PRELIMINARY STUDY ON FAT CRYSTAL PROPERTIES OF PIG CARCASS USING RAMAN SPECTROSCOPY

Michiyo Motoyama, Kouichi Chikuni and Keisuke Sasaki

NARO Institute of Livestock and Grassland Science, National Agricultural Research Organization (NARO),

2 Ikenodai, Tsukuba, Ibaraki, Japan

Abstract –

To understand fat crystal properties and their effects on carcass fat quality characteristics, a preliminary laboratory level study on pig carcasses was conducted using a portable Raman instrument. Three pigs (112-115 kg) were slaughtered by a normal commercial procedure and Raman spectra of their carcass surface adipose tissue were taken just after transferring the carcass into a refrigerating room (3.4°C) until 11 days after the transferring. As the result, it has been shown that the fat crystallinity increases even after the carcasses cooled down entirely. Also, the formation of the metastable crystal polymorph, β', is observed in the early period of carcass cooling. It is indicated that the rate of temperature decrease in the present study is too fast, or the minimal temperature is too high to the carcass fat crystallize in the most stable polymorph. These information may contribute to develop the technique that brings carcass fats in more preferable properties.

Key Words – Porcine subcutaneous fat, crystallinity, crystal polymorph, Raman spectroscopy

I. INTRODUCTION

Fat crystal properties such as crystallinity and polymorph type effect decisively on the appearance and texture of fat based foods. For example, chocolates have been the most studied fat based food and applied the techniques that bring cocoa fats in good appearance and palatability [1].

Regarding meat, adipose tissues are consisted mostly of fats. Their fats may exist in liquid form when the animal is warm. Once it is slaughtered, they undergo solidification accompanied by the fall in carcass temperature. The carcass cooling procedures can be varied in many respects, *e.g.* rate of temperature decrease, minimal temperature and duration of chilling; however, their effects on meat fat characteristics such as luster and hardness have not been understood.

To investigate the fat crystal properties of meat carcasses, spectroscopy is the most suitable method with a high application potential. It is non-destructive and much faster than the methods measuring crystallinity such as thermo analyses. Among spectroscopies, Raman spectroscopy is the most appropriate method to investigate fat properties. Since conformational changes of fats during solidification are usually accompanied with large polarizability changes, their Raman spectra reflect these changes with high sensitivity and are particularly useful in this respect. In the present study, we have conducted a preliminary laboratory level experiment on pig carcass fats using a portable Raman spectroscopic instrument to understand fat crystal properties and their effects on carcass fat quality characteristics.

II. MATERIALS AND METHODS

This study was conducted in accordance with the requirements of the basic guideline concerning animal experimentations at research institutions under the jurisdiction of Ministry of Agriculture, Forestry and Fisheries of Japan.

Animals and the carcass cooling

Three barrows from the same litter, which were crosses of a Landrace × Large White sow and a Duroc boar, were fed using the same multi-phase feeding regime until live weights of 112, 112 and 115 kg. The pigs were stunned electrically and slaughtered according to a normal commercial procedure. Following dressing, carcasses were transferred into a refrigerating room (average temperature: 3.4°C, air-circulation volume: 80 changes/h) within 20 min after slaughter. Relative humidity of the room was more than 90% throughout the

experiment. Temperatures of the room and the carcass surface (10 cm distance from the mid dorsal axis at the 3rd lumbar position) were monitored by calibrated T-type thermocouples.

Raman spectroscopic measurement

Raman spectra of the carcass surface, the outer layer of subcutaneous adipose tissue, were measured at 5-8 cm distance from the mid dorsal axis at 3-4 lumbar position. Measurements were conducted in the refrigerating room just after transferring the carcass into the room (0 h) until 11 days after the transferring. A portable Raman spectrometer with 785-nm excitation wavelength (EZRaman-I, Enwave Optronics, Irvine) was used. The excitation laser power was 150 mW and the backscattered Raman signals were collected with 60-s accumulation time. Three measurements from different positions within the above described area were averaged. The spectra were subtracted background and cosmic rays, then normalized with the C=C stretching band (approximately 1655 cm^{-1}) intensity being based on an assumption that the fat unsaturation degree had not changed during the experiment. Band intensities were acquired by fitting using Lorentzian function.

