# The influence of constant rigor temperature and storage time on the internal reflectance (FOP) in pork muscle

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SUMMARY: The influence of constant rigor temperature was studied for *M. longissimus dorsi* (LD) and *M. biceps femoris* (BF) from unstressed pigs at 2, 12, 20, 25, 30, 35 and 39°C. The internal reflectance values (FOP) were registered every half hour during the first 8 h p.m. and at 24 h p.m. At 24 h p.m. the pH, the drip loss and the protein solubility in high and low ionic strength were also analysed. The influence of storage time at +4°C on the FOP-values was studied for *M. longissimus dorsi* (LD), *M. biceps femoris* (BF) and *M. semimembranosus* (SM) between 24 h p.m. and 6 days p.m.

LD developed PSE at a somewhat lower rigor temperature than BF. PSE spots had occurred for LD at 30°C and for BF at 35°C. At 39°C both LD and BF had severe PSE. It took between 4 and 24 h to reach relative constant FOP-values. At temperatures below 25°C it took approximately 8 h, whereas at 39°C it took on average 5 h. The soluble proteins in low ionic strength explained most of the variation in the FOP reflectance values in both BF ($R^2$ = 80.1%) and LD ($R^2$ = 65.8%). The internal reflectance increased with storage time up to 6 days p.m., ~5 units/day in LD and ~2 units/day in SM and BF.

INTRODUCTION: One of the most common quality defects in pork is PSE. This Pale Soft Exudative condition occurs in muscles that have undergone fast post-mortem glycolysis due to stress in the live animal (WISMER-PEDERSEN, 1959). OFFER and KNIGHT (1988) argue, however, that even unstressed pigs can develop PSE if the carcass is cooled too slowly. In this study we have investigated the varying degrees of PSE that can be induced in unstressed pork muscles such as LD and BF by simply allowing them to go into rigor at constant temperatures. As PSE-meat is exudative, measurement of the water-holding capacity (WHC) is a good and economically important way to characterize PSE-meat. However, measurement of the WHC is not very fast and therefore not so useful in practice. Instruments for internal light reflectance measurements are more commonly used and in this study a Fibre Optic Probe (FOP) was utilized. A further objective of this investigation was to study how well these FOP-values correlate with other meat quality traits such as drip loss and water and salt soluble proteins measured 24 h post-mortem. The influence of both time during rigor and storage time up to six days on the FOP-values was followed, as in fact very few data are available on the FOP-time-dependence.

MATERIAL and METHODS: Only commercial cross-bred pigs (Hampshire (Yorkshire x Landrace)) were used in the following two investigations. The influence of constant rigor temperature was studied for *M. longissimus dorsi* (LD) and *M. biceps femoris* (BF) when $pH_1 \geq 6.1$ and the mean value was 6.4. For the temperatures 2, 12 and 39°C, six animals/temperature were studied. Samples held at temperatures of 20, 25, 30 and 35°C were all taken from the same pig and a total of four pigs were analysed. The muscles were sampled 0.75 h after debleeding. The muscles were deboned, defatted, packed in plastic bags and put into water-baths as quickly as possible. After completion of rigor the muscles were stored at +4°C. The FOP-values were registered every half hour during the first 8 h p.m. and at 24 h p.m. At 24 h p.m. the pH, the drip loss and the protein solubility in high and low ionic strength were also analysed.

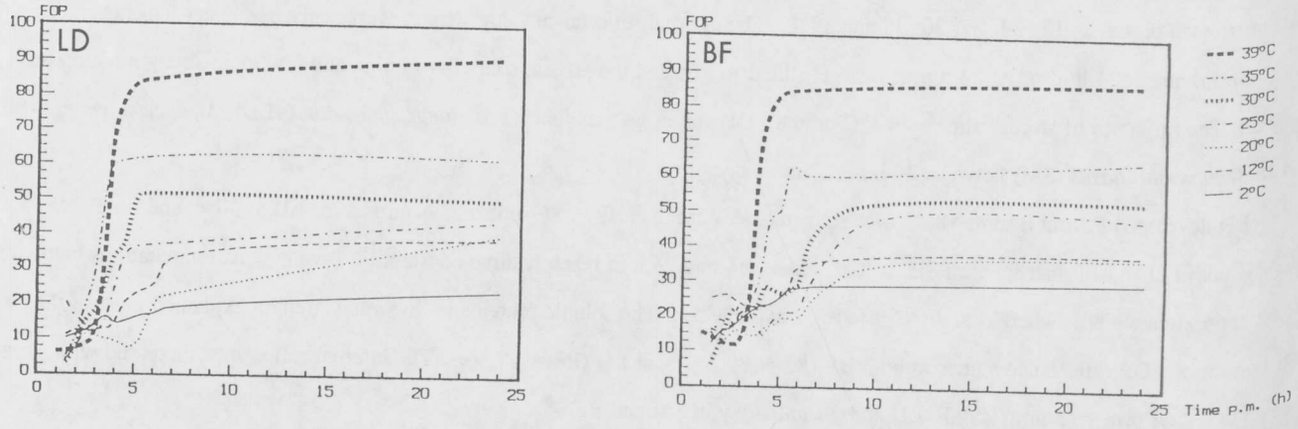
The influence of storage time between 24 h p.m. and 6 days p.m on FOP-values was studied for *M. longissimus dorsi* (LD), *M. biceps femoris* (BF) and *M. semimembranosus* (SM).

