NEAR INFRARED SPECTROSCOPY ON EARS TO CLASSIFY PIGS BASED ON CARCASS AND FAT COMPOSITION

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Abstract – The aim of this study was to test the ability of near infrared spectroscopy (NIRS) on ears to classify pigs based on carcass and fat composition. After slaughter, the left ears from 195 pigs were collected and their lobe scanned (350-2500 nm) using a portable LabSpec®4 spectrometer equipped with a fibre-optic high intensity contact probe. Two partial least squares discriminant analyses (PLS-DA) based on ear NIR spectra were performed to classify pork carcasses according to low or high: content of adipose tissues (total carcass fat; total and loin subcutaneous fat), content of backfat fatty acid (FA) groups (saturated FA (SFA), monounsaturated FA (MUFA), polyunsaturated FA (PUFA), omega–3 and omega–6 FA), iodine value, and depth of fat and lean at the grade site. PLS-DA1 (the whole population was split down the middle into two groups) correctly classified about 80% of the carcasses from both low or high groups according to total carcass fat, total and loin subcutaneous fat, MUFA and omega–6 FA content, and fat and lean depth, and over 70% based on SFA and PUFA content. When only the extremes of the population were considered (PLS-DA2), a higher percentage of carcasses were correctly classified into both low or high extremes for total carcass fat, total and loin subcutaneous fat, MUFA and omega–6 FA content, and fat and lean depth (about 90%), and for SFA and PUFA content (over 80%). Conversely, in both discrimination analyses less than 70% of the carcasses with low or high omega–3 FA content and iodine value were correctly classified. These preliminary results show NIRS as a fast method to classify pork carcasses based on post-slaughter carcass quality outcomes.

Key Words – Discrimination, fat, NIRS, pigs.

I. INTRODUCTION

Hog carcasses in Canada can be classified into estimated lean yield index categories based on back fat measurement, loin depth and warm carcass weight including head, kidney, leaf lard and feet [1]. The index then forms the basis by which the average price derived through the market is adjusted to provide settlement to producers for each carcass.

Beyond grading for lean yield, knowing adipose tissue content and fatty acid (FA) composition would be of additional value when evaluating carcass merit. Fatty acid composition in part defines the nutritional value of pork, and because pigs are monogastrics, their fat composition is strongly affected by dietary FA [2]. As a consequence, increasing unsaturated FA in the diet results in softer carcass fat, which can lead to processing problems, affecting the quality and shelf life of processed pork products, and their ability to meet fresh pork export specifications [3]. Measuring fat content and FA composition can, however, be time consuming and costly. Quantifying carcass fat requires arduous carcass cut-outs and the comprehensive analysis of FA profiles involves solvent extraction of lipids, FA methylation and gas chromatographic analysis. Measuring the iodine value (IV) of pork fat has been a more rapid way to determine the degree of FA unsaturation, but if the FA composition is known, the IV can be calculated [4].

In contrast to conventional analyses, near infrared spectroscopy (NIRS) is a sensitive, fast, and non-destructive technology [5] that has shown considerable potential for predicting the FA profile of pig subcutaneous fat [6], and for classification of pigs according to breed or feeding regime [7,8]. However, to the best of our knowledge, this technology has not been tested to discriminate pigs based on carcass and fat composition. Azizian et al. [9] also demonstrated that the Fourier Transform

NIR technique can be used to estimate body fat in humans by scanning each subject's upper ear. Therefore, the aim of the present study was to test the potential for NIRS on ears to classify pigs based on carcass and fat composition. This may also have merit for pre-slaughter identification of animals which would benefit from a change in diet.

II. MATERIALS AND METHODS

A. Animals

One hundred and ninety five 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 (Hypor Canada, Regina, SK, Canada). Pigs were fed a typical Canadian commercial diet (Control; 44% wheat, 38% barley, 15% canola meal, 1% soyabean meal; Masterfeeds, Red Deer, AB, Canada), a high-oleic diet (Canola; 10% ExtraPRO® containing 50% full fat canola and 50% extruded field peas; O&T Farms, Ltd., Regina, SK, Canada), or a high linolenic diet (Flaxseed; 10% LinPRO® containing 50% flaxseed and 50% extruded field peas; O&T Farms, Ltd.), for the last three weeks prior to slaughter. In all cases, diets were formulated (Verus Animal Nutrition, Winnipeg, MB, Canada) to meet the nutrient requirement of the pigs [10]. 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 [11].

B. Slaughter processing and ears collection

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. After slaughter, the left ear from every pig was collected and kept at 2 ºC for 2 days until spectra collection.

C. 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 lobe from intact ears at the laboratory. The spectrometer scanned 50 times per reading (~5 s) over the visible and 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. Two spectra per ear were collected and then averaged. Instrument control was performed with the Indico™ Pro software package (Analytical Spectral Device-ASD Inc., Boulder, CO, USA).