III. RESULTS AND DISCUSSION

After dressing, the carcass weights were 68.5, 70.5 and 73.0 kg. Just before transferring into the refrigerating room, carcass surface temperature was about 23°C. It was 15.5°C at 1 hour after transferring, 13.8°C at 2 hours, 10.0°C at 6 hours, 6.3°C at 12 hours and maintain less than 5.5°C after 17 hours.

Raman spectra of a carcass are shown in Figure 1. They have changed drastically within the early temperature dropping period. For a detailed quantification of fat crystallinity changes, 1175-cm^{-1} Raman band intensity is plotted in Figure 2. This band is assigned to CH_2 rocking mode. It is known that this band is sensitive to *trans-gauche* rotational isomerization of alkyl chains [2], and its Raman intensity is high in the *trans* isomer which is equivalent to high crystallinity of fats. 1175-cm^{-1}-intensity increases rapidly synchronizing the early temperature decrease. The drastic change in the spectra is therefore due to the increase in the fat crystallinity. Also the band intensity continues to grow slightly throughout the experiment (Figure 2). It indicates that the carcass fat crystallinity increases not only in the duration of carcass cooling process but also after carcasses cooled down entirely.

Then, to understand the crystal polymorph type of pig carcasses, 1418-cm^{-1} Raman band intensity is acquired (Figure 3). This is assigned

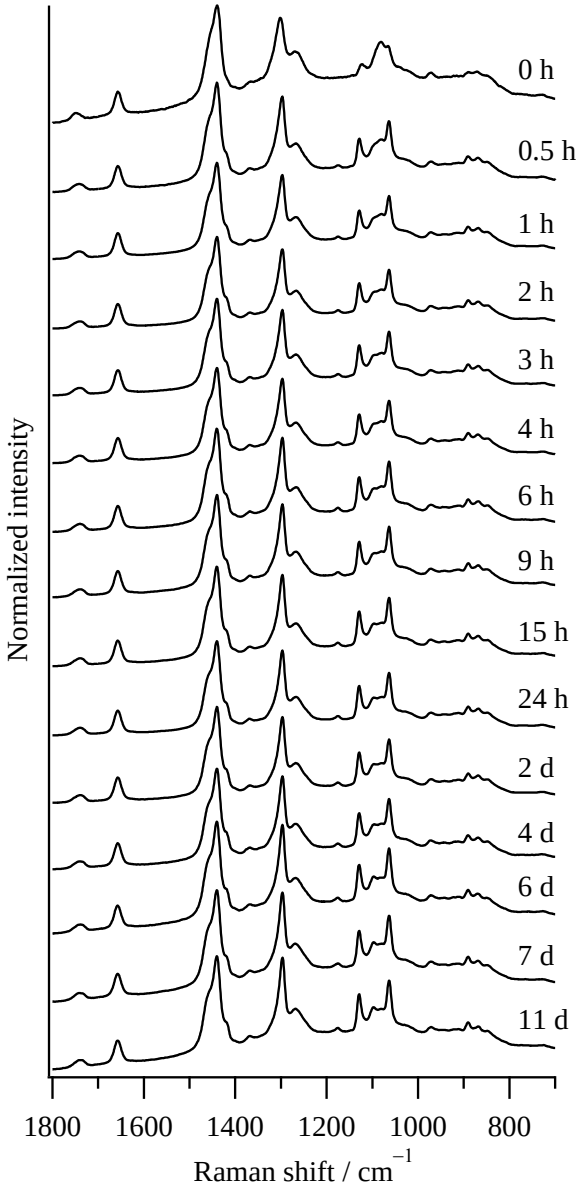

Figure 1. Raman spectra of the surface adipose tissue of a carcass. The spectra are shown with vertical shifts in order to express time course.

to CH_2-scissors mode and a distinctive band of β' polymorph of fats [3]. The band intensity rapidly grows parallel to the early increase in crystallinity. It is widely known that pork fats tend to be crystallized in β polymorph which is the most stable form of fats [4]. The formation of less stable polymorph, β', indicates that the rate of temperature decrease in the present study is too fast, or the minimal temperature is too high to the carcass fat crystallize in the most stable polymorph.