The internal reflectance was measured with the Fibre Optic Probe (Mk I, MRI, TBL, Leeds). It is designed to measure light scatter with minimal interference from light absorption by myoglobin ($\lambda$ = 900 nm). pH was measured with a xerolyte electrode or in a iodoacetate - KCl solution according to BENDALL (1978). The drip loss was determined as the percentage loss of a 2.0 cm thick slice. The slice hung in a plastic bag for 2 days in +4°C. The soluble proteins were determined mainly according to a method developed by the Danish Meat Research Institute, Roskilde, Denmark except that the protein content was determined by Kjeldahl.

Statistical methods. Data were analysed with the Statistical Analysis System (SAS Institute Inc., 1987) (GLM, Stepwise Regression procedure) and with the New Mathematical Statistics Package (NMSP, 1984). (Pearson's correlation coefficient).

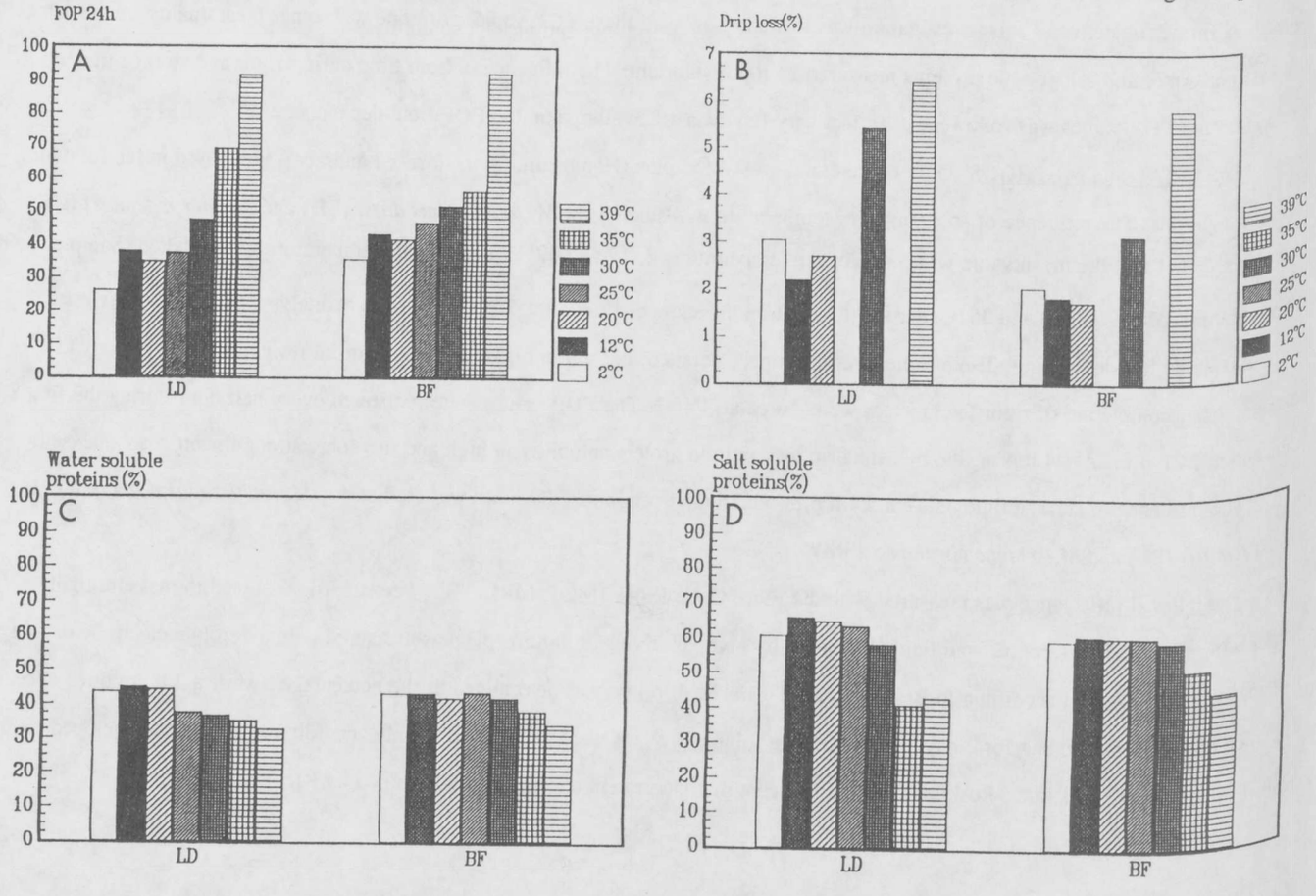
RESULTS and DISCUSSION:

Figure 1. FOP-values in porcine LD and BF versus time 0 - 24 h p.m. at different constant rigor temperatures.




In Figure 1, the FOP-values, as a function of the time post-mortem at different constant rigor temperatures, are presented. When the muscles were sampled (0.75 h p.m.), the FOP-value was three times higher in BF (~21) compared to LD (~7) although the pH was about the same (~6.4) for the two muscles. This is probably due to different meat structures in the two muscles. It took between 4 and 24 h to reach relative constant FOP-values. At temperatures below 25°C it took approximately 8 h, whereas at 39°C it took on average 5 h. LD reached the constant FOP-value somewhat before BF.

Figure 2. FOP, drip loss and percentage water and salt soluble proteins 24 h p.m. for LD and BF at different constant rigor temperatures.



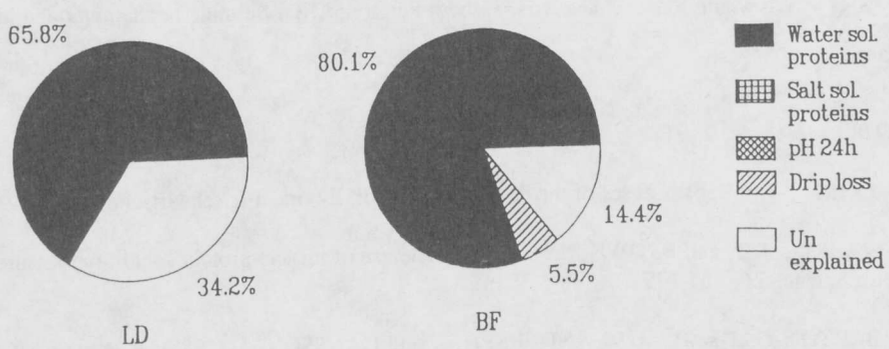
Not only the rate of increase in light reflectance but also the ultimate FOP-values differed between rigor temperatures (see Figure 2 A), being highest (~ 90) at 39°C and decreasing to a constant value of 35 - 40 at 12 and 20°C, whereas at 2°C a further decrease in the FOP-values down to 25 - 35 was obtained. In Figure 2 B - D, the other meat quality traits (drip loss and percentage water and salt soluble proteins at 24 h p.m.) can also be compared for the two muscles at different rigor temperatures.

When assessing PSE-meat, we often use three different methods; visual assessment, drip loss and FOP-measurement. For both LD and BF, the meat is considered to be PSE when the drip loss is $> 5\%$ and the FOP-value is $\geq 55$ in LD and 70-75 in BF. The visual assessment showed that PSE spots had occurred for LD at 30°C and for BF at 35°C. At 30°C, LD had a drip loss $> 5\%$ but the FOP-value was below 55. At 35°C, no drip loss measurement was performed for BF but the FOP-value was below the PSE-discrimination level of 70 - 75. At 39°C, both LD and BF had severe PSE. This clearly shows that even severe PSE can be obtained in unstressed pigs just by slow cooling, a so called temperature-induced PSE.