D. Carcass and fat composition analyses

Carcass composition was quantified through a full carcass cut-out. From the backfat collected, 5 g was sampled and 50 mg subsamples were freeze-dried, direct methylated with 0.5M sodium methoxide, and FA methyl esters analysed by gas chromatography according to Turner et al. [12]. From the FA analysis, IV was calculated using the following equation [4]: IV = [C16:1] × 0.95 + [C18:1] × 0.86 + [C18:2] × 1.732 + [C18:3] × 2.616 + [C20:1] × 0.785 + [C22:1] × 0.723, where brackets indicate the proportion of a particular FA (% total FA). Depth of fat and lean at the grade site was measured using a Destron PG-100 probe (International Destron Technologies, Markham, ON, Canada).

E. Statistical analysis

Two partial least squares discriminant analyses (PLS-DA, [13]) based on ear NIR spectra were performed to classify carcasses according to low or high: content of adipose tissues (total carcass fat; total and loin subcutaneous fat), content of backfat FA groups (saturated FA (SFA), monounsaturated FA (MUFA), polyunsaturated FA (PUFA), omega–3 and omega–6 FA), iodine value, and depth of fat and lean at the grade site. For the first analysis (PLS-DA1), the whole population was split approximately down the middle into two groups: low or high adipose tissue and FA content, iodine value, and fat and lean depth. For the second analysis (PLS-DA2), only the extremes of the

population based on the content and depth of those carcass quality traits were taken into consideration (about the 70 lowest and 70 highest carcasses within the population range).

PLS-DA 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 (low = 1, high = 2). According to this model, a carcass was classified into a specific category (low or high adipose tissue and FA content, iodine value, and fat and lean depth) 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. Spectral data management and PLS-DA were performed by means of The Unscrambler® software (version 10.2, Camo, Trondheim, Norway).

III. RESULTS AND DISCUSSION

Table 1 summarizes the range, mean, standard deviation and coefficient of variation (CV) of carcass and fat composition from pigs used in this study.

Table 1 Descriptive statistics for carcass and fat composition from pigs (n = 195)

Traits	Range	Mean	SD	CV(%)
Total carcass fat (kg)	6.4-18.1	11.5	2.39	20.8
Total subcutaneous fat (kg)	4.7-14.8	8.9	2.07	23.3
Loin subcutaneous fat (kg)	2.0-7.5	4.1	1.09	26.8
Fat depth (mm)	11.0-43.5	23.5	7.59	32.3
Lean depth (mm)	26.0-77.0	58.2	8.69	14.9
SFA (mg/g backfat)	381.1-575.4	494.6	38.02	7.7
MUFA (mg/g backfat)	328.4-480.7	401.3	28.18	7.0
PUFA (mg/g backfat)	73.3-156.2	107.7	18.67	17.3
Omega–3 (mg/g backfat)	7.5-42.8	20.2	9.08	44.9
Omega–6 (mg/g backfat)	64.6-121.0	87.5	12.04	13.8
Iodine value	52.5-70.9	60.6	3.55	5.9

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; SD: standard deviation; CV: coefficient of variation.

When all the population was taken into consideration (PLS-DA1, Table 2), ≥ 80% of the carcasses were correctly classified by NIRS according to low or high total carcass fat, total and loin subcutaneous fat, MUFA and omega–6 FA content, and fat and lean depth, and over 70% based on SFA and PUFA content. When only the extremes of the population were considered (PLS-DA2, Table 2), a higher percentage of carcasses were correctly classified by NIRS into both low or high extremes for total carcass fat, total and loin subcutaneous fat, MUFA and omega–6 FA content, and fat and lean depth (≥ 90%), and for SFA and PUFA content (over 80%).

Table 2 Discrimination results based on near infrared spectra collected on pig ears

	Correctly classified (Low/High, %)	
Traits	PLS-DA1	PLS-DA2
Total carcass fat	83.0/77.5	89.4/93.0
Total subcutaneous fat	86.4/88.2	98.6/92.9
Loin subcutaneous fat	82.2/79.5	89.2/93.2
Fat depth	77.6/81.2	95.3/93.8
Lean depth	82.6/90.2	92.1/94.7
SFA	71.1/86.7	79.5/82.6
MUFA	86.7/84.5	95.6/92.3
PUFA	87.4/76.1	88.9/82.8
Omega–3	43.3/56.1	58.5/43.5
Omega–6	88.7/80.6	94.1/93.4
Iodine value	37.2/72.3	71.0/31.3

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; PLS-DA: partial least squares discriminant analysis.

Regarding the omega–3 FA, a better NIRS discrimination based on the low or high content of this FA group (~50% of the carcasses were correctly classified) could have been expected, since a high variability in the content of the omega–3 FA (CV = 44.9%, Table 1) was observed in this study. As a consequence, it was apparent the lack of NIRS discrimination based on low or high omega-3 FA influenced the ability to discriminate between groups with low or high IV. Additionally, a low correlation between NIR spectra collected in ears and the content of specific FA in backfat used to calculate IV could be another reason why NIRS was unsuccessful to discriminate carcasses based on this value. Hence, additional analyses to understand potential issues with NIRS

discrimination based on omega–3 FA content and IV are still required.

IV. CONCLUSION

These preliminary results show NIRS as a fast method to classify pork carcasses based on post-slaughter carcass quality outcomes. Use of NIRS in live animals could lead to multiple potential applications, such as dietary manipulation to improve carcass value, sorting pigs for different markets, or breeding selection for carcass characteristics based on real-time values.

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