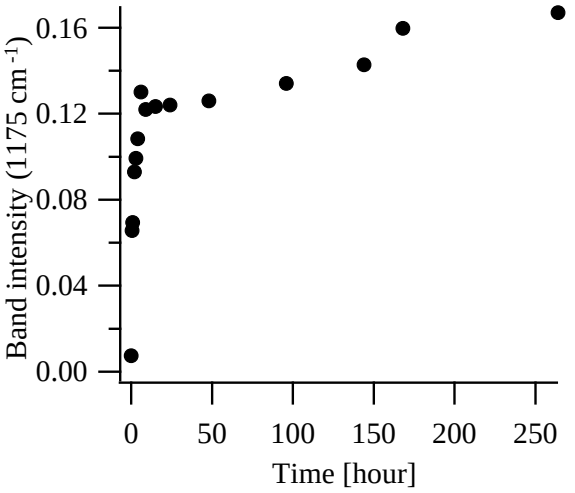

Figure 2. 1175-cm^{-1} band intensity change after transferring the carcasses into the refrigerating room.

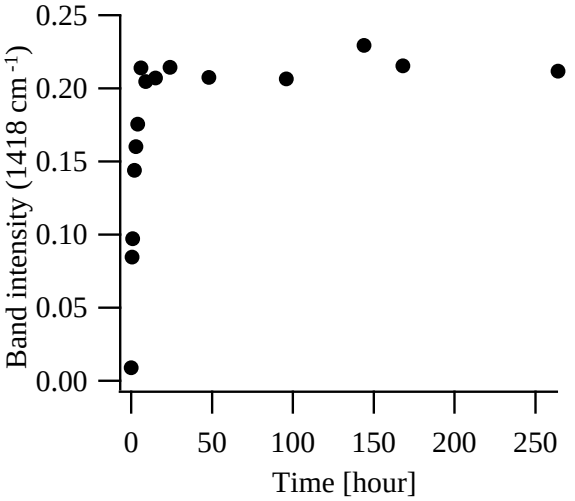

Figure 3. 1418-cm^{-1} band intensity change after transferring the carcasses into the refrigerating room.

After the early crystallization period, the 1418-cm^{-1} Raman band intensity does not change much until the end of the experiment (Figure 3). It indicates that the β'-polymorph content may not change once carcasses are cooled down. So the observed crystallinity increase after cooling down seems to be the contribution of other polymorph formation.

Using Raman spectroscopy, it has been shown that the fat crystallinity increases during the entire duration of the experiment and the metastable polymorph forms during the early crystallization period. These new insights on carcass fat crystal properties help us to understand carcass fat quality characteristics.

IV. CONCLUSION

Raman spectroscopy has revealed the fat crystallinity and type of polymorphs of pig carcasses. By using a portable Raman instrument, such a fat property is able to be checked on meat processing line, in a short time and non-destructively. This information helps the carcass grading be more precise and may contribute to develop the technique that brings more preferable fat properties.

ACKNOWLEDGEMENTS

Mr. Takumi Narita, Dr. Mika Ooe, Dr. Susumu Muroya, Ms. Yumiko Endo are gratefully acknowledged for their assistance during our experiments. M. M. also thanks Tokyo Instruments Inc. for their Raman instrument. This study was supported in part by the grant 'Research for production of valuable livestock by feeding self-sufficient forage crops' from Agriculture, Forestry and Fisheries Research Council, Ministry of Agriculture, Forestry and Fisheries of Japan.

REFERENCES

1 Timms, R. E. (2003). Confectionary fats handbook. Properties, production and application. Bridgwater: The Oily Press.

2 Maroncelli, M., Strauss, H. L. & Snyder, R. G. (1985). On the CD_2 probe infrared method for determining polymethylene chain conformation. Journal of Physical Chemistry, 89(20), 4390-4395.

3 Sato, K., Arishima, T., Wang, Z. H., Ojima, K., Sagi, N. & Mori, H. (1989). Polymorphism of POP and SOS. 1. Occurrence and polymorphic transformation. Journal of the American Oil Chemists Society, 66(5), 664-674.

4 Foubert, I., Dewettinck, D., Van de Walle, D., Dijkstra, A. J. & Quinn, P. J. (2007). Section 7, Physical properties: Structural and physical characteristics, In F. D. Gunstone, J. L. Harwood & A. J. Dijkstra, The Lipid Handbook 3rd ed. (pp. 471-534). Boca Raton: CRC Press.