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USE OF NEAR INFRARED TECHNOLOGY TO PREDICT FATTY ACID GROUPS IN COMMERCIAL GROUND MEAT PRODUCTS

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SUMMARY

Near infrared transmittance (NIT, 850 to 1048 nm) spectroscopy was used to predict groups of fatty acids (FA), namely saturated FA (SFA), monounsaturated FA (MUFA) and polyunsaturated FA (PUFA), in commercial ground meat samples aiming to develope a fast and reliable method for their determination in support of label declaration by the new EC Regulation 1169/2011. Dataset was built using 81 samples of commercial ground meat from different species: beef, pork, chicken and turkey. In some samples, meat was mixtured with different ingredients such as bread, cheese, spices and additives. Samples were first analysed by NIT instrument for spectral information and reference FA values were obtained by gas chromatographic analysis. Prediction models for SFA, MUFA and PUFA expressed on total FA exhibited coefficients of determination of calibration of 0.822, 0.367 and 0.780 on intact samples, and 0.879, 0.726 and 0.908 on minced samples, respectively. Good results were also obtained when FA groups were expressed as g/100g of fresh meat: the coefficient of determination of calibration increased to values larger than 0.915. Moreover, comparing the slightly lower coefficient of determination in cross-validation of intact compared with minced meat suggested that equations developed for minced samples were more accurate than those built for intact products. Results highlighted the effectiveness of NIT spectroscopy to predict the major FA groups in commercial meat products.

Key-words: fatty acid, ground meat, infrared spectroscopy

INTRODUCTION

The nutritional quality of meat is one of the most important aspects for global meat industry and depends on the type of meat, the cut, additives and recipe (Weeranantanaphan et al., 2011; Wyness et al., 2011). Meat and meat products are important sources of a wide range of nutrients such as proteins, fat, vitamins and minerals but their composition varies widely according to the category (Cosgrove et al., 2005; Prynne et al., 2009). Fatty acids (FA) have an important role in meat quality profile thanks to their nutritional value and sensory attributes. Moreover, in the last years many studies have investigated the relationship of red meat consumption with the extension of common cardiovascular diseases, colon cancer, type 2 diabetes and stroke. The main responsible for these diseases seems to be meat FA composition, the high salt content of some preparations and possible carcinogenic compounds formation during cooking (Bingham et al., 2002; Feskens et al., 2013; Kantogianni et al., 2008; McAfee et al., 2010).

In response to human nutritionists and dieticians the European Union has reinforced the attention to labelling law in order to achieve a high level of health protection for consumers. The EC Regulation 1169/2011 has introduced some new mandatory information for labelling such as the specification of main FA groups: saturated FA (SFA), monounsaturated FA (MUFA) and polyunsaturated FA (PUFA). Chemical determination of FA is time consuming, expensive, and it requires long sample preparation. Therefore, the use of fast and reliable tools such as near infrared technology could be

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useful to face these limitations. This paper aimed to investigate the feasibility of using near infrared transmittance (NIT) spectroscopy to predict SFA, MUFA and PUFA in commercial ground meat samples.

MATERIAL AND METHODS

Sample collection

Samples (n=81) were collected randomly in supermarkets and butchers located in Veneto and Trentino-Alto Adige regions (northeast Italy) from October 2014 to February 2015. Products acquired were ground meat, hamburger, meatballs, sausages, and other commercial products with ground meat. Forty-one samples were composed of beef meat as main ingredient, 24 of pork meat, 8 of a mix of beef and pork meat and the remaining 9 samples were made with chicken and turkey. In addition to meat, 46 samples contained spices, bread, cheese, flavourings, preservatives, acidity regulators and other additives based on the formulation of the company recipe.

Near infrared analysis

Meat samples were first analysed without treatments; intact samples were placed into circular glass cup (diameter 140 mm, depth 17.5 mm) at room temperature and NIT spectroscopy was carried out using FoodScan (FOSS, Electric A/S, Hillerød, Denmark) from 850 to 1048 nm (2 nm interval). Then, each sample was cut off, mixed mechanically with the knife mill Retsch Grindomix GM200 (Retsch GmbH & Co, Haan, Germany) and analysed again by FoodScan. Each spectrum was obtained by 24 scans performed at one time for each sample. After spectra collection an amount of minced samples was used for reference analysis.

