RAPID AUTHENTICATION OF ENHANCED QUALITY PORK BY VISIBLE AND NEAR INFRARED SPECTROSCOPY

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Abstract – This study tested the ability of visible and near infrared spectroscopy (Vis-NIRS) to authenticate enhanced quality pork. One hundred and forty eight pigs from several genetic backgrounds, genders and diets were slaughtered at either 120 or 140 kg. Following splitting of the carcass, the right half carcass was blast chilled (BC) at -20 °C with a 2.5 m/sec wind speed for 1 h and moved into a cooler at 2 °C for 23 h, whereas the left half carcass was conventionally chilled at 2 °C for 24 h (Non-BC). The half loin from each left carcass side was moisture enhanced (ME; 0.50% salt and 0.49% disodium phosphate; pump rate 10%), whereas the other half was not subjected to ME treatment (Non-ME). Both ME and Non-ME half loins and another one from the right half carcass (BC) were cut in half, and the quarter loins were packed and aged for 2 or 14 days in a 1 °C cooler (2 and 14 d aged). The half and quarter loins were randomized by location to reduce location effects. After aging, Vis-NIR spectra were collected on the intact chops at the end of the loin using a portable LabSpec®4 spectrometer (350-2500 nm) at the laboratory. Partial least squares discriminant analysis based on Vis-NIR spectra correctly classified 90 and 95% of the 2 and 14 d aged pork samples. Vis-NIRS also correctly classified 99 and 96% of the Non-ME and ME pork samples aged for 2 d, and 95 and 94% of the Non-ME and ME samples aged for 14 d, respectively. Conversely, Vis-NIRS technology only correctly classified 57 and 54% of the Non-BC and BC samples aged for 2 d, and 53 and 54% of those aged for 14 d, respectively. Vis-NIRS technology can accurately discriminate the 14 d from 2 d aged and the ME from Non-ME pork samples but not the BC from Non-BC ones.

I. INTRODUCTION

To meet customer demands, pork processors are currently using processes such as moisture enhancement (ME) or blast chilling (BC) to consistently produce a pork product with enhanced quality. Moisture enhanced meat is produced through multineedle injection of a brine solution that may contain ingredients such as salt, phosphates, sodium lactate, and lemon juice solids. The ME process produces a retail product with increased juiciness and tenderness and with substantially improved sensory quality [1]. BC can quickly reduce temperatures and has improved pork quality by lessening the incidence of PSE muscle [2]. Although some conflicting results exist, BC improved muscle color scores and firmness in some studies [3]. Additionally, it is well known that during meat aging, tenderness increases and characteristic flavors are developed [4].

In order to assure quality control and guarantee consumers that they are getting exactly what they paid for and not an inferior quality pork, rapid methods to distinguish pork products with enhanced quality are required.

Near infrared spectroscopy (NIRS) is a sensitive, fast, and non-destructive technology, neither requiring reagents nor producing waste, that with minimal or no sample preparation provides information about the molecular bonds of organic compounds and tissue ultra-structure in a scanned sample [5]. NIRS has been successfully used for classification purposes in several species [6]. However, to the best of our knowledge, this technology was not to discriminate differentiated quality pork products. Therefore, the aim of the present study was to examine the potential of visible (Vis) and NIR spectroscopy to authenticate enhanced quality pork.

II. MATERIALS AND METHODS

A. Animals

One hundred and forty eight pigs from several genetic backgrounds, genders, diets, and slaughter weights (3 × 2 × 3 × 2) were raised at the Lacombe Research Centre (LRC-Agriculture and Agri-Food Canada, Lacombe, AB, Canada). The genotypes were Duroc, Lacombe (Peak Swine Genetics, Leduc, AB, Canada) and Iberian (Semen Cardona, Cardona, Barcelona, Spain) sires × commercial Large White*Landrace F1 dams. Animals were fed a typically Canadian commercial diet, a high-oleic diet (canola based diet), or a high linolenic diet (flaxseed based diet) formulated to increase the omega-3 content in pork (O&T Farms, Ltd., Regina, SK, Canada). Pigs had *ad libitum* access to feed and water. All pigs in the study were managed, handled and slaughtered in accordance with the principles and guidelines established by the Canadian Council of Animal Care [7].

