POTENTIAL OF NEAR INFRARED SPECTROSCOPY TO ESTIMATE MEAT QUALITY ATTRIBUTES FROM CATTLE FED SUNFLOWER OR FLAXSEED

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Abstract – The aim of this study was to test the ability of near infrared reflectance spectroscopy (NIRS) to predict meat quality attributes from cattle fed sunflower or flaxseed. At 24 h post mortem, the left carcass sides from 63 steers were split between the 12th and 13th ribs and objective colour measurements and pH were recorded on *M. longissimus thoracis* (LT). Afterwards, a 2.5 cm steak from the posterior side of each LT was ground and scanned over a NIR spectral range from 400 to 2498 nm. Adjacent steaks from each LT were aged for 16 days and used to perform shear force and proximate analyses. NIRS calibrations, tested by cross-validation, showed high predictability for crude protein, moisture and fat content with R^2 and root mean square error of cross-validation (RMSECV, % fresh matter) of 0.86 (0.47), 0.96 (0.58) and 0.86 (1.10), respectively. The ability of NIRS to predict meat quality traits was more limited (R^2 from 0.71 to 0.84), probably because of collecting NIR spectra on ground samples and the time elapsed between the reference and NIR analyses. Hence, further research applying NIRS to estimate meat quality attributes will require the use on-line of a fibre-optic probe on intact samples.

Key Words - NIRS, chemical composition, beef quality.

I. INTRODUCTION

Today's health conscious consumers are willing to pay higher prices for value-added beef products with enhanced levels of fatty acids beneficial to human health such as omega-3, rumenic and vaccenic acids [1, 2].

The amount and proportion of fatty acids (FA) in intramuscular fat are key factors that influence beef quality [3]. Groups of fat cells containing solidified highly saturated fat with a high melting point appear whiter than fat with less saturation and a lower melting point, such that fat appearance is an aspect of lean meat quality affected by FA composition. Additionally, the ability of unsaturated FA to rapidly oxidize, especially those containing more than two double bonds, increases the rate of rancidity development and colour deterioration of meat as well as the flavour development during cooking [3]. On the other hand, individual FA have very different melting points that affect the firmness or softness of the fat in meat, especially the subcutaneous and intermuscular fat, but also the intramuscular fat, which, in turn may affect other characteristics of meat such as tenderness.

Meat quality attributes are currently measured by means of relatively slow, destructive and often expensive methods. Nevertheless, characteristics such as colour and tenderness are important criteria that affect consumers' beef purchase decisions. Hence, there is an urgent need to find a fast and efficient alternative method to estimate these criteria, particularly in meat with enhanced levels of FA with potential health effects.

NIRS technology is a rapid and non-destructive method, neither requiring reagents nor producing waste, which provides information about the molecular bonds of organic compounds and tissue ultra-structure in a scanned sample [4]. NIRS has been successfully used to predict the chemical composition of meat, but the results for meat quality attributes are less conclusive [5]. Therefore, the aim of this study was to test the ability of NIR spectroscopy as an early predictor of beef quality traits from steers, particularly those enriched with linoleic and linolenic acids biohydrogenation intermediates.

II. MATERIALS AND METHODS

A. Animals and diets

Sixty-four yearling steers (533 ± 44.0 kg liveweight) were fed at the Lacombe Research Centre, Alberta, Canada, and randomly assigned to one of four diets (15% flax + 70% red clover silage, 15% flax + 70% grass hay, 15% sunflower seed + 70% red clover silage, 15% sunflower seed + 70% grass hay) with an additional 15% made of ground barley, straw and vitamin/mineral supplement to balance estimated rates of gain between oilseed diets (all dry matter basis). The steers were part of an ongoing study evaluating the effects of these diets on enrichment of healthy FA in beef. Steers had *ad libitum* access to feed and water with 8 animals to a pen, two pens per diet and slaughtered at an average of 205 days on test. During the study one animal from the flaxseed and grass hay treatment was withdrawn due to lameness.

