ASSESSMENT OF PORCINE FAT QUALITY BY FIBER-OPTIC SPECTROPHOTOMETRY

M. Irie[1] and H. J. Swatland[2]

Livestock Division, Osaka Agricultural Research Center
442 Shakudo, Habikino-shi, Osaka 583, Japan

Summary

Research was undertaken to determine if reflectance (interactance) measured with a portable fiber-optic probe (Colormet) can be used to assess porcine fat quality. Soft fat generally had lower interactance than hard fat, $p < 0.05$ from 400 to 700 nm, although interactance spectra of hard and soft fat were similar in shape. At 4℃, interactance from 450 nm to 700 nm at the inner layer of backfat was correlated ($p < 0.01$) with subjective soft fat score ($r = 0.60$ to 0.70), and with the refractive index ($r = -0.62$ to -0.65) and melting point ($r = 0.59$ to 0.60) of heat-extracted lipid. Colormet interactance L^* at 4℃ was correlated ($p < 0.01$) with soft fat score($r = 0,72$), refractive index ($r = -0.66$), and melting point ($r = 0.61$). Interactance decreased as the temperature of the fat was increased from 22 to 44℃ ($p < 0.01$). Soft fat had lower interactance than fats that were slightly soft, slightly hard and hard at 4, 22 and 40℃, although softness and temperature may interact to affect interactance. These results indicate that soft porcine fat may be detected easily by fiber-optic spectrophotometry.(**Key Words**: Fat, Pork, Spectrophotometry, Softness)

Introduction

Fat quality is an important factor for meat quality. As pigs become leaner, problems have occurred with a reduction of fat quality, especially in EEC countries (CEC, 1984). In Italy, Russo (1988) pointed out that soft fat is the most undesirable defect in meat processing. In Japan, soft fat evaluated subjectively is a cause for down-grading a pork carcass, because soft fat has an undesirable appearance and is liable to develop rancidity (Irie et al., 1983). There is now an interest in fat quality relative to human health.

For the objective assessment of fat quality, ultrasonic and rheological methods have been developed (Irie and Ohmoto, 1982; Chikuni et al., 1982; Dransfield and Jones, 1984; Miles et al., 1985) but have not yet achieved any wide industrial use. Many aspects of meat quality may be measured optically, including the yellowing of beef fat by β-carotene (Swatland, 1987). Research was undertaken to determine if an optical method, the Colormet probe, can be used as a method for evaluating porcine fat quality, especially for softness. The optical measurement was compared to refractive index and melting point.

Materials and Methods

Loins from 31 typical commercial pigs were collected from a local abattoir and kept in a meat cooler at 4℃ for two days before assessment for fat softness. None of the loins had any yellow fat (a pathological feature in porcine adipose tissue; Danse and Steenbergen-Botterweg, 1974). The softness of the inner layer of backfat was assessed subjectively in the meat cooler at 4℃ by palpation by a trained specialist, using a four-point scale (1, soft; 2, slightly soft; 3, slightly hard; and 4, hard), as in the fat quality used for grading pork carcasses in Japan. Physical measurements were made on adipose samples from the same region.

Optical properties were measured with a Colormet meat probe (Metron Instruments, St John's Newfoundland), which has a xenon flash that illuminates the sample interior via optical fibers. The light collected directly from the tissue by optical fibers, termed interactance (Conway

[1]Address reprint requests to Dr. M. Irie, Osaka Agricultural Research Center, Osaka 583, Japan.
[2]Department of Animal and Poultry Science, University of Guelph, Guelph, N1G 2W1, Canada.
Received April 25, 1992
Accepted September 7, 1992

et al., 1984), is measured by a photodiode array spectrometer. Interactance spectra differ from reflectance spectra and, strictly, cannot be used for CIE (Commission International de l'Eclairage) transformations. However, CIE L* still gives a useful index of paleness and is used here with a prefix to indicate interactance (iL*). The Colormet probe was standardized on a white teflon block.

