# USE OF NEAR INFRARED SPECTROSCOPY AS SELECTION TOOL FOR PSE PORK

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**Abstract – In this study, the capability of near infrared spectroscopy (NIRS) to detect pale, soft and exudative (PSE) pork at 24 hours post mortem was investigated. In a first experiment, 30 *Longissimus dorsi* (LD) samples were collected of which 15 muscles were incubated immediately post mortem at 40°C for 4 hours to induce more PSE characteristics. In a second experiment, 16 *Semimembranosus* (SM) samples, showing visual PSE characteristics, and 14 SM muscles with normal meat quality were collected. In both cases, NIRS technology was used to classify the muscles according to whether PSE characteristics were present or not. Good classification results were obtained with 90% and 93.3% correct classification after cross-validation for respectively LD and SM muscle samples. Results indicated that NIRS has potential to discriminate PSE from normal pork at 24 hours post mortem.**

**Key Words – Classification, Meat quality, Pig**

## I. INTRODUCTION

As consumers pay increasingly attention to the quality of food products, the presence of PSE pork is still a major concern for the fresh pork and processing industry. PSE pork is associated with an increased rate of glycolysis and a slow temperature decrease post mortem [1, 2]. As the pH drops within 45 minutes after slaughter to less than 5.7 in extreme PSE [3], more proteins are denatured, resulting in pale meat with a soft texture and low water holding capacity. Not only using extreme PSE pork when processing meat products, e.g. cooked ham, causes problems, also the use of meat with intermediate PSE characteristics can lead to processed meat products with a lower and non-acceptable end quality. Although efforts are done to separate pork with PSE characteristics and then process such meat to obtain final products with improved properties and consumer acceptability [4], currently used objective and subjective methods are still not selective enough to distinguish intermediate PSE categories from good quality meat. As it is generally accepted that final pH values, measured 24 hours after slaughter, of PSE meat are quite similar to those of normal quality meat, pH measurements done at the reception of the meat factories are not satisfactory to detect meat with intermediate PSE characteristics. Hence, a more reliable technique is needed to detect (intermediate) PSE pork more accurately, so that economic losses are minimized for the pork industry. Previous studies showed the potential of NIRS to measure pork meat quality [5, 6, 7, 8]. The aim of this study was to investigate the use of NIRS to detect PSE pork under normal operating conditions.

## II. MATERIALS AND METHODS

*Sample collection and measurements*

A total of 15 pigs were randomly selected at the slaughterhouse of which the LD muscles from both carcass halves were hot deboned. Some studies have already shown that subjecting muscles early post mortem to high temperatures offers a simple and reliable method to produce PSE-like pork [4, 9]. Therefore, PSE condition was induced by incubating the deboned LD muscle sampled at 30 minutes post mortem from one half of the carcass at 40°C for 4 hours followed by chilling to 4°C. The deboned LD muscle from the other half of the carcass was immediately cooled at 4°C. During 8 hours, pH and temperature were monitored in the slaughterhouse after which the LD samples were transported to the laboratory and further stored at 4°C. After 24 hours the ultimate pH (Hanna HI99163, Hanna Instruments, Temse, Belgium) and electrical conductivity (PQM) (PQM-I/KOMBI, Intek Klassifizier-ungstechnik, Aibach, Germany) were measured as well as the CIE $L^*a^*b^*$ color values using a Hunterlab colorimeter (MiniScan XE, Hunter Associates Laboratory, Reston, VA, USA). Drip loss was determined using the Honikel [10] method. From all LD muscles, NIR spectra were collected using an Antaris II Analyzer (Thermo Fisher Scientific, Erembodegem, Belgium) with a fiber optics probe, measuring reflectance from 4000 to 12000 $cm^{-1}$. Samples were presented once to the probe. Per sample, 128 scans with a resolution of 16 $cm^{-1}$ were averaged. An aliquot of the LD samples was kept at -80°C to determine the sarcoplasmic and myofibrillar protein solubility (mg soluble protein/g total protein) according to Claeys et al. [11].

