DETERMINATION OF QUALITY CHARACTERISTICS IN PORK MUSCLES BY VISIBLE AND NEAR INFRARED REFLECTANCE SPECTROSCOPY

Barlocco, N. [1], Vadell, A[1], Ballesteros, F.[1], G. Gallietta [1], Cozzolino, D. [2]

[1] Facultad de Agronomia, Universidad de la Republica, UDELAR, Av. Garzon 780. Montevideo, Uruguay.
[2] INIA La Estanzuela - Uruguay. Actual address: AWRI. PO Box 197. Urrbrae - 5064. South Australia.

Background

Traditional wet chemical analysis of foodstuffs and products from animals and vegetables has been used to characterise their composition and quality, but these procedures are not well defined chemically and are costly, time-consuming and sometimes hazardous (Osborne et al., 1993). From the analytical chemist's point of view the composition of meat is complex. The main components are the proteins of the muscle, moisture, collagenous materials, together with lipids and small amounts of free amino acids, enzymes, carbohydrates and minerals (Lawrie, 1985). On the other hand, quality for the consumer is subjective, seen partly in terms of visible features, such as the pleasure attributes of the product and partly in terms of awareness of invisible qualities such as microbial and toxicological safety and nutritional value. The role of the food industry is to meet consumer expectations of quality whether visible or invisible through appropriate quality control and quality management methods (Murray et al., 2001). In general, the quality of animal muscle as the product meat is defined in terms of customer demand i.e. how much the customer is consistently prepared to pay for it (Lawrie, 1985). Although man has appreciated the quality of animal muscle as meat from the very earliest times, an objective definition of what is meant by quality is still a major problem in the meat industry today. Meat quality is described as a combination of physical, structural and chemical characteristics of meat, which results in maximum desirability from the standpoint of appearance and eatability. Fat and moisture content of meat products are important to the consumer, producer and researcher. Near Infrared Reflectance Spectroscopy (NIRS) was originally developed to provide a rapid measurement of the composition of grains and oilseeds (Osborne et al., 1993). NIRS has emerged in the last 30 years as a rapid method for testing the quality of intact samples from the light they reflect and it is likely to be the best means of achieving this quality control effectively and conveniently. The optical properties of meat readily provide a means of determining the gross composition of muscle tissue in terms of chemical composition. At present there is little information on how NIRS can sense the quality of the muscle "as meat". Most of the published works were based on filter instruments, old software and fibre optics, with little emphasis on how to present the sample to the instrument, sampling, effect of storage on the sample (Cozzolino and Murray, 2002).

Objectives

The aim of this work was to explore the use of the visible and near infrared reflectance spectroscopy to determine moisture (M), intramuscular fat (IMF), and colour values (*L*, *a* and *b*) in pork muscle samples.

Methods

Forty-four (n=44) pork muscle (*longissimus thoracis*) samples were obtained after a feeding trial which compared the use of both commercial feeds and pastures to finishing pigs (T1 = 100% commercial feed; T2, T3 and T4 different proportions of commercial feed and pastures) (data not presented). Pigs were slaughtered (aprox 100 kg live weight) under commercial conditions (stunned electrically, exsanguinated, scalded, de-haired, eviscerated and split into sides), where no treatments at slaughter were carried out. Slaughter procedures conformed to The National Meat Institute of Uruguay (INAC - Uruguay). Carcass weight and length were measured after 24 hours of slaughter. The samples were taken after slaughter (carcass weight after 24 hours aprox. 84 kg). Pork muscles were taken from the 10th rib, wrapped in aluminium foil and kept on freezer (two weeks) before analysis. About 100 to 200 g of muscle was thawing at room temperature (20 – 22 ^{0}C) and homogenised during one to two minutes with a food multiprocessor blender (Philips RI - 3142, Brazil). The blender cup was washed first with hot water, followed by cold water and towel dried between samples. Samples were analysed by reference methods for moisture and intra-muscular fat (IMF) (AOAC, 1990). Before colour measurement, samples were thawed at room temperature (20 - 22 °C) for 12 hours. The CIE L^*, CIE a^* and CIE b^* values were determined on the intact muscle using a digital camera chroma meter (CR 10 Minolta Co. Ltd, Osaka, Japan). The camera averages the colour reading from an 8-mm measured area, with a standard illuminant D and has an 8/d geometry. Each data was the mean of three applications. Samples were scanned both intact and minced in the reflectance mode (400 – 2500 nm) in a scanning monochromator NIRS 6500 (NIRSystems, Silver Spring, MD, USA). Spectra collection and multivariate analysis were performed using NIRS 2 software, version 3.01, from Infrasoft International (ISI, Port Matilda, PA, USA). Each spectrum was collected in the visible and near infrared range at 2 nm intervals (1050 data points). Immediately after homogenisation, minced samples were scanned in a circular cup (50 mm diameter, 10 mm depth) (Part number IH – 0307, NIRSystems, USA) sealed with disposal paper back. Reflectance data were stored as log (1/R) (where R: reflectance) at two nm intervals. Two pairs of lead sulphide detectors collected the reflectance spectra and were referenced to corresponding readings from a ceramic disk. The spectrum of each muscle sample is the average of 32 successive scans. Predictive equations were developed using modified partial least square (MPLS) regression with internal cross-validation (Shenk and Westerhaus 1993) and scatter correction using Standard Normal Variate (SNV) and detrend transformations (Barnes *et al.* 1989). Cross validation estimates the prediction error by splitting the calibration samples into groups (four in this study). One group (n: 11) was reserved for validation and the remaining groups were used for calibration (n: 33). The process was repeated until all groups have been used for validation once. The outlier elimination pass was set to allow the computer program to remove outliers twice before completing the final calibration (Shenk and Westerhaus 1993). The mathematical treatment applied was (2,5,5,2). The first number indicates the order of derivative (one is the first derivative of log 1/R), the second number is the gap in data points over which the derivative is calculated; the third number is the number of data points used in the first smoothing and the fourth number refers to the number of data points over which the second smoothing is applied. Calibration statistics calculated included the standard error of calibration (SEC), the coefficient of determination in calibration (R^2_{cal}), the standard error of cross validation (SECV) and the coefficient of determination in cross validation (R^2_{val}) (Shenk and Westerhaus 1993). The optimum calibrations were selected based on minimising the standard error of cross validation (SECV) with the highest R^2_{cal}.

