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Breeds and muscle types modulate performance of near-infrared reflectance spectroscopy to predict the fatty acid composition of bovine meat

B.P. Mourot [a,b], D. Gruffat [a,*], D. Durand [a], G. Chesneau [b], G. Mairesse [b], D. Andueza [a]

[a] National Institute for Agronomic Research (INRA), UMR 1213 Herbivores, Research Centre of Clermont-Ferrand/Theix, F-63122 Saint-Genès-Champanelle, France
[b] Valorex, La Messayais, 35210 Combourtillé, France

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ABSTRACT

This study aimsto assess near-infrared reflectance spectroscopy feasibility for predicting beef fatty acid (FA) composition. Experimental scheme included four breeds (Angus, Blond d'Aquitaine, Charolais, Limousin) and three muscles, *Longissimus thoracis* (LT), *Rectus abdominis* (RA), *Semitendinosus* (ST). The results showed that 1) increasing FA content variability with several breeds increased calibration model reliability (R^2CV>0.86) for the major individual and groups of FA unless polyunsaturated FAs, 2) *Longissimus thoracis* FAs were better predicted than RA FAs while no ST FAs were correctly predicted (R^2CV<0.71). This difference could be explained by FA content, FA variability or specific muscle physico-chemical characteristics.

1. Introduction

The nutritional quality of beef, through its fatty acid (FA) composition, is of major importance for the beef industry. There has been a concurrent demand from human nutritionists and dieticians, and also from consumers to know the values of the nutritional composition of beef. The meat industry needs to control product quality quickly and early on the cattle slaughter process in order for consumers to be aware of the quality of food available. Gas liquid chromatography (GLC), the reference method currently used to determine this composition, is time-consuming, costly and generates chemical waste. Near-Infrared Reflectance Spectroscopy (NIRS) has been shown to provide fast, non-destructive, and cost-effective measurements. The increasing use of NIRS in food analysis has spread to all food industries: meat, dairy products, grains and seeds and fruit and vegetables (Bertrand & Dufour, 2006).

NIRS technology is used in beef to predict several parameters with varying degrees of precision: 1) proximate chemical composition of samples, and nutritional composition (Prieto et al., 2011), 2) technological parameters (De Marchi, Penasa, Cecchinato, & Bittante, 2013), 3) sensory attributes (Ripoll, Albertí, Panea, Olleta, & Sañudo, 2008) and 4) the authentication of the product (Morsy & Sun, 2013).

Concerning the FA predictions, NIRS was efficient in estimating meat FA composition especially individual saturated (SFA) and monounsaturated (MUFA) FAs (Prieto et al., 2014). Despite the considerable nutritional interest of polyunsaturated FAs (PUFA), they are not estimated with the same efficiency according to the species studied. For instance, in pork loin (González-Martín, González-Pérez, Alvarez-García, & González-Cabrera, 2005), broiler breast (Zhou, Wu, Li, Wang, & Zhang, 2012) or lamb meat (Guy, Prache, Thomas, Bauchart, & Andueza, 2011), NIRS was used to efficiently predict the most important individual and total PUFAs. In contrast, when PUFAs are present in low amounts and/or with low variability like in beef, these FAs are poorly predicted (Sierra et al., 2008; Weeranantanaphan, Downey, Allen, & Sun, 2011). These poorer results were obtained with one or two breeds and a uniform diet per study but both factors, breeds and diets (Bureš, Bartoň, Zahrádková, Teslík, & Krejčová, 2006; Scollan et al., 2001) had an influence on the FA muscle composition.

Our hypothesis is that the use of various breeds fed with different diets could provide a wider range of fat content and fatty acid composition which would allow for a better statistical basis for prediction of beef muscle FA composition by NIRS.

In general, only *Longissimus thoracis* (LT) muscle is used in NIRS prediction of muscle FA composition. However, this muscle is not the easiest to access on the carcass. From an industrial point of view, it should be more advantageous to obtain FA calibration models from other muscles. Moreover, muscle is another parameter of variability in FA composition (Purchas & Zou, 2008) and FA calibration models could differ from those obtained using LT.

