EARLY PREDICTION OF THE QUALITY OF PORCINE MEAT BY FT-IR SPECTROSCOPY

Dorthe Kjær Pedersen* **and Søren Balling Engelsen**

The Royal Veterinary and Agricultural University, Food Technology, Rolighedsvej 30, DK-1958 Frederiksberg C, Denmark
TEL: (+45) 35 28 35 64, e-mail: dkp@kvl.dk*

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Background:
Pork quality is very complex and multifactorial in nature. The juiciness of pork is one of the most important quality attributes to the consumer, while the water holding capacity (WHC) is a critical functional quality parameter. WHC is important with regard to water and weight losses during storage, manufacturing, processing and preparation of the meat, for yield and colour in cured meat products as well as appreciation by the consumer. As weight loss implies financial loss, WHC is an important technological quality parameter for the meat industry. At present, no reliable method exists to assess meat quality at an early post mortem state. However, efforts are currently focussed on developing a new screening method which can, at an early state, predict key quality attributes of the end-product. Apart from the impact on contemporary meat science, there is also a major economic benefit to being able to sort in meat quality classes before the carcasses reach the cooler rooms.

Fourier transform infrared (FT-IR) technology has substantial potential as a quantitative quality control tool for the food industry. Molecular absorption of mid-IR radiation results in the excitation of the fundamental vibrational modes. Accordingly, the mid-IR spectrum of a compound contains a wealth of structural information and could be regarded as a sample 'fingerprint'. The general success of vibrational spectroscopy combined with multivariate data analysis in food analysis made it a natural candidate to investigate for possible prediction of end-product quality attributes such as water holding and juiciness. To date, it has not been possible to assess the meat quality until the carcass has gone through rigor mortis and has fully temperature equilibrated to cold storage conditions, i.e. the day after slaughter. Spectroscopy is applied in slaughterhouses for prediction of certain quality attributes of meat such as intramuscular fat, connective tissue, total fat content, protein content and moisture content (Wold *et al.*, 1999; Isaksson *et al.*, 1996; Schwarze, 1996). The advantage of a spectroscopic method is that it is rapid, non-invasive and makes it possible to simultaneously determine several quality parameters, e.g. fat, water holding and connective tissue.

Objectives:
The objective of this work is to attain knowledge of the meat quality of pig carcasses from FT-IR spectroscopic measurements carried out early in the slaughter process, i.e. within one hour of sticking.

Methods:
Two different investigations were performed: one in a research slaughterhouse (Investigation I), the other at a conventional slaughterhouse (Investigation II). In Investigation I the Danish Institute of Agricultural Sciences, Foulum, Denmark provided 36 pig carcasses for measurements. The pigs were subjected to three different stress levels prior to slaughter: (1) 13 pigs were injected with 0.3 mg ephinephrine / kg live weight 15 hours prior to slaughter; (2) 12 pigs were subjected to running on a tread mill for 14-20 min prior to slaughter; (3) 11 pigs received no special pre-slaughter treatment. The Arid-Zone MB100 FT-IR (Bomem, Québec, Canada) was employed for measurements of IR spectra (1800-800 cm^{-1}) 35-40 min after sticking. Attenuated Total Reflectance (ATR) (Model # 0055-383T, Spectra-Tech, Shelton, CT, USA) was applied as a sampling unit. A resolution of 4 cm^{-1} was employed and 64 spectra were recorded and averaged. Water holding capacity according to Honikel (1998) was measured as drip loss, whereby the loss of water was registered from a 2.5 cm thick slice of muscle taken 24 hours post mortem placed hanging in a net and suspended in a plastic bag for 48 hours at +4°C. In Investigation II the measurements were carried out at a commercial Danish slaughterhouse. In the course of two days 66 carcasses were measured. The Arid-Zone MB100 FT-IR was employed for measurements 45-50 min after sticking. Water holding capacity was measured as drip loss, whereby the loss of water was registered from two pieces of muscle taken 24 hours post mortem hanging for 24 hours in a plastic cup with a removable container at +4°C (Rasmussen *et al.*, 1996).

Predictions based on FT-IR spectral information were performed with partial least squares regression (PLSR) which (after centering of the data) projects the spectral data onto common orthogonal structures, called latent variables, by describing the maximum covariance between the spectral information and the water holding capacity reference. In this study predictions were validated with full cross validation (leave one out). The multivariate data analysis was performed with the chemometric program Unscrambler 7.6 (CAMO, Trondheim, Norway) and Matlab 5.3 (The Matworks Inc., Natick, MA, USA).