B. Slaughter and sample collection

Animals were slaughtered at the Lacombe Research Centre. At 24 h postmortem, the left carcass sides were split between the 12th and 13th ribs and objective colour measurements and pH were recorded. The left *M. longissimus thoracis* (LT) from each animal was removed from the carcass and a 2.5 cm steak from the posterior end removed for collection of NIR spectra. The remainder of the muscle was trimmed of all extraneous fat, vacuum packaged and held at 2 °C until 16 days after slaughter. Following the ageing period, 2.5 cm steaks were removed from each LT for instrumental texture and proximate analyses.

C. Meat quality analyses

At 24 h postmortem, following 20 min of blooming, meat colour was measured as CIE L* (brightness), a* (red-green axis) and b* (yellow-blue axis) [6] with a portable Minolta colorimeter CR-300 with Spectra QC-300 Software (Minolta Canada Inc., Mississauga, ON), and pH was recorded using a Hanna HI99163 pH meter equipped with a Hanna Smart electrode FC232 for meat (Hanna Instruments, Laval QC). Previous to shear force analysis, raw aged steak was grilled (Garland Grill ED30B [Condon Barr Food Equipment Ltd., Edmonton, AB]) to an internal temperature of 35.5 ºC controlled by a temperature probe inserted into the mid-point of the steak (Hewlett Packard HP34970A Data Logger [Hewlett Packard Co., Boise ID]), turned and cooked to a final temperature of 71 ºC. Upon removal from the grill, each steak was placed into a polyethylene bag, sealed and immediately immersed in an ice/water bath to prevent further cooking. Steaks were then transferred to a 2 °C cooler and allowed to stand for a 24-hour period. On removal from the bag, six cores, 19 mm in diameter, were removed parallel to the fibre grain. Peak shear force was determined on each core perpendicular to the fibre grain by means of a TA-XT Plus Texture Analyzer equipped with a 30 kg load cell and a Warner-Bratzler shear head running at a crosshead speed of 200 mm/min and using Texture Exponent 32 Software (Texture Technologies Corp., Hamilton, MA). Shear force was recorded as the average of all six cores.

Proximate analyses were performed on LT trimmed of all external connective tissue and ground (Robot Coupe Blixer BX3 [Robot Coupe USA Inc., Ridgeland MS]). The grind was analyzed for protein [7] and moisture and fat [8] using CEM rapid analyzer systems (Sprint Protein Analyzer Model 558000, Smart Turbo Moisture Analyzer Model 907990, and Smart Trac Fat Analyzer Model 907955 [CEM Corporation, Matthews, NC]).

D. Spectra collection

An aliquot of ground meat was placed in the ring cups of the NIRS machine with the help of a modified syringe in order to avoid air bubbles, and the cup was backed with thin black foam. Subsequently, each meat sample was scanned 32 times over the range (400–2498 nm) using a NIRSystems Versatile Agri Analyzer (SY-3665-II Model 6500, FOSS, Sweden), and spectra averaged by the equipment software. Two meat samples per animal were scanned using two different cells. The two reflectance spectra were visually examined for consistency and then averaged, with the mean spectrum being used to predict the meat quality parameters. The spectrometer interpolated the data to produce

measurements in 2 nm steps, resulting in a diffuse reflectance spectrum of 1050 data points. Absorbance data were stored as log (1/*R*), where *R* is the reflectance. Instrument control and initial spectral manipulation were performed with WinISI II software (v1.04a; Infrasoft International, Port Matilda, MD).

E. Data analysis

Calibration and validation were performed using The Unscrambler program (version 8.5.0, Camo, Trondheim, Norway). Two passes of elimination of outliers (H and T) were allowed. Partial least square regression type I (PLSR1) was used for predicting quality attributes using NIR spectra as independent variables. Internal full cross-validation was performed in order to avoid over-fitting the PLSR equations. Thus, the optimal number of factors in each equation was determined as the number of factors after which the standard error of cross-validation no longer decreased. The accuracy of prediction was evaluated in terms of coefficient of determination (R^2) and root mean square error of cross-validation (RMSECV).

III. RESULTS AND DISCUSSION

Descriptive statistics for chemical composition and quality attributes are summarized in Table 1. The values found were similar to those indicated by Juárez et al. [9] in omega-3 enhanced beef.