* Corresponding author at: National Institute for Agronomic Research (INRA), UMR 1213 Herbivores, Site of Theix, F-63122 Saint-Genès-Champanelle, France. Tel.: +33 473624256; fax: +33 473624639.
E-mail address: dominique.gruffat@clermont.inra.fr (D. Gruffat).

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Therefore, the objectives of this study were to evaluate the potential of NIRS to predict the FA composition of LT muscle using calibration models produced from meat samples of several bovine breeds (Angus, Blond d'Aquitaine, Charolais, Limousin) and diets (barley straw and concentrate with or without lipid supplementations and with or without antioxidant supplementations), and to compare NIRS calibrations for FAs from several muscles (LT, *Semitendinosus* (ST) and *Rectus abdominis* (RA)) of Charolais bulls.

2. Material and methods

2.1. Animals and meat samples

The muscle samples came from two different experiments in order to gather 143 bulls between 15 and 18 months old (67 Charolais, 26 Angus, 25 Blond d'Aquitaine, 25 Limousin). All the details on the experimental design and diets for the experiment on Charolais bulls were previously described by Eugène et al. (2011). All the details on the experimental design and diets for the other experiment on Angus, Blond d'Aquitaine and Limousin bulls were previously described by Gruffat et al. (2013).

At the end of the rearing period, the bulls were slaughtered in the experimental abattoir of INRA (Saint-Genès-Champanelle, France). Samples (~100 g) of the LT muscle of the 4 breeds were collected at 24 h *post mortem* from the 10th thoracic rib of the ribbed carcass. Muscle samples were cut into small cubes (1 cm^3), immediately frozen in liquid nitrogen and stored at −80 °C. Just before analysis, the frozen samples of the LT muscle were ground into fine and homogeneous powders in liquid nitrogen with a mixer mill (Retch MM 301,Hann Germany).

In addition to the LT muscle of the 67 Charolais previously described, *Rectus abdominis* (RA) and *Semintendinosus* (ST) muscles of the same animals were sampled as previously described.

2.2. Measurements

2.2.1. Fatty acid analysis

Total lipids were extracted from 6 g of meat powder according to the method of Folch, Lees, and Sloane Stanley (1957) by mixing the LT muscle powder with a 2/1 chloroform/methanol mixture (vol/vol) and quantified by gravimetry. Fatty acid extraction and transmethylation into fatty acid methyl esters (FAME) were subsequently performed according to the methods of Bauchart, Gladine, Gruffat, Leloutre, and Durand (2005). Fatty acid methyl ester analysis was performed with GLC using a Peri 2100-chromatography system (Perichrom Society, Saulx-les-Chartreux, France) fitted with a CP-Sil 88 glass capillary column (Varian, Palo Alto, CA; length = 100 m; diam. = 0.25 mm). The carrier gas was H2 and the oven and flame ionization detector temperatures described by Scislowski, Durand, Gruffat, and Bauchart (2004) were used. Total FAs were quantified using C19:0 as an internal standard. The identification of each individual FAME and the calculation of the response coefficients for each individual FAME were performed using the quantitative mix C4-C24 FAME (Supelco, Bellafonte, PA).

2.2.2. Reflectance spectrum of muscles in the visible and NIR wavelength

The reflectance spectrum of muscles in the visible and near-infrared wavelength (400–2500 nm) was measured on ground samples. They were firstly thawed at room temperature for 1 h. Then portions weighing about 3 g were scanned in duplicate in the reflectance mode in a NIRS 6500 scanning monochromator (NIRSystems, Silver Spring, MD, USA) using ISI software, version 3.01, from Infrasoft International (Infrasoft International, South Atherton St. State College, PA 16801, USA) equipped with an autocup module. Muscle samples were scanned in a circular cup (diameter 50 mm, depth 10 mm) (Part number IH – 0307, NIRSystems, Infrasoft International, South Atherton St. State College, PA 16801, USA), compressed and sealed with a disposable paper-backed wrap. Reflectance data were recorded at 2 nm intervals and stored as log (1/reflectance).