B. Sample collection and treatments

When the animals reached the designated slaughter weight (either 120 or 140 kg), they were sent to the federally inspected abattoir at the LRC, stunned (400 V for 3 seconds), exsanguinated and dressed in a simulated commercial manner. Processing of carcasses included pasteurization (16 nozzles at 12 L/nozzle for 10 seconds with 86.4°C water for a total of 192 L/carcass) using an on-line stainless steel pasteurizing cabinet. Following splitting of the carcass, the right half carcass was blast chilled (BC) at -20 °C with a 2.5 m/sec wind speed for 1 h and moved into a cooler at 2 °C for 23 h. The left half carcass was conventionally chilled at 2 °C for 24 h (Non-BC). A half loin from each left carcass side was moisture enhanced (ME; 0.50% standard salt and 0.49% disodium phosphate; pump rate 10%; Hela Spice Canada Inc., Uxbridge, ON, Canada), whereas the other half was not subjected to ME treatment (Non-ME). Both ME and Non-ME half loins and another one from the right half carcass (BC) were cut in half, and the quarter loins were packed and aged for 2 or 14 days in a 1 °C cooler (2 and 14 d aged). The half and quarter loins were randomized by location to reduce location effects. After the corresponding ageing period, the chop at the end of the loin from each quarter loin was used for collection of Vis-NIR spectra.

C. Vis-NIR spectra collection

A portable LabSpec®4 Standard-Res spectrometer (Analytical Spectral Device-ASD Inc., Boulder, CO, USA) equipped with an ASD fibre-optic high intensity contact probe (21 mm window diameter) was used to scan the intact chops at the laboratory. The spectrometer scanned 50 times per reading (~5 s) over the Vis-NIR range (350-2500 nm) in reflectance mode, and spectra were averaged by the equipment software. The data were interpolated to produce measurements in 1 nm steps, resulting in a diffuse reflectance spectrum of 2151 data points. Absorbance data were stored as log (1/*R*), where *R* was the energy reflected. Five spectra per chop were collected to increase the area of muscle scanned and reduce the sampling error (5), and then averaged. Instrument control and initial spectral manipulation were performed with the Indico™ Pro software package (Analytical Spectral Device-ASD Inc., Boulder, CO, USA).

D. Statistical analysis

Principal component analysis (PCA) was performed to decompose and compress the data matrix and to detect outlier samples. Partial least squares discriminant analysis (PLS2-DA, [8]) was applied on the raw spectra to classify samples into each of the treatments studied (2 and 14 d aged; Non-ME and ME; Non-BC and BC). This model seeks to correlate spectral variations (X) with defined classes (Y), attempting to maximize the covariance between the two types of variables for group differences and ignoring variance within a class. In this type of approach, Y is a dummy matrix with arbitrary numbers assigned to the different classes to be distinguished (2 d aged = 1, 14 d aged = 2; Non-ME = 1, ME = 2; Non-BC = 1, BC = 2). According to this equation, a sample was classified as meat belonging to a specific category (2 or 14 d aged; Non-ME or ME; Non-BC or BC) if the predicted value was within ±0.5 of the dummy value. The accuracy of the models obtained was evaluated using the percentage of correctly classified samples. Cross-validation was performed to validate calibrations and to restrict the number of PLS terms incorporated in the regression, to prevent over-fitting. Spectral data

management and PLS2-DA were performed by means of The Unscrambler® software (version 10.2, Camo, Trondheim, Norway).

III. RESULTS AND DISCUSSION

When the Vis-NIR spectra were collected on the non-BC and non-ME chops aged for 2 and 14 d, the regression model developed using a PLS2-DA and including 6 PLS terms correctly classified 90 and 95% of the pork samples, respectively (Table 1). Similar results were observed when the calibration model was cross-validated, where 10 and 7% of the pork samples aged for 2 and 14 d were misclassified, respectively. Regarding the spectra collection on the Non-ME and ME pork samples aged for 2 d, the discrimination model, including 7 PLS terms, correctly classified 99 and 96% of the samples, respectively. With regard to the validation, 1 and 10% of the pork samples from Non-ME and ME treatments were misclassified, respectively. When the Non-BC and BC samples were aged for 2 days, the PLS2-DA (1 PLS term) could only correctly discriminate 57 and 54% of the pork samples in the calibration, and 57 and 55% in the validation, respectively. This indicates that, by means of the Vis-NIR spectra, it was not possible to distinguish 2 d aged pork samples from BC carcasses from those conventionally chilled, since there would be about 50% chance of classifying a sample as BC or Non-BC.