Results and Discussion

Correlation's between wavelengths and reference data were observed at 924 nm, 1452 nm and 1934 nm with L^* value; at 580 nm with a^* value and at 536 nm, 570 nm and 810 nm with b^* value on homogenised presentation. The CIE L^* values were highly correlate with water absorption bonds on homogenised presentation. The visible region at 632 nm was suggested by other authors to be use for determine the relative quantities of oxymyoglobin, myoglobin and total pigments in meat using fiber optics (Swatland 1995). Although no individual pigments were measured by reference method, high correlation was found between the CIE values and the corresponding theoretical absorption of the individual pigment in the visible region.

Table 1 showed the NIRS calibrations and cross validation statistics for IMF, M, CIE L^*, CIE a^* and CIE b^* values in pork muscle homogenates. NIRS calibration statistics showed high (R^2_{cal}) > 0.90 for IMF and moisture on pork muscle homogenates. Both the CIE L^* and CIE a^* values, gave a coefficients of determination (R^2_{cal}) > 0.60 in the pork muscles analysed. Low correlations were found for CIE b^* values. Homogenisation of the sample severely alters the structure of the muscle, destroying and randomising the fiber arrangement of the muscle as well as averaging the effects of scattering by the fibers in the tissue (Swatland, 1995; Cozzolino and Murray, 2002). In muscle homogenates, the sample preparation, the chemical analysis and the subsampling to perform the chemical analysis remaining the variables that can affect the accuracy and reproducibility of the near infrared analysis. In particular this is true for the determination of intramuscular fat and pigments.

Conclusions

The results obtained in these study suggest that VIS/NIR instruments (400 - 2500 nm) have an excellent potential to provide information related with the CIE system (L^* and a^*) on pork muscles samples as well as with chemical composition (IMF, M). In the future VIS/NIR colour measurements combined with other meat characteristics (chemical and physical) could provide a more accurate information of pork meat quality.

Reference

AOAC. 1990. Official methods of analysis of the Association of Official Analytical Chemists. Edited by K. Helrich. Published by the Association of Official Analytical Chemists, Inc., 15th edition, Arlington, Virginia; USA. 1298 pp.

Barnes, R.J.; Dhanoa, M.S. and Lister, S.J. 1989. Standard Normal variate transformation and detrending of near infrared diffuse reflectance spectra. Applied Spectroscopy **43**: 772 - 777.

Cozzolino, D. and Murray, I. 2002. Effect of sample presentation and animal muscle species on the analysis of meat by near infrared reflectance spectroscopy. Journal of Near Infrared Spectroscopy 10**:** 37 - 44.

Lawrie, R.A. 1985. Meat Science. 4th. Edition. Pergamon Press, Oxford.

Murray, I.; Aucott, L. and Pike, I.H. 2001. Use of discriminant analysis on visible and near infrared reflectance spectra to detect adulteration of fishmeal with meat and bone meal. Journal of Near Infrared Spectroscopy **9:** 297 - 311.

Osborne, B.G.; Fearn, T. and Hindle, P.H. 1993. Practical NIR spectroscopy with application in food and beverage analysis. Second Edition. Longman Scientific and Technical. 227pp.

Shenk, J.S. and Westerhaus, M.O. 1993. Analysis of Agriculture and Food Products by Near Infrared Reflectance Spectroscopy. Monograph. Infrasoft International. Port Matilda, P.A. USA.

Swatland, H. J. 1995 On Line Evaluation of Meat. Technomic Publishing Co., Lancaster, USA, pp 185-204.

Data

Table 1. NIRS calibration statistics for pork muscle samples using second derivative and SNVD.

	Mean	SD	SEC	R^2_{cal}	SECV	R^2_{val}
IMF (%)	4.1	0.9	1.1	0.93	2.2	0.73
Moisture (%)	70.3	2.3	0.2	0.99	0.8	0.90
CIE *a*	6.3	2.1	1.5	0.96	1.7	0.90
CIE *b*	8.7	1.6	1.3	0.30	1.5	0.20
CIE *L*	48.4	5.6	3.4	0.62	4.5	0.58

SD: standard deviation; SEC: standard error in calibration, SECV: standard error in cross validation, IMF: intramsucular fat, R^2_{cal} : coefficient of determination in calibration, R^2_{val}: coefficient of determination in validation.