The role of the first overtone of water absorption in the prediction of quality parameters of pork meat

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Introduction

Meat represents a large component of human food and its quality is of concern to consumers, control authorities and retailers. Meat differs in various aspects including sensory, technological, nutritional and hygienic quality. Control procedures must be carried out to ensure that meat is maintained at a high quality. Different techniques such as chemical analysis, instrumental methods, sensory analysis and screening methods have been used for meat qualification. However, those techniques are destructive, time-consuming and consequently unsuitable for online application. NIR spectroscopy has been applied to the quantitative determination of major constituents in meat and meat products and as an authentication tool in order to prevent fraud and to detect handling aspects such as freezing, thawing etc.[1-5]

In pork, the most prominent quality defect is pale, soft, exudative (PSE) meat. PSE meat is characterised by a pale lean, soft texture, and a low water-holding capacity. The PSE condition results from an accelerated rate of glycolysis during early post-mortem. A subsequent rapid decrease in pH immediately after slaughter results in greater protein denaturation than in non-PSE (normal) muscle. Such denaturation leads to elevated water loss and altered light scattering characteristics .[3,4]

Meat can be a target for adulteration and one method involves the sale of thawed meat as fresh. Within the European Union, the sale of frozen-then-thawed meat as fresh is outlawed by labelling directives. During freezing and thawing of meat, ice crystal growth causes biochemical and physical changes. The latter result in the disruption of cellular organelles and release of their contents into the meat drip juice.

Lean muscle contains approximately 75% water. Water in the meat may be bound, entrapped or free. Bound water is the water that exists in the vicinity of non-aqueous constituents (like proteins) and has reduced mobility. Entrapped water is another fraction of water that can be found in muscles; it can be easily converted to ice during freezing. Free water is defined as the water which can flow unimpeded from the tissue. In all cases (normal and PSE meat; fresh and frozen-then-thawed meat) changes in water content and proportion of free and bound water occurs.[6]

Numerous water absorbance bands in the near infrared (NIR) region have been identified and used for the investigation of different biological and aqueous systems (i.e. “Aquaphotomics”).[7] The aim of this work was to investigate differences in the absorption of normal and PSE meat and fresh and frozen-then-thawed meat, and especially the role of the first overtone region of water for the classification of pork meat.

Materials and Methods

Samples

Meat samples were collected from 72 cross-breed pigs, each with an approximate live weight of 115 kg. The pH of muscle samples was measured directly at 45 minutes post-mortem. Carcasses were divided into two classes according to pH values: normal meat with pH_{45} values higher than 5.8 and PSE meat with pH_{45} values lower than 5.8. Porcine muscle (*Longissimus thoracis et lumborum*) samples were taken 24 h after slaughter from the 12th to13th ribs and divided into two parts. One part of each sample was scanned immediately, with a second part being packed and sealed in a plastic bag to be deep frozen at -32°C for 6 h and kept at -21°C. Samples were thawed after one month and measured again.

Near infrared Spectroscopy

NIR measurements were performed using a NIRQuest 512 spectrometer (Ocean Optics, Inc.). Spectral data were collected between 900 and 1700 nm using a reflectance fiber-optic probe. Two or three measurements on different parts of the sample were made to minimise any possible effects of structural variation in the samples.

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Pirouette Version 2.0 (Infometrics, Inc., Woodinville, WA, USA) was used for spectral data processing. Soft independent modelling of class analogy (SIMCA) was implemented to create models of the respective meat types based on their NIR spectra.

Results and Discussion

Differences in absorption spectra were observed between normal and PSE meat, as well as between fresh and frozen-then-thawed meat, despite very similar chemical compositions of samples. The biggest differences were observed in the 1350–1480 nm region, in which various forms of water exhibit absorption. Additional absorption maxima were found at 1363 and 1384 nm and intensity differences from 1403 to 1416 nm were observed in spectra of PSE meat (Figure 1). Observed maxima in PSE meat were in the range of water-matrix coordinates C_2, C_4 and C_5, as proposed by Tsenkova.[7] Similar changes were observed between spectra of fresh and frozen-then-thawed meat.