Colormet measurements were made at three different positions and at three temperatures (4, 22 and 40℃). Samples were vacuum-packed between measurements to retard oxidation. The total number of spectra was 279 (31 loins × 3 replicates × 3 temperatures). Each spectrum had 31 wavelengths, from 400 to 700 nm in 10 nm increments.

Lipid was extracted from adipose samples by cutting them into small pieces with a knife and placing them in a filter funnel (Whatman No. 4 paper) in an oven at 105℃ for 3h. The refractive index of heat-extracted lipid was measured with an Abbe Refractometer (Model B, Zeiss, 7082 Oberkochen, Germany) at 40℃. Samples were pre-heated to 40℃ on a histological warming plate and the reflectometer was heated by circulating warm water. Melting point was measured by a slip-point method, as follows. Capillary tubes (1 mm internal diameter, 50 mm long) were filled to a height of 10 mm from one end and placed in a freezer until the lipid was firm. After removal from the freezer, the capillary tube was immersed next to a thermometer in a beaker of water. The temperature was increased at a rate of 0.5℃ min^{-1} with stirring until the lipid melted. Four of more replicates were averaged. Data were analyzed with Student's t-test and simple regression analysis (Steel and Torrie, 1980).

Results

Interactance spectra at 4℃ for softness 1 to 4 are shown in figure 1. All four spectra had low interactance around 420, 550 and 580 nm caused by hemoglobin from residual erythrocytes in the dense capillary bed of adipose tissue (Swatland, 1987). Interactance generally was proportional to firmness: spectra for softness 1, 2 and 3 were separate ($p < 0.05$), but spectra for softness 3 and 4 were very similar. The spectral distribution of correlation coefficients of interactance with softness in shown in figure 2. At 4℃, correlations were significant ($p < 0.01$) at all wavelengths.

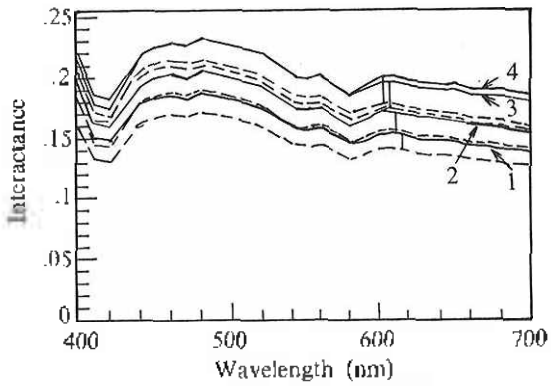

Figure 1. Colormet interactance spectra for pork fat ranging from softness 1 (soft) to softness 4 (hard) at 4℃. Mean values are shown by solid lines, mean values minus standard deviations by broken lines, and vertical bars link means to their standard deviations.

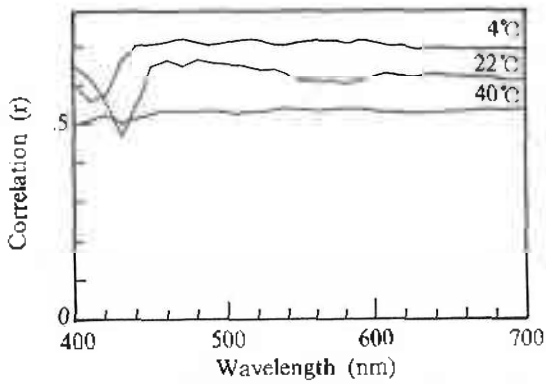

Figure 2. Spectral distribution of correlation coefficients of softness with interactance at 4, 22 and 40℃.

Refractive indices and melting points are shown in table 1. Soft fat tended to have a high refractive index and a low melting point, as expected from earlier research (Irie et al., 1985). However, discrimination of softness with these tests was only possible in the case of softness 1 versus 2. With integrated spectra, Colormet iL* was correlated with softness, refractive index and melting point at all temperatures (table 2).