Results and discussions:
FT-IR spectra (1800-800 cm^{-1}) of the samples from Investigation I (36 samples) and of the samples from Investigation II (66 samples) are shown in Figure 1. The spectra are dominated by secondary amide, protein information. The intense peak at approximately 1640 cm^{-1} is caused by the C=O stretch in amide I and contribution from the OH bending vibration from water. At approximately 1550 cm^{-1} the amid II band, NH_2 scissors, for secondary amides is found, and the band for ester carbonyl stretch from the intramuscular fat is observed at 1746 cm^{-1}. The remaining part is complex fingerprint information, including the Amide III at approximately 1300 cm^{-1}. The drip losses in Investigation I varied from 0.71 % to 7.25 %, while the drip losses in Investigation II varied from 0.63 % to 7.83 %.

PLSR of FT-IR spectra (1500-950 cm^{-1}) versus drip loss was performed for Investigation I (36 samples). The correlation coefficient (r) is 0.89, while the prediction error (RMSECV(Root Mean Square Error of Cross Validation)) is 0.68 %. For a PLSR of FT-IR spectra (1500-950 cm^{-1}) versus drip loss for Investigation II (66 samples) r is 0.77, while RMSECV is 1.06 %. Predicted drip loss (%)

versus measured drip loss (%) for a combined PLSR-model of both Investigation I and II are shown in Figure 2. As expected, some differences between the two investigations are seen due to the application of different reference methods, Honikel in Investigation I and Rasmussen in Investigation II. In spite of these differences, it is possible to combine data from the two investigations in a common PLSR calibration.

The regression for Investigation I, a designed experiment performed at a research slaughterhouse, is significantly better than the regression for Investigation II, a 'real world' experiment performed at a conventional slaughterhouse. The meat material in Investigation II is expected to contain larger biological variations influencing the spectroscopic measurements. Larger variations in the material can make the regression performance difficult. But Investigation II more realistically reflects future conditions for measurements at the slaughter line.

Conclusions:

FT-IR spectroscopic measurements were applied for prediction of water holding capacity of porcine meat in a research slaughterhouse and in a conventional slaughterhouse. PLSR calibration of 66 pigs at the conventional slaughterhouse showed a prediction error of 1.1 % for drip losses ranging from 0.6 to 7.8 %.

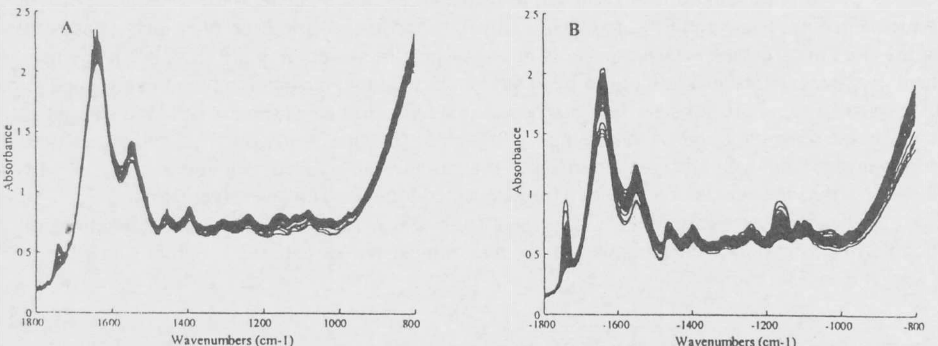

Figure 1. FT-IR spectra (1800-800 cm^{-1}) of 36 pig carcasses (Investigation I) measured 35-40 min after sticking (**A**) and of 66 pig carcasses (Investigation II) measured 45-50 min after sticking (**B**).

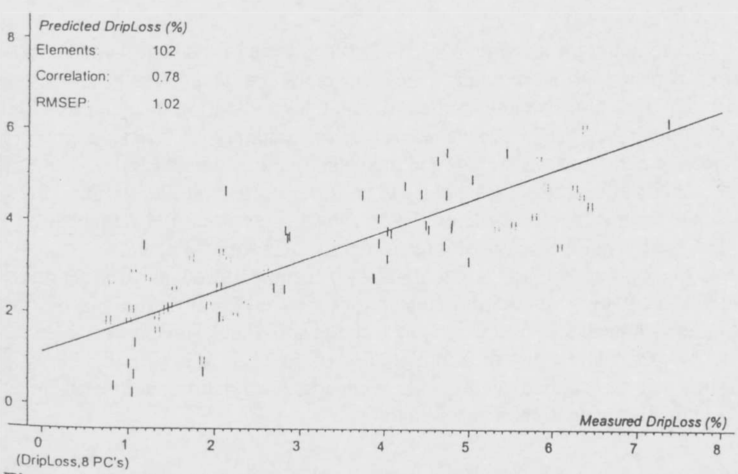

Figure 2. Predicted drip loss versus measured drip loss for a PLSR model (8 PC's) of FT-IR spectra (1500-950 cm^{-1}) of 102 pig carcasses (Investigation I+II).

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