Chemical analysis

Total lipids were extracted from 4 g of sample by accelerated solvent extraction using a Dionex ASE 350 system (Thermo Scietific, Dreieich, Germany), with petroleum ether extraction solvent. Preparation of ester derivatives of FA for chromatographically analysis were performed with a method adapted from Christie (1993). On 40 mg of the extracted fat 1 mL of sulphuric acid (H_2SO_4) in methanol was added and samples were then placed in an oven at 65°C overnight. At the end of methylation 2 mL of n-heptano and 1 mL of potassium carbonate were added. After centrifugation for 10 minutes at 4000g the supernatant was collected. Separation and quantification of the FA methyl esters were carried out using a gas chromatography Agilent 7820A GC System (Agilent Technologies, Santa Clara, CA) with hydrogen as a carrier gas. Gas chromatograph was equipped with Flame Ionization Detector (FID) and Supelco Omegawax capillary column (30 m×0.25 mm id, 0.25 μm film thickness). The output was quantified using GC ChemStation (Agilent Technologies). Fatty acids were identified upon comparison with the known FA standards (Supelco FAME mixC4–C24 #18919-1AMP; Sigma-Aldrich, Castle Hill, Australia) and expressed as percentage of FA group on the total FA identified. Moreover, FA groups were expressed on the total fresh meat. Fat content, protein content, collagen content and moisture were determined using the FoodScan (FOSS Electric A/S, Hillerød, Denmark).

Statistical analysis

Spectral data were analyzed using WinISI software (Infrasoft International, Port Matilda, PA, USA) and modified partial least squares (MPLS) regressions. Cross-validation was performed splitting the calibration dataset in 5 groups, using one of them to check the results (prediction) and the remaining four to construct the calibration model. Data were treated with different combinations of scattering corrections and different mathematical pre-treatments. The critical "T" outlier value was set at 2.5. The best equation for each FA group was selected on the basis of the highest coefficient of determination in cross-validation (R^2cv). Other fitting statistics used to evaluate the prediction models were the standard error of calibration (SEC), the coefficient of determination of calibration (R^2), the standard error of cross-validation (SEcv), and the residual predictive deviation (RPD) calculated as the ratio of SD of reference data to the SEcv (Sinnaeve et al., 1994)

RESULTS AND DISCUSSION

The fat percentage of intact and mixed commercial ground meat samples obtained by FoodScan is presented in Table 1. Means of SFA, MUFA and PUFA were 43%, 47% and 10% of total FA and 6%, 7% and 1% of fresh meat determined by gold method (Table 2). The variability of each FA group determined on intact samples was similar to the variation of the same FA on minced samples (Table 2).

Comparison of mean FA groups with other studies is difficult because of the variability of the meat type and their recipes. However means of SFA and PUFA were higher and of MUFA lower than Fernández-Cabanás et al. (2011) who obtained values of 40.32% for SFA, 51.96% for MUFA and 7.72% for PUFA in the analysis of 86 sausages. PUFA Mean of turkey hamburgers and meatballs obtained by Ferreira et al. (2000) higher than mean value of PUFA from the present work. However, it is worth noting that in our study chicken and turkey meat samples accounted for only 10% of the data.

Considering FA groups measured on total FA, the R^2 was lower in intact (0.822, 0.367 and 0.780 for SFA, MUFA and PUFA, respectively) than in minced samples (0.879, 0.726 and 0.908, respectively) (Figure 1a). The same pattern was found considering FA expressed on fresh meat, with R^2 values which were always greater than 0.900 for all the FA groups, both in intact and minced samples (Figure 1b). The R^2_{CV} of FA groups

expressed on total FA of intact meat were 0.794 for SFA, 0.315 for MUFA and 0.730 for PUFA, and in minced meat they were 0.863, 0.490 and 0.876, respectively (Table 2). Finally, the R^2_{CV} of FA groups expressed on fresh meat of intact samples were 0.979, 0.957 and 0.896 for SFA, MUFA and PUFA, respectively, and in minced samples they were 0.985, 0.983 and 0.958, respectively.

Table 1. Fat content (%) of intact and minced commercial ground samples obtained by NIT instrument (FoodScan)[a]

	Mean	SD	CV (%)	Min	Max
Intact meat	14.13	5.11	35.73	2.73	23.73
Minced meat	13.95	4.95	35.48	2.45	25.21

[a]Abbreviations: SD, standard deviation; CV, coefficient of variation; Min, minimum; Max, maximum

Table 2. Descriptive and prediction statistics for FA groups of intact and minced commercial ground meat samples [a]

