Meat Science 98 (2014) 279–288

Contents lists available at ScienceDirect

Meat Science

journal homepage: www.elsevier.com/locate/meatsci

Use of near infrared spectroscopy for estimating meat chemical composition, quality traits and fatty acid content from cattle fed sunflower or flaxseed

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ARTICLE INFO

Article history:
Received 5 June 2013
Received in revised form 4 April 2014
Accepted 3 June 2014
Available online 11 June 2014

Keywords:
NIRS
Meat quality
Fatty acid
Sunflower
Flaxseed

ABSTRACT

This study tested the ability of near infrared reflectance spectroscopy (NIRS) to predict meat chemical composition, quality traits and fatty acid (FA) composition from 63 steers fed sunflower or flaxseed in combination with high forage diets. NIRS calibrations, tested by cross-validation, were successful for predicting crude protein, moisture and fat content with coefficients of determination (R^2) (RMSECV, g · 100 g^{-1} wet matter) of 0.85 (0.48), 0.90 (0.60) and 0.86 (1.08), respectively, but were not reliable for meat quality attributes. This technology accurately predicted saturated, monounsaturated and branched FA and conjugated linoleic acid content (R^2: 0.83–0.97; RMSECV: 0.04–1.15 mg · g^{-1} tissue) and might be suitable for screening purposes in meat based on the content of FAs beneficial to human health such as rumenic and vaccenic acids. Further research applying NIRS to estimate meat quality attributes will require the use on-line of a fibre-optic probe on intact samples.

1. Introduction

Today's health conscious consumers are willing to pay higher prices for value-added beef products with enhanced levels of fatty acids (FAs) beneficial to human health (Benjamin & Spener, 2009; Field, Blewett, Proctor, & Vine, 2009). Adding sunflower seeds or flaxseed to cattle diets presents opportunities for producing beef products with enhanced levels of FAs with potential health benefits such as conjugated linoleic acid (CLA, e.g. rumenic acid, *cis*(*c*)9,*trans*(*t*)11–18:2) and vaccenic acid (*t*11–18:1), as a result of bacterial biohydrogenation of polyunsaturated fatty acids (PUFAs) in the rumen (Basarab et al., 2007; Nassu et al., 2011).

The amount and proportion of FAs in intramuscular fat are key factors that influence beef quality (Wood et al., 2003). On the one hand, intramuscular fat with a high proportion of saturated fatty acids (SFAs) can affect meat appearance since 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, but diets high in SFAs are associated with increased levels of cardiovascular diseases (Hu & Willett, 2002). On the other hand, the susceptibility of unsaturated FAs to rapid oxidation, 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 and, therefore, the shelf life of the meat (Wood et al., 2003). Moreover, individual FAs have very different melting points, thus changes in proportions of FAs affect the firmness or softness of the fat, especially subcutaneous and intermuscular, but also the intramuscular fat, which, in turn may affect other characteristics of meat such as tenderness.

Both FA composition and 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 and overall satisfaction. Many countries are developing instrumental grading systems with automatic data capture (e.g. Canada, Europe). As these systems for data capture and flow mature, opportunities to measure quality characteristics at line speed will become extremely valuable. Hence, an urgent need has developed to find a fast and efficient alternative method to estimate these criteria, particularly in meat with enhanced levels of FAs with potential health effects.

Near infrared reflectance spectroscopy (NIRS) is a rapid, objective 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 (Downey & Hildrum, 2004), making it an ideal tool to study characteristics of meat. Indeed, NIRS has been successfully used to predict the chemical composition of meat, but the results for meat quality attributes have been inconclusive (Prieto, Roehe, Lavín, Batten, & Andrés, 2009a). The

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http://dx.doi.org/10.1016/j.meatsci.2014.06.005
0309-1740/

ability of NIRS to predict FA content in meat has also been tested; predictability being reliable for FA groups but less so for individual FAs (Prieto et al., 2011; Realini, Duckett, & Windham, 2004; Sierra et al., 2008). Therefore, the aim of this study was to test the ability of NIR spectroscopy as an early predictor of meat chemical composition, quality traits and some indicators or groups of FAs from cattle fed sunflower or flaxseed.

2. Material and methods

2.1. Animals and diets

Sixty-four yearling British × Continental crossbred steers with final pre-slaughter body weights averaging 533 ± 44.0 kg were cared for according to Canadian Council on Animal Care guidelines (CCAC, 1993) and fed at the Lacombe Research Centre (Alberta, Canada). Steers were randomly assigned to one of four diets with a 70:30 forage:concentrate ratio (dry matter basis). The forage was either grass hay or red clover silage, the concentrate contained either flaxseed or sunflower seed added to provide 5.4% oil to the diet, and the remainder of the concentrate included barley and a supplement providing vitamin/mineral to meet or exceed requirements (NRC, 2000). Steers had *ad libitum* access to feed and water with 8 animals per pen, two pens per diet, and were 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.