To examine the use of NIRS to detect PSE pork under normal operating conditions, 16 SM muscles, showing visual PSE characteristics, i.e. pale color and exudative properties, and 14 normal SM muscles were selected at the cutting room of a Belgian cooked ham factory. All the selected SM muscles were provided with the *Adductor* (AD) muscle. Meat quality (pH, PQM, $L^*a^*b^*$) and NIR measurements were performed in the same way as the PSE induction experiment on LD muscle, but in this experiment the analyses were carried out at the production plant. After collecting meat quality parameters and NIR spectra, salt injection was executed in the cooked ham company. Afterwards, the SM samples were transported to the laboratory where they were prepared to cooked meat products in a pilot plant for cooked ham production. Texture profile analysis (TPA) was determined on the final cooked products using a TA.XT2i Texture Analyser (Stable Micro Systems, Surrey, UK). TPA measurement was performed on 3 transverse cuts of SM muscle at the transition to the AD muscle.

*Data analysis*

To test the significance of differences between 1) normal and PSE-induced LD samples, 2) normal and PSE SM samples, data were subjected to an unpaired *t*-test using SPSS Statistics (IBM, version 20). Discriminant analysis (SPSS Statistics, IBM, version 20) was carried out to classify 1) the LD samples in normal and PSE-induced samples, 2) the SM samples according to their external PSE characteristics. For the NIR spectral data, factor analysis was first performed to reduce the absorbance data at different wavenumbers into fewer number of factors which were used for further discriminant analysis. Preprocessing techniques on the NIR spectra were investigated to improve classification results.

## III. RESULTS AND DISCUSSION

Results of meat quality measurements on both normal and PSE-induced pork LD muscles are shown in Table 1.

Table 1. Mean and standard deviation (SD) of the meat quality parameters of normal (n=15) and PSE-induced (n=15) pork LD muscle

| Meat quality parameter | Normal LD | | PSE LD | | |
|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | P |
| pH 30 min p.m. | 6.34 | 0.30 | 6.22 | 0.28 | 0.27 |
| pH 4h 30 min p.m. | 5.79 | 0.26 | 5.29 | 0.07 | < 0.001 |
| pH 24h p.m. | 5.37 | 0.07 | 5.41 | 0.07 | 0.08 |
| PQM 24h p.m. | 6.63 | 2.88 | 16.07 | 1.30 | < 0.001 |
| Drip loss (%) | 5.12 | 1.29 | 5.68 | 1.04 | 0.20 |
| L* 24h p.m. | 51.21 | 2.95 | 59.47 | 3.52 | < 0.001 |
| a* 24h p.m. | 6.53 | 1.17 | 6.99 | 1.03 | 0.27 |
| b* 24h p.m. | 13.40 | 0.75 | 15.54 | 0.86 | < 0.001 |
| Sarcopl. prot. sol. (mg/g) | 74.11 | 2.43 | 62.29 | 4.07 | < 0.001 |
| Myofibr. prot. sol. (mg/g) | 14.93 | 0.53 | 11.91 | 0.89 | < 0.001 |

Although the $pH_{30min}$ was not different between both groups, incubating the LD muscles at 40°C for 4 hours resulted in a lower pH value 4 hours post mortem ($P < 0.001$). As the pH fell below 5.8 while muscle temperature was above 35°C, the muscle was sensitive to heat denaturation and thus PSE [4, 12]. The ultimate pH for both chilling regimes was similar. PSE-induced pork also had significantly higher PQM, $L^*$ and $b^*$ values measured 24 hours after slaughter. It should be mentioned that the differences in drip loss between normal and PSE-induced LD muscles was less than expected, as during cooled storage and before meat quality measurements, a lot of drip was lost from the induced LD samples compared to the control LD samples. A reduced protein solubility (both sarcoplasmic and myofibrillar protein) in PSE-induced LD muscle than in normal LD muscle was observed ($P < 0.001$). Similar results were reported by van Laack & Kauffman [13] and Ryu et al. [14]. Figure 1 shows the mean spectra of both normal and PSE-induced LD muscles, modified to the first derivative.

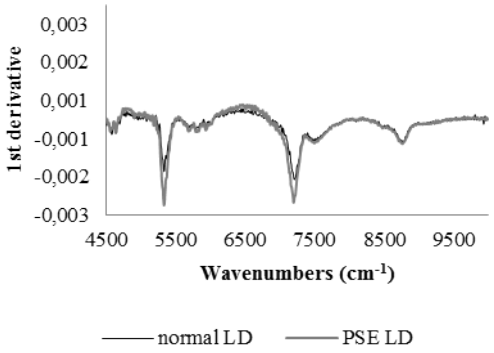


Figure 1. Mean NIR spectra of normal (n=15) and PSE-induced (n=15) LD muscles

Spectral differences were observed within regions from 7000-6500 and 5500-5000 $cm^{-1}$. Systematic shifts in spectral data were observed around 7200 and 5300 $cm^{-1}$. Absorption bands of carbonyl and amino groups can be observed within those spectral regions [6]. NIR spectral data were used to classify the LD muscles according to the chilling regime to which they had been subjected. Classification results after cross-validation for both traditional and NIR spectral data are shown in Table 2.