SIMCA models for discrimination of normal and PSE meat and fresh and frozen-then-thawed meat were developed. The spectral wavelengths that were responsible for the classification of meat samples can be identified using discriminating power plots (Figures 2 and 3). In the discriminating power plot, each wavelength in the spectral range is plotted against its importance in discriminating the samples; the higher the value of discriminating power, the greater the influence of that wavelength in classifying the samples. The important spectral information for discriminating between meat classes is summarised in Table 1. The most important spectral information for discriminating between fresh and frozen-then-thawed meat was in the range 1374–1387 nm (1374, 1379, 1384 and 1387–1395 nm) whereas for discrimination between normal and PSE meat involved absorptions at 1392, 1397, 1408, 1414, 1457 and 1464 nm. These wavelengths were in the range of water-matrix coordinates C4, C_5 and C_9. Spectral differences that were important for discriminating between fresh and frozen-then-thawed meat, and normal and PSE meat, were mostly related to water structure.

Table 1. Absorbance bands making a large contribution to discrimination of meat samples.

Water-matrix coordinates as proposed by Tsenkova[7]	Normal - PSE meat	Fresh - frozen-then-thawed meat
C1 - 1336–1348nm	1344 nm	1344 nm
C2 - 1360–1366nm	1363 nm	
C3 - 1370–1376nm		1374 nm
C4 - 1380–1388nm	1384, 1392 nm	1379, 1384, 1387 nm
C5 - 1398–1418nm	1397, 1401, 1408, 1414 nm	1395 nm
C9 - 1458–1468nm	1457, 1464 nm	
C10 - 1472–1482nm	1476 nm	

SIMCA models based on spectral data provided good classification of meat samples. The accuracy of SIMCA models based on spectral data in the 1340–1500 nm region was similar to those obtained using the 900–1700 nm region. Results for SIMCA models that distinguish between fresh and frozen-then-thawed meat are presented in Table 2.

Table 2. SIMCA classification of fresh and frozen-then-thawed meat.

	Calibration set		Test set		
	Fresh meat	Frozen-then-thawed meat	Fresh meat	Frozen-then-thawed meat	Non-classified
Fresh meat 900–1700 nm	72	0	40	1	
Frozen-then-thawed meat 900–1700 nm	0	66	4	32	1
Fresh meat 1340–1500 nm	72	0	39	1	1
Frozen-then-thawed meat 1340–1500 nm	5	61	8	29	

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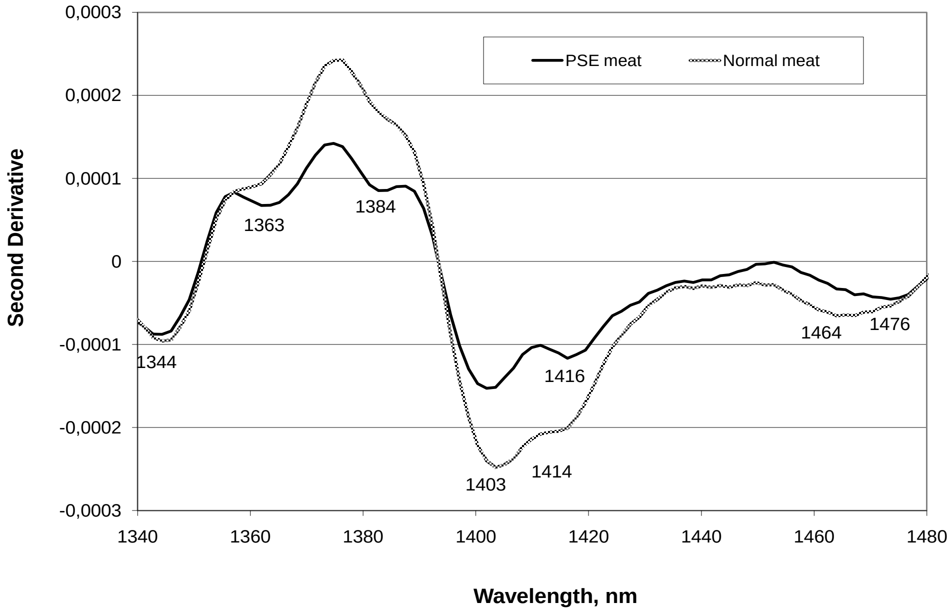

Figure 1. Second derivative average spectra of normal meat and PSE meat.