The results in Figure 2 C show that there was a continuous decrease of water soluble proteins in LD between 20 and 39°C, with the largest decrease between 20 and 25°C. In BF, the decrease was less and started at somewhat higher temperatures, which can be one of the reasons for BF having a lower drip loss at 30°C, compared to LD. Concerning the salt soluble proteins (Figure 2 D), the largest decrease was seen between 30 and 35°C in both LD and BF. HONIKEL and KIM (1986) showed a decreased solubility of the water soluble proteins at such a low temperature as 15°C, but these results were obtained for *M. psoas major* with a $pH_1 < 5.8$.

In order to get an insight into the relationships between the meat quality traits measured at 24 h p.m., a stepwise linear regression procedure was performed using the FOP-value as a dependent variable and the water and the salt soluble proteins, $pH_u$ and drip loss as independent variables. As can be seen in Figure 3, the water soluble proteins explained most of the variation in the FOP-reflectance values in both BF ($R^2 = 80.1\%$) and LD ($R^2 = 65.8\%$). For BF drip loss also gave a small additional contribution in the explanation of the FOP-values. In the present investigation only normal and temperature-induced PSE-meat was studied and the $pH_u$ ranged between 5.2 and 5.7.

Figure 3. Percent variation explained in the $FOP_{24}$ values by $pH_{24}$, drip loss and protein solubility.




The fact that protein denaturation explains most of the variation in internal reflectance agrees well with LUNDSTRÖM et al. (1988) and LOPEZ-BOTE et al. (1989). There are, however, differences. In the investigation of LUNDSTRÖM et al., having only normal and PSE-meat, it was the salt soluble proteins that explained most of the variation. LOPEZ-BOTE et al. (1989) found that the concentration of soluble sarcoplasmic proteins showed the highest correlations with assessments such as drip loss and reflectance in a population of muscles showing both PSE and DFD as well as normal meat. However, if DFD muscles were excluded, the concentration of total soluble proteins was a slightly better predictor of quality. Both the present investigation and the one of LOPEZ-BOTE et al. (1989) showed that the sarcoplasmic proteins could be denatured in normal meat thereby causing an increased drip. The simple correlation coefficients between FOP and drip loss were $r = 0.86^{***}$ (BF) and $r = 0.66^{***}$ (LD) in this investigation.

We have, on several occasions, noticed that the reflectance is enhanced when the FOP-value is remeasured after storage. In Table 1, results from three different investigations, for the muscles LD, BF and SM, are presented. The FOP-values increased with storage time and the enhancement was greatest in the loin, compared to the ham muscles. The mean increase was ~5 units/day for LD and 2 units/day for BF and SM. If we compare the PSE-frequency at 24 days p.m. and after some days storage using the same discrimination level for the FOP, we would in some cases be able to see an increase from 5% to 50% in the PSE-frequency for LD. This shows the importance of measuring the FOP immediately after cutting, to be able to have comparable values.

Table 1. FOP-values between 24 h and 6 days p.m. and FOP increase/day for the muscles LD, BF and SM.

| Muscle | n | FOP 24 h | FOP (days p.m.) | | FOP increase/day |
|---|---|---|---|---|---|
| M. longissimus dorsi (LD) | 74 | 33.0 | 51.5 | (5) | 4.6 |
| M. biceps femoris (BF) | 40 | 39.0 | 44.0 | (3) | 2.5 |
| M. biceps femoris (BF) | 80 | 44.0 | 53.0 | (6) | 1.8 |
| M. semimembranosus (SM) | 50 | 6.0 | 49.0 | (3) | 1.5 |
| M. semimembranosus (SM) | 53 | 48.0 | 56.0 | (6) | 1.6 |

CONCLUSIONS: The results show that even pigs with normal $pH_1 \geq 6.1$ are very sensitive to high rigor temperatures which can lead to severe PSE at the highest temperatures. LD developed PSE at a somewhat lower temperature than BF. The water soluble proteins started to decrease at temperatures above 20°C for LD and for the salt soluble proteins the largest decrease was seen between 30 and 35°C in both LD and BF.

It was the water soluble proteins that explained most of the variation in FOP reflectance values in both BF ($R^2 = 81.1\%$) and LD ($R^2 = 65.8\%$). The simple correlation coefficients between FOP and drip loss were $r = 0.66^{***}$ (LD) and $r = 0.86^{***}$ (BF), respectively.

The results also show that it takes between 4 and 24 h to reach relative constant FOP-values for pigs with normal $pH_1$. The reflectance can also increase with storage time, more in LD (~5 units/day) compared with BF (~2 units/day). This shows the importance of measuring the internal reflectance at the same time p.m., in order to obtain comparable values.

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