2.2. Slaughter and sample collection

Animals were slaughtered at the Lacombe Research Centre federally inspected abattoir. At 24 h postmortem, the left carcass sides were knife-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 5.0 cm steak from the posterior end was ground for collection of NIR spectra and stored at −80 °C for subsequent FA analysis. The remainder of the muscle was trimmed of all extraneous fat and individual 2.5 cm steaks were cut, vacuum packaged and aged at 2 °C until 16 days after slaughter. Following the ageing period, steaks were subjected to instrumental texture and proximate analyses.

2.3. Proximate and meat quality analyses

At 24 h postmortem, following 20 min of exposure to atmospheric oxygen, meat colour was measured as CIE L^* (brightness), a^* (red–green axis) and b^* (yellow–blue axis) (CIE, 1978) with a portable Minolta colorimeter CR-300 with Spectra QC-300 Software (Minolta Canada Inc., Mississauga, ON, Canada), and pH was recorded using a Hanna HI99163 pH meter equipped with a Hanna Smart electrode FC232 for meat (Hanna Instruments, Laval QC, Canada). Prior to shear force measurement, raw aged steaks were grilled (Garland Grill ED30B; Condon Barr Food Equipment Ltd., Edmonton, AB, Canada) to an internal temperature of 35.5 °C monitored using a temperature probe inserted into the mid-point of the steak (Hewlett Packard HP34970A Data Logger; Hewlett Packard Co., Boise, ID, USA), and turned and cooked to a final temperature of 71 °C. 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 h 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 (WB) shear head running at a crosshead speed of 200 mm · min^{-1} and using Texture Exponent 32 Software (Texture Technologies Corp., Hamilton, MA, USA). WB 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 Blixir BX3; Robot Coupe USA Inc., Ridgeland, MS, USA). The grind was analysed for protein (Moser & Herman, 2011), moisture and fat content (Leffler et al., 2008) using CEM rapid analyser systems (Sprint Protein Analyzer Model 558000, Smart Turbo Moisture Analyzer Model 907990, and Smart Trac Fat Analyzer Model 907955; CEM Corporation, Matthews, NC, USA).

2.4. Fatty acid analysis

From ground meat collected, 50 g were sampled and frozen until used for FA analysis according to Mapiye et al. (2012).

2.5. 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 (Fig. 1). 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) benchtop equipment, and spectra averaged by the equipment software. Two meat samples per animal were scanned using two different cells, increasing the area of muscle scanned and reducing the sampling error (Downey & Hildrum, 2004). The two reflectance spectra were visually examined for consistency and then averaged, with the mean spectrum being used to predict meat chemical composition, quality traits and FA composition. 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).

2.6. Data analysis

Calibration and validation of the NIRS data were performed using The Unscrambler® program (version 10.2, Camo, Trondheim, Norway). Two passes of elimination of outliers (H and T) were allowed, the number of outliers removed from the population being 2. Spectral data (n = 61) were subjected to multiplicative scatter correction (MSC; Dhanoa, Lister, Sanderson, & Barnes, 1994) and Standard Normal Variate and Detrend (SNV-D; Dhanoa, Lister, & Barnes, 1995) to reduce multicolinearity and the confounding effects of baseline shift and curvature on spectra arising from scattering effects due to physical effects. First or second-order derivatives, based on the Savitzky–Golay procedure (Naes, Isaksson, Fearn, & Davies, 2002), were applied to the spectra to heighten the signals related to the organic compounds of the meat samples (Davies & Grant, 1987). Partial least square regression type I (PLSR1) was used to predict chemical composition, quality attributes and FA content using NIR spectra as independent variables. Internal full cross-validation (leave one-out) was performed to avoid overfitting 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 the coefficient of determination (R^2) and root mean square error of cross-validation (RMSECV).

3. Results and discussion

3.1. Prediction of chemical composition and meat quality attributes

Table 1 summarises the ranges, means, standard deviations (SD) and coefficients of variation (CV) of meat chemical composition and quality characteristics. The values found were similar to those indicated by Juárez et al. (2011) and Mapiye et al. (2013) in omega-3 enhanced beef. The CV was lowest for water (1.7%) and highest for intramuscular