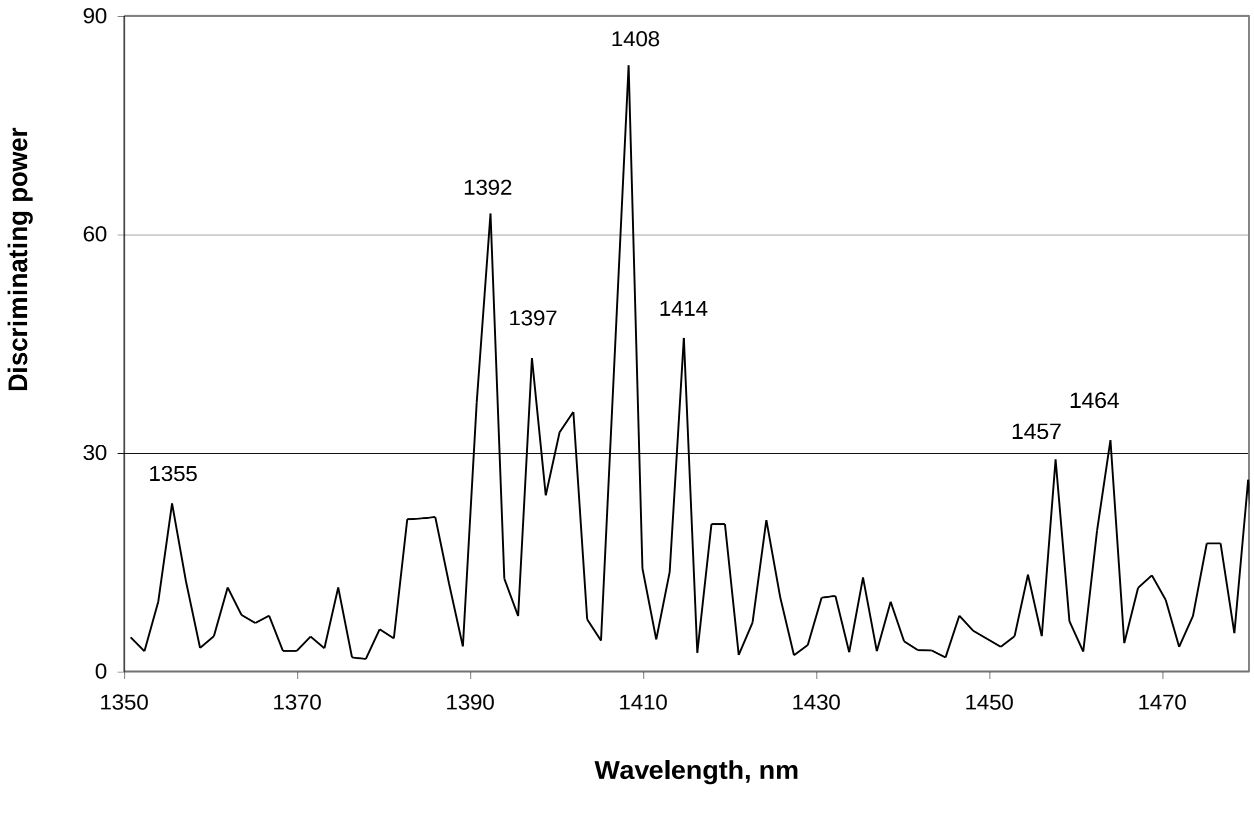

Figure 2. Discriminating power plot of SIMCA procedure for discrimination of normal meat and PSE meat.