Table 2. Percentage correct classification after cross-validation for normal and PSE-induced LD samples

| | Normal LD | PSE LD | Total |
|---|---|---|---|
| PQM 24h p.m. | 86.7 | 100 | 93.3 |
| $L^*$ 24h p.m. | 93.3 | 86.7 | 90.0 |
| $b^*$ 24h p.m. | 93.3 | 100 | 96.7 |
| PQM + $b^*$ 24h p.m. | 100 | 100 | 100 |
| Protein solubility | 100 | 93.3 | 96.7 |
| NIR spectra | 93.3 | 86.7 | 90.0 |

After factor analysis the raw, non-preprocessed NIR spectra were reduced to 5 factors which explained 99.8% of the variance. Discriminant analysis, using those 5 factors as independent variables, resulted in a 90% correct classification after cross-validation. The classification results obtained with NIR were very good, however not as conclusive as those achieved with the traditional quality parameters $PQM_{24h}$ and $b^*_{24h}$. In this study, no classification based on the ultimate pH could be obtained. Results of meat quality measurements on both normal and PSE SM muscles are shown in Table 3.

Table 3. Mean and standard deviation (SD) of the meat quality parameters of normal (n=14) and PSE (n=16) pork SM samples

| Meat quality parameter | Normal SM | | PSE SM | | |
|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | P |
| pH 24h p.m. | 5.63 | 0.12 | 5.44 | 0.08 | < 0.001 |
| PQM 24h p.m. | 15.50 | 1.62 | 16.44 | 1.14 | 0.07 |
| $L^*$ 24h p.m. | 50.07 | 2.75 | 63.96 | 2.06 | < 0.001 |
| $a^*$ 24h p.m. | 10.38 | 2.11 | 9.57 | 1.51 | 0.24 |
| $b^*$ 24h p.m. | 16.55 | 2.00 | 19.04 | 1.08 | < 0.001 |
| Chewiness (Nmm) | 96.32 | 19.24 | 79.23 | 11.44 | 0.01 |
| Hardness (N) | 43.20 | 3.85 | 44.91 | 3.60 | 0.22 |
| Stiffness (N/mm) | 10.67 | 2.43 | 9.83 | 2.57 | 0.83 |

PSE SM samples had significantly lower pH and significantly higher $L^*$ and $b^*$ values than normal SM samples measured 24 hours post mortem at the cutting room of the cooked ham factory. Concerning the TPA parameters, chewiness of the PSE samples, measured at the transition zone between SM and AD muscle, was significantly lower than for the normal SM samples. Classification results after cross-validation based on conventional and TPA parameters as well as on NIR spectral data are shown in Table 4.

Table 4. Percentage correct classification after cross-validation for normal and PSE SM samples

| | Normal SM | PSE SM | Total |
|---|---|---|---|
| pH 24h p.m. | 78.6 | 87.5 | 83.3 |
| $L^*$ 24h p.m. | 100 | 100 | 100 |
| $b^*$ 24h p.m. | 71.4 | 93.8 | 83.3 |
| TPA | 78.6 | 93.8 | 86.7 |
| NIR spectra | 85.7 | 100 | 93.3 |

NIR spectral data were used to classify the SM muscles according to the presence of visual PSE characteristics. After factor analysis the raw NIR spectra were reduced to 3 factors, explaining 99.9% of the variance. Discriminant analysis, using those 3 factors as independent variables, resulted in a 93.3% correct classification after cross-validation. The classification results obtained with NIR are promising, however still not as good as those observed with $L^*_{24h}$.

## IV. CONCLUSION

The obtained classification results showed the potential of the use of NIR as selection tool for PSE pork. Further work remains to be done to develop a more robust classification system that can be implemented at industrial level.

## ACKNOWLEDGEMENTS

This research was financed by IWT Flanders (Brussels, Belgium), Belpork vzw, meat companies and suppliers of NIR instruments. The authors would like to thank the staff of the participating slaughterhouse and cooked ham company for their assistance. The NIR equipment provided by Thermo Fisher Scientific was gratefully acknowledged.

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