2.3. Data analysis

Calibrations were performed using WinISI II version 1.60 (Infra-soft International, South Atherton St. State College, PA 16801, USA) on FA expressed in mg/100 g of fresh meat (except total lipids and total FAs which were expressed in g/100 g of fresh tissue). NIR calibration equations were obtained by modified partial least squares regression using the range 400–2500 nm or 700–2500 nm. All the details for the construction of NIR calibration equations regarding scatter correction, mathematical pretreatment, identification of outlier samples and cross validation procedure were described by Guy et al. (2011). The best combination of wavelength range, scattering correction and mathematical pre-treatment was selected for each constituent on the basis of the lowest standard error of cross-validation (SECV). The statistics used to evaluate the calibration models included SECV, coefficient of determination for cross-validation (R^2CV) and the residual predictive deviation (RPD), defined as the ratio of standard deviation of reference data to the SECV (Williams, 2001).

To evaluate the differences in FA composition of the different muscles, the data were submitted to an analysis of variance, and the means (when different) were compared using the Tukey test, using aov() and TukeyHSD() function of the R stats package (R Foundation for Statistical Computing, Vienna, Austria).

3. Results

3.1. Feasibility of NIRS to predict the FA composition of LT samples from several bovine breeds

3.1.1. Fatty acid composition measured using the GLC reference method

The ranges, means and coefficients of variation (CV) of LT intramuscular lipid FA concentration observed in the database are presented in Table 1. Mean SFA and MUFA contents were similar (628.4 mg/100 g and 575.2 mg/100 g respectively), whereas mean PUFA contents were 3 times lower (198.3 mg/100 g). Oleic acid (18:1 Δ9 *cis*) and palmitic acid (16:0) were on average the most abundant FAs (396.4 mg/100 g of fresh muscle, ranging from 41.7 to 1427 mg/100 g and 322.9 mg/100 g of fresh muscle, ranging from 50.6 to 1056.3 mg/100 g respectively). Stearic acid (18:0) averaged 232.8 mg/100 g, ranging from 41.3 to 631.1 mg/100 g. Another important individual FA was linoleic acid (18:2 n-6) with a mean of 107.5 mg/100 g of fresh tissue muscle. All PUFAs (except *trans* PUFA n-6 and CLA) had a lower CV (under 40%) than individual and total SFAs and MUFAs.

3.1.2. NIRS predictions

The average absorbance of the VIS/NIR spectra for ground LT muscle from the four bovine breeds is presented in Fig. 1(A). The Limousin and Blond d'Aquitaine samples had identical absorbance, the higher absorbance values being generally observed from 1450 nm to 2500 nm. The Charolais and Angus samples followed the same absorbance evolution with lower absorbance.

The calibration statistics for the intramuscular FA profile obtained in ground muscle samples are given in Table 2. The prediction equations for total lipids showed R^2CV of 0.95 and the highest RPD values of all constituents (4.6). R^2CV and RPD values obtained for total FAs, linear and total SFAs were the same (0.93 and 3.8, respectively). Lower values were found for branched SFAs, with $R^2CV = 0.84$. Statistics of R^2CV and RPD values obtained for total *cis* and total MUFAs ranged from 0.92 to 0.93 and from 3.6 to 3.7, respectively.

Statistics obtained for some major individual SFAs, such as 14:0, 16:0 and 18:0 had an R^2CV value of 0.93, 0.94 and 0.89 and an RPD value of 3.8, 3.9 and 3.0, respectively. Results obtained for 12:0, 17:0 and 20:0 were lower, with R^2CV and RPD values ranging from 0.82 to 0.84 and