In relation to objective colour measurements, although the variance explained by the model was higher than 70% for L*, a* and b* values, RMSECV were still high (1.27, 1.45 and 0.77, respectively) as compared to SD, resulting in RPD below 2. Since the NIRS spectral range included the visible region, more accurate predictions could have been expected. Nevertheless, the time elapsed between the objective colour measurements and NIRS analysis (approx. 5 h) could have reduced the reliability of these NIRS predictions. Indeed, during the time elapsed, the proportions of pigments in meat might have been modified, thus giving rise to changes in colour.

The statistical summary of calibration and prediction by cross-validation is presented in Table 2. Accurate NIRS predictions were found for crude protein (R^2 = 0.86; RMSECV = 0.47% fresh matter, FM), moisture (R^2 = 0.96; RMSECV = 0.58%) and fat content (R^2 = 0.86; RMSECV = 1.10% FM), showing RPD (SD /RMSECV) of 2.10, 2.17 and 1.97, respectively, suitable for screening purposes [10].

Table 1 Descriptive statistics for chemical composition and quality attributes of beef samples (n = 63).

	Range	Mean	SD	CV (%)
Chemical components				
Crude protein ($g \cdot 100g^{-1}$ FM)	18.2-22.9	20.3	0.97	4.8
Moisture ($g \cdot 100g^{-1}$)	71.0-75.6	73.2	1.23	1.7
Fat ($g \cdot 100g^{-1}$ FM)	1.7-11.2	4.3	2.14	49.9
Quality attributes				
CIE colour L*	29.7-39.9	34.2	2.23	6.5
CIE colour a*	15.0-23.9	19.9	1.83	9.2
CIE colour b*	5.4-10.9	8.1	1.22	15.1
pH 24 h	5.4-5.9	5.6	0.10	1.7
Shear force 16 d (kg)	3.4-9.1	5.2	1.19	23.1

FM: fresh matter; SD: standard deviation; CV: coefficient of variation.

The ability of NIRS to predict the pH value at 24 h was low (R^2 = 0.73; RMSECV = 0.09; RPD = 1.14), probably due to the sample preparation (intact for reference method vs. ground for NIR spectra). Prieto et al. [11] indicated that scanning the samples after grinding could reduce the precision of pH predictions due to a lack of information about the muscle structure i.e. light scattering properties in intact muscle tissue.

Table 2 Prediction of chemical composition and quality attributes of beef samples using NIR spectra*

	p	R^2	RMSEC	RMSECV	RPD
Chemical components					
Crude protein	8	0.86	0.32	0.47	2.10
Moisture	8	0.96	0.35	0.58	2.17
Fat	7	0.86	0.84	1.10	1.97
Quality attributes					
CIE colour L*	5	0.80	1.02	1.27	1.69
CIE colour a*	7	0.71	1.11	1.45	1.25
CIE colour b*	6	0.77	0.62	0.77	1.56
pH 24 h	5	0.73	0.05	0.09	1.14
Shear force 16 d	8	0.84	0.41	0.59	1.72

*: after eliminating two outliers; p: number of PLS terms utilized in the calibration equation, R^2: coefficient of determination of calibration, RMSEC: root mean square error of calibration; RMSECV: root mean square error of cross-validation; RPD: ratio performance deviation.

Prediction of shear force at 16 days aging showed high R^2 (0.84) and relatively low RMSECV (0.59 kg), albeit, the RPD was not high enough to consider the equation suitable for screening purposes. Again, this could be due to the sample treatment before spectra collection, since the structure of the muscle and the fibre arrangements are severely altered during grinding. Nevertheless, the 84% of variance explained by the model shows potential of NIRS as an early predictor of shear force after aging, since the prediction would likely be more accurate when collecting spectra on intact samples.

The high predictability of the main chemical components and limited predictability for meat quality parameters in this study are in agreement with those indicated by previous beef studies when sample preparation was performed before NIR spectra collection, as reviewed in Prieto *et al.* [5].

IV. CONCLUSION

NIRS accurately predicts the chemical composition of beef from steers fed diets with a high content of linoleic and linolenic acids. The prediction ability for meat quality attributes was limited, probably because of collecting NIR spectra on ground samples and the time elapsed between the reference and NIRS analyses. Hence, further research applying NIRS to estimate meat quality attributes will require the use on-line of a fibre-optic probe on intact samples.

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