TABLE 1. PHYSICAL CHARACTERISTICS OF HEAT-EXTRACTED LIPID FROM PORK FAT

Softness score	Refractive index		Melting point	
	Means	S.D.	Means	S.D.
1 (soft)	1.46132[a]	0.00049	31.10[a]	1.52
2	1.46019[b]	0.00049	35.90[b]	3.54
3	1.45980[b]	0.00069	36.15[b]	3.23
4 (hard)	1.45976[b]	0.00069	38.09[b]	2.69

[a,b] Values with different superscripts in the same column differ, $p < 0.05$.

TABLE 2. SIMPLE CORRELATION COEFFICIENTS OF COLORMET INTERACTANCE L* WITH PHYSICAL CHARACTERISTICS OF PORK FAT

Temperature	Softness score	Refractive index	Melting point
4℃	0.72**	−0.66**	0.61**
22℃	0.63**	−0.58**	0.68**
40℃	0.55**	−0.50**	0.69**

** $p < 0.01$.

Softness was correlated with refractive index and melting point, $r = -0.65$ and 0.62, respectively ($p < 0.01$).

The translucency of fat generally increases with temperature, with a corresponding decrease in interactance (Swatland, 1987). However, there was little change from 4 to 22℃, and not until 40℃ was interactance decreased ($p < 0.01$ at all wavelengths). At 22℃ relative to 4℃, there was a slight increase in the discrimination of softness 3 and 4 (figure 3). At 40℃ discrimination between softness 3 and 4 was further enhanced, but with a loss of discrimination between softness 2 and 3.

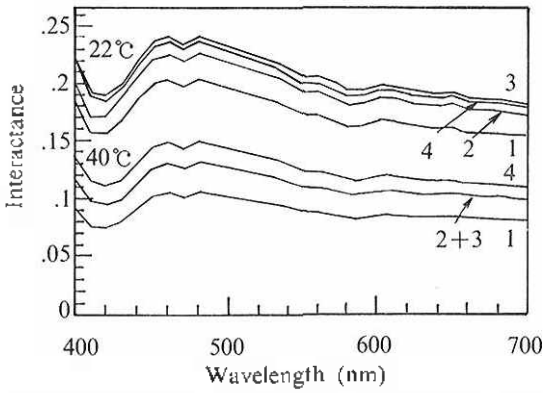

Figure 3. Colormet interactance spectra for pork fat ranging from softness 1 (soft) to softness 4 (hard) at 22 and 40℃. Standard deviations were similar in magnitude to those shown in figure 1.

Discussion

One would expect fat with a high proportion of unsaturated fatty acids to be more liquid, more translucent, and with a lower interactance than fat with a high proportion of saturated fatty acids at the same temperature. Fiber-optic spectrophotometry could detect subtle differences that one could hardly discriminate correctly from the appearance of soft fat. However, there were some subtleties in the relationship that are important if probe measurements of interactance are to be used to predict fat softness. Comparing figures 1 and 3, it is evident that the discrimination of softness changes at different temperatures.

Carcass temperature decreases from around 40℃ shortly after slaughter to around 4℃ in a commercial meat cooler the day after slaughter. Both times are convenient for making probe measurements, either when the pork carcass is graded for fat depth shortly after slaughter or, the next day, just before it is broken into wholesale cuts. At the earlier time it looks as if discrimination of softness 3 versus 4 will be

difficult while, at the later time, it looks as if discrimination of softness 2 and 3 will be difficult. However, at any temperature used in this study, it was possible to detect soft fat among fat with different characteristics. To detect soft fat easily and rapidly without their damage is important for industrial use in Japan.

