the higher temperature (Table 1). The high temperature (15 °C) had two effects on the whole process. On the one hand, it resulted in the heat-induced partial denaturation of muscle protein at

earlier time; on the other hand, it accelerated the process of rigor resolution later.

Duck breast had a similar change to chicken breast, except for a short-term delay phase at an earlier time (Figure 3 c & d, Table 1). Noticeably, duck breast had not completed the resolution phase till 48 h postmortem.

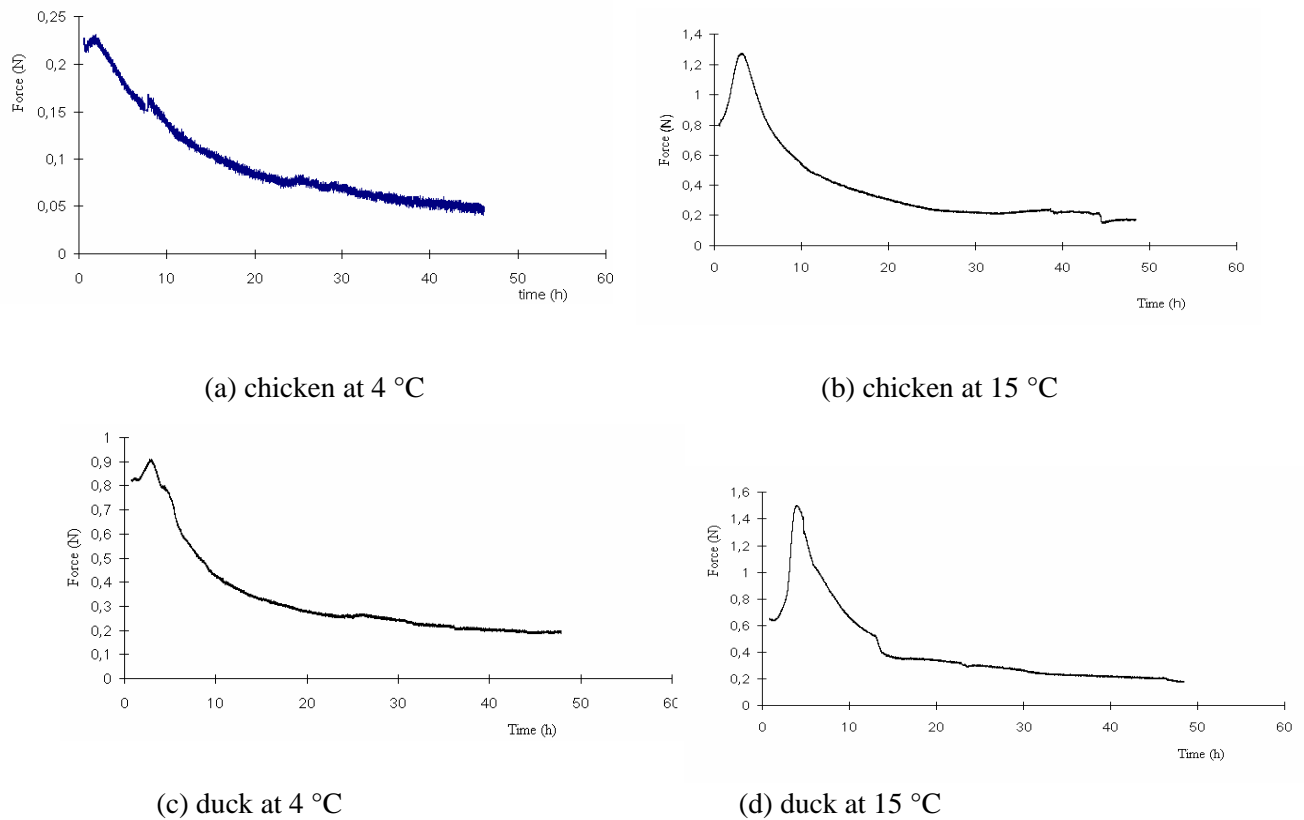


Figure 3. Curves of rigor mortis of chicken and duck breasts at 4 °C and 15 °C.

Table 1. Mathematical models for rigor mortis of chicken and duck breasts at 4°C and 15 °C

| | Chicken breast | | Duck breast | |
|-----------------------|---|---|--|--|
| | 4°C | 15°C | 4°C | 15°C |
| Models | $F(N) = 2E-08t^4 - 5E-06t^3 + 0.0004t^2 - 0.015t + 0.246$ | $F(N) = -4E-07t^4 + 1E-05t^3 + 0.001t^2 - 0.078t + 1.228$ | $F(N) = 6E-07t^4 - 8E-05t^3 + 0.004t^2 - 0.094t + 1.052$ | $F(N) = -2E-06t^4 + 0.0002t^3 - 0.0041t^2 - 0.006t + 1.04$ |
| T1 (h) ¹ | 2.069 | 3.49 | 3.25 | 4.32 |
| T2 (h) ² | 38.56 | 31.2 | none | 41.83 |
| Fmax (N) ³ | 0.226 | 1.25 | 0.889 | 1.467 |
| R ² | 0.994 | 0.932 | 0.979 | 0.812 |

¹ the time at maximum rigor; ² the time at resolution complete; ³ maximum force (N)

Conclusion

A new approach was proven feasible to track more accurately and continuously the process of rigor and its resolution within a relatively long time postmortem.

References

Bate Smith E. C. Changes in elasticity of mammalian muscle undergoing rigor mortis. J. Physiol. 1939, 96:

176-193.

- Bate Smith E. C. and Bendall J R. Factors determining the time course of rigor mortis. *J. Physiol.* 1949, 110: 47-65.
- Currie R. W. and Wolfe F. H. Rigor related changes in mechanical properties (tensile and adhesive) and extracellular space in beef muscle. *Meat Science*, 1980, 4: 123-143.
- Hertzman C, Olsson U, Tornberg E. The influence of high temperature, type of muscle and electrical stimulation on the course of rigor, ageing and tenderness of beef muscles. *Meat Science* 1993, 35: 119–141.
- Lawrie R.A. and D.A. Ledward. 2006. The eating quality of meat. In: *Lawrie's meat science* (7 ed.) Woodhead Publishing Limited and CRC Press LLC. USA. pp. 279-341.
- Suzuki, T. An ultramicroscopic study on rigor mortis. *Forensic Science*, 1976, 8: 207-216.
- Vain A., Kauppila R., Humal L.H., Vuori E. Grading rigor mortis with myotonometry: A new possibility to estimate time of death.
- Tornberg E., Wahlgren M., Brondum J., Engelsen S. B. Pre-rigor conditions in beef under varying temperature- and pH-falls studied with rigometer, NMR and NIR. *Food Chemistry*, 2000, 69: 407–418.
- Ayadi A., Culioli J., Abouelkaram S. Sonoelasticity to monitor mechanical changes during rigor and ageing. *Meat Science*, 2007, 76: 321-326.