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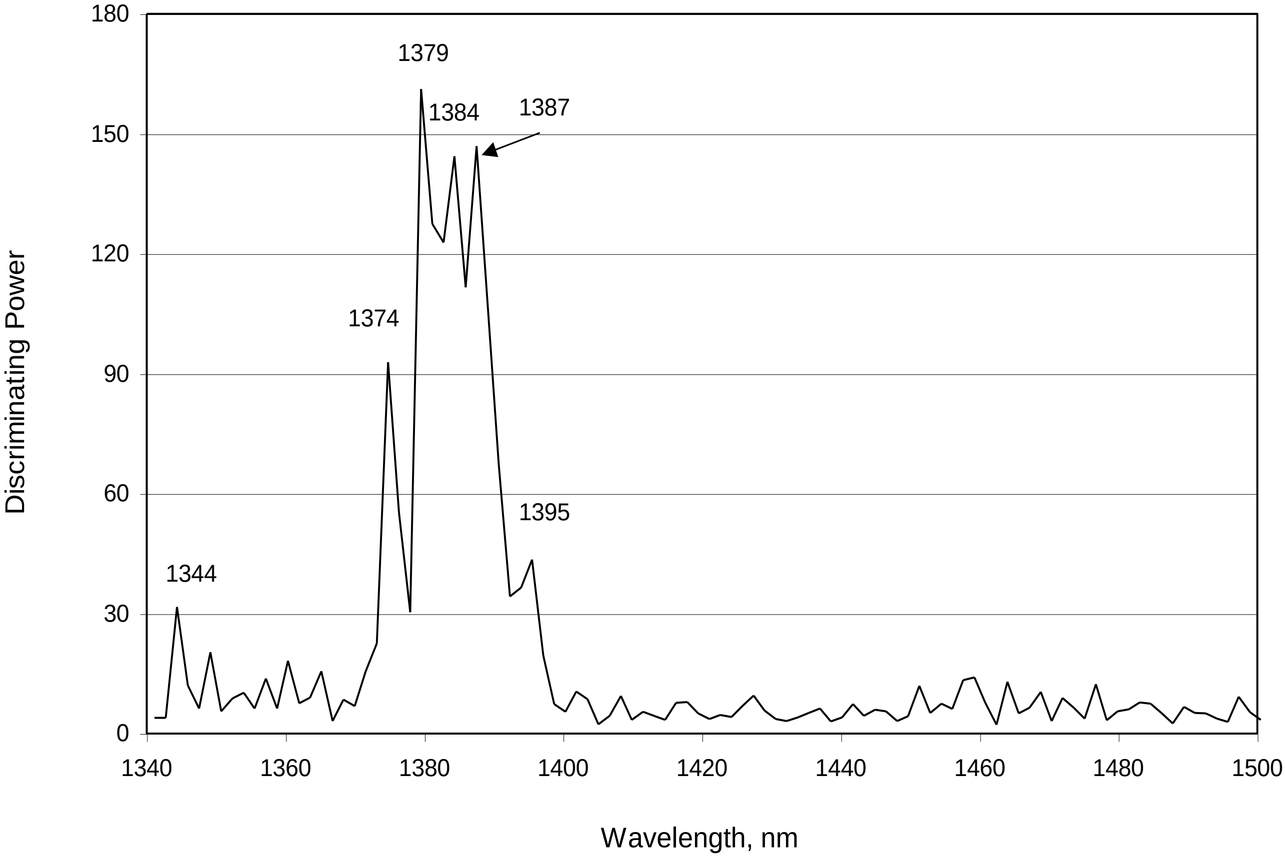

Figure 3. Discriminating power plot of SIMCA procedure for distinguishing between fresh and frozen-then-thawed meat.

Conclusion

Differences in the absorption spectra of fresh and frozen-then-thawed meat, and normal and PSE pork meat, were strongest between 1340 and 1500 nm. This spectral region is attributed to the first overtone of water, and indicates functionally different structures of water in different kinds of meat. These differences could be used to discriminate between meat classes.

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