The solution to the problem of separating slightly soft, slightly hard and hard fats calls for further research on the effects of temperature on the optical properties of carcass fat. As a working hypothesis, it appears that the combined effects of degree of saturation and temperature are not linear. Thus there may be maximum and minimum temperature plateaus in reflectance, beyond or below which intrinsic differences in saturation have a negligible effect. At the reflectance minimum, when triglyceride is molten because of high temperature or unsaturaion, there may be an independent background level of reflectance from cell membranes and other elements of adipose tissue microstructure. At the reflectance maximum, triglyceride may become opaque and almost white, thus concealing differences associated with fatty acid saturation. It should be possible to test these ideas by examining separately the optical properties of purified triglyceride differing in degree of saturation and adipose tissues differing in cell size.

Although soft fat is a current problem in the meat industry, this situation might easily be reversed if the feeding of polyunsaturates to pigs is developed in the future as a strategy for reducing dietary saturated fat. Regardless of whether fat softness is a practical problem or a dietary asset, it is still important to be able to measure it accurately.

In conclusion, optical methods may be suitable for assessing or grading the quality of pork fat, provided that the interactions of temperature and degree of saturation can be elucidated. At least, fiber-optic spectrophotometry is a useful method to detect porcine soft fat. Whether or not optical methods will prove superior to direct rheological measurement for on-line grading remains to be seen, but the advantage of being able to combine measurements of fat softness with other optical measurements of meat quality justifies further research on this topic.

Acknowledgements

Research was supported by the Government of Osaka, the Office of Research at the University of Guelph, and the Ontario Ministry of Agriculture and Food.

Literature Cited

CEC. 1984. Commission of the European Communities. Fat Quality in Lean Pigs (Edited by J. D. Wood). Meat Research Institute Special Report No. 2. Langford. Bristol. U.K.

Chikuni, K., S. Ozawa, T. Koishikawa and M. Yoshitake. 1982. Relation between a sensory evaluation of hardness of porcine subcutaneous adipose tissue and its objective properties. Bull. Natl. Inst. Anim. Ind. (Japan). 38:115-119.

Conway, J. M., K. H. Norriss and C. E. Bodwell. 1984. A new approach for the estimation of body composition: infrared interactance. Am. J. Clin. Nutr. 40:1123-1130.

Danse, L. H., J. C. Norriss and W. A. Steenbergen-Botterweg. 1974. Enzyme histochemical studies of adipose tissue in porcine yellow fat disease. Vet. Path. 11:465-476.

Dransfield, E. and R. D. Jones. 1984. Texture and mechanical properties of pork back fat. J. Food Technol. 19:181-196.

Irie, M. and K. Ohmoto. 1982. Studies on physical characteristics and techniques for evaluation in porcine soft fat. Jpn. J. Swine Sci. 19:165-170.

Irie, M., K. Ohmoto and K. Nishimura. 1985. Standard measurements for the determination of porcine soft fat. Final Rep. Res. Grants Meat & Meat Prod. (Ito Found). 3:156-164.

Irie, M., M. Sakimoto and K. Ohmoto. 1983. Siryouno souiga tonshino sanka-anteiscini oyobosu eikyou. (Effect of diets on oxidative stability of porcine fat). Jpn. J. Swine, Sci. 20:19.

Miles, C. A., G. A. J. Fursey and R. C. D. Jones. 1985. Ultrasonic estimation of solid/liquid ratios in fats, oils and adipose tissue. J. Sci. Food Agric. 36:215-228.

Russo, V. 1988. Proceeding of the Meeting "Pig Carcass and Meat Quality". Pig carcass and meat quality: requirements of industries and consumers. pp. 1-22. Universitá di Bologna. Reggio Emilia. Italy.

Swatland, H. J. 1987. Optical properties of white and yellow beef fat in relation to carcass grading. Can. Inst. Food Sci. Technol. J. 20:383-386.

Steel, R. G. D. and J. H. Torrie. 1980. Principles and Procedures of Statistics. A Biometrical Approach. 2nd edit. McGraw-Hill Book Company, New York, USA.