Table 1 Discrimination results based on raw visible and near infrared spectra

	Correctly classified (%)	
Treatment	Calibration	Cross-Validation
2 d aged/14 d aged	90.0/95.0	90.0/92.8
Non-ME/ME (2 d aged)	99.3/96.3	99.3/89.7
Non-BC/BC (2 d aged)	57.4/54.4	56.8/55.0
Non-ME/ME (14 d aged)	95.2/94.4	93.8/91.6
Non-BC/BC (14 d aged)	52.7/54.1	50.0/52.7

ME: moisture enhancement; BC: blast chilling.

When the quarter pork loins were aged for 14 d, the discrimination results for the Non-ME and ME pork samples were slightly lower than those reported for the 2 d aged ones; discrimination models (7 PLS) correctly classified over 95 and 94% of the Non-ME and 94 and 92% of the ME samples in calibration and cross-validation processes, respectively. When the Non-BC and BC samples were aged for 14 d, about 50% of both pork samples were correctly classified (53 and 50% of the Non-BC and 54 and 53% of the BC pork samples during calibration and cross-validation, respectively; 1 PLS). Hence, Vis-NIRS technology was not successful to discriminate BC pork samples aged for 14 d from those conventionally chilled.

Since the aging and ME processes entail changes in meat related to texture and water content, the successful Vis-NIRS performance in the discrimination of 2 from 14 d aged and Non-ME from ME pork samples could be due to the information related to water content and the structure of the muscle (i.e., the fibre arrangement of the muscle) obtained from the NIR region. Indeed, in Figure 1, differences between the 2 and 14 d aged and the Non-ME and ME (2 d aged) pork samples were observed in the NIR region due to the absorption of O-H bonds of water (970, 1450 and 1940 nm; [9]) and C-H bonds of fat (1215, 1725 and 1765 nm), the latter as a consequence of the inverse relationship between fat and water content in meat. Additionally, differences between the 2 and 14 d aged and between the Non-ME and ME (2 d aged) pork samples were found due to the N-H bonds of protein in the NIR region (2180, 2300, 2352 and 2470 nm) and the redox states of myoglobin in the Vis region (548, 580 and 762 nm; [10]), respectively. On the contrary, the spectra from the Non-BC and BC pork samples aged for 2 d were very similar, only showing minimal differences in the NIR region due to the O-H and C-H bonds absorption, which were not enough for Vis-NIRS technology to successfully distinguish between both samples.

When the average spectra of the pork samples aged for 14 d were plotted (data not shown), differences between the Non-ME and ME samples were observed in the same regions than those found for the 2 d aged pork samples. However, no differences were found between the spectra from the Non-BC and BC samples.

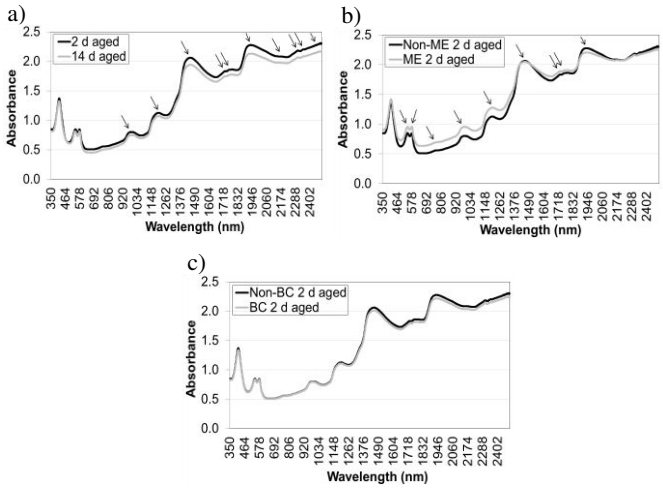

Fig. 1. Average Vis-NIR spectra (n = 148) of a) 2 and 14 d aged pork samples, b) moisture enhanced (ME) and non-ME and c) blast chilled (BC) and non-BC pork samples aged for 2 d.

CONCLUSION

Vis-NIRS technology has the potential to discriminate 2 from 14 d aged and moisture enhanced from non-moisture enhanced pork samples. Conversely, Vis-NIRS technology was not able to distinguish blast chilled pork samples from those conventionally chilled. This technology could hold value for on-line application in processing plants and at retail to authenticate pork of enhanced quality.

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