Trait	Mean	SD	CV(%)	Math	T	SEC	R^2	SEcv	R^2cv	RPD
Intact meat, % of total FA										
SFA	42.55	6.59	15.50	SNV 1,4,4,1	7	2.67	0.822	2.86	0.794	2.21
MUFA	46.92	4.51	9.61	MSC 2,10,10,1	1	2.45	0.367	2.59	0.315	1.19
PUFA	10.25	6.86	66.89	NONE 2,5,5,1	10	2.32	0.780	2.58	0.730	1.92
Intact meat, g/100 g of fresh meat										
SFA	5.89	2.4	40.78	SNV+D 1,4,4,1	9	0.26	0.987	0.33	0.979	6.87
MUFA	6.67	2.63	39.36	SNV+D 2,5,5,1	9	0.42	0.973	0.54	0.957	4.75
PUFA	1.46	1.18	80.92	SNV+D 2,5,5,1	10	0.26	0.915	0.28	0.896	3.1
Minced meat, % of total FA										
SFA	42.89	6.63	15.46	MSC1,8,8,1	8	2.20	0.879	2.36	0.863	2.68
MUFA	46.78	4.37	9.34	SNV+D 2,5,5,1	10	1.85	0.726	2.52	0.490	1.4
PUFA	10.04	6.9	68.66	Detrend 1,4,4,1	10	1.52	0.908	1.76	0.876	2.84
Minced meat, g/100 g of fresh meat										
SFA	5.9	2.29	38.86	SNV+D 2,5,5,1	9	0.23	0.990	0.28	0.985	7.99
MUFA	6.59	2.5	37.91	MSC 2,5,5,1	10	0.28	0.988	0.33	0.983	7.46
PUFA	1.42	1.17	82.37	MSC 2,5,5,1	10	0.17	0.964	0.18	0.958	4.88

SFA (saturated fatty acids): sum of $C_{4:0}$, $C_{6:0}$, $C_{7:0}$, $C_{8:0}$, $C_{9:0}$, $C_{10:0}$, $C_{11:0}$, $C_{12:0}$, $C_{13:0}$ (and iso and anteiso), $C_{14:0}$ (and iso and anteiso), $C_{15:0}$ (and iso and anteiso), $C_{16:0}$ (and iso and anteiso), $C_{17:0}$ (and iso and anteiso), $C_{18:0}$ (and iso and anteiso), $C_{19:0}$, $C_{20:0}$, $C_{21:0}$, $C_{22:0}$, $C_{23:0}$, $C_{24:0}$; MUFA (monounsaturated fatty acids): sum of $C_{10:1}$, $C_{12:1}$, $C_{14:1}$ (and isomer), $C_{15:1}$, $C_{16:1n9}$, $C_{16:1n7}$, $C_{16:1}$, $C_{17:1n7}$, $C_{18:1}$ (and isomers), $C_{19:1}$, $C_{22:1n9}$, $C_{24:1n9}$; PUFA (polyunsaturated fatty acids): sum of $C_{18:2n6}$, $C_{18:2}$ (and isomers), $C_{18:3n6}$, $C_{18:3n3}$, $C_{20:2n6}$, $C_{20:3n6}$, $C_{20:3n3}$, $C_{20:4n6}$, $C_{20:5n3}$, $C_{22:2n6}$, $C_{22:5n3}$, $C_{22:6n3}$.

[a]Abbreviations: SD, standard deviation; CV, coefficient of variation; Math, mathematical treatment; T, number of terms used to perform the calibration model; SEC, standard error of calibration; R^2, coefficient of determination of calibration; SE_{CV}, standard error of cross-validation; R^2cv, coefficient of determination of cross-validation; RPD, residual predictive deviation, calculated as ratio of SD of reference data to the SE_{CV}; SNV, standard normal variate; MSC, multiplicative scatter correction; NONE, without treatment of scatter correction; SNV+D: standard normal variate and detrending. The first digit of the mathematical treatment represents the number of the derivative, the second the gap over which the derivative is calculated, the third the number of data points in the first smoothing, and the fourth the number of data points in the second smoothing.

The results evidenced better fitting statistics for prediction models calculated for minced than intact samples; this was expected because sample preparation affects the reliability of near infrared prediction models (Prieto et al., 2009; Guy et al., 2011). The RPD value allows an impartial evaluation of the performance of calibrations between studies examining the same traits with different measurement units and different samples. De Marchi et al. (2012) analysed the FA profile of chicken breast expressed as % of total FA and reported similar RPD values for MUFA and PUFA as well as lower values for SFA compared with our study. Regarding the prediction of FA (expressed on fresh meat) in the ground bovine *Longissimus thoracis* muscle samples, Mourot et al. (2014) obtained slightly worse RPD values than those obtained in the present work. Mourot et al. (2015) investigated the FA profile in four beef cattle breeds (Angus, Blond d'Aquitaine, Charolais, Limousin) and three muscles, *Longissimus thoracis*, *Rectus abdominis* and *Semitendinosus*, and calculated RPD values for SFA, MUFA and PUFA of *Longissimus thoracis* being lower than our results. The same authors also reported that the inclusion of samples from several breeds allowed to capture more variability of FA content, thus leading to an increased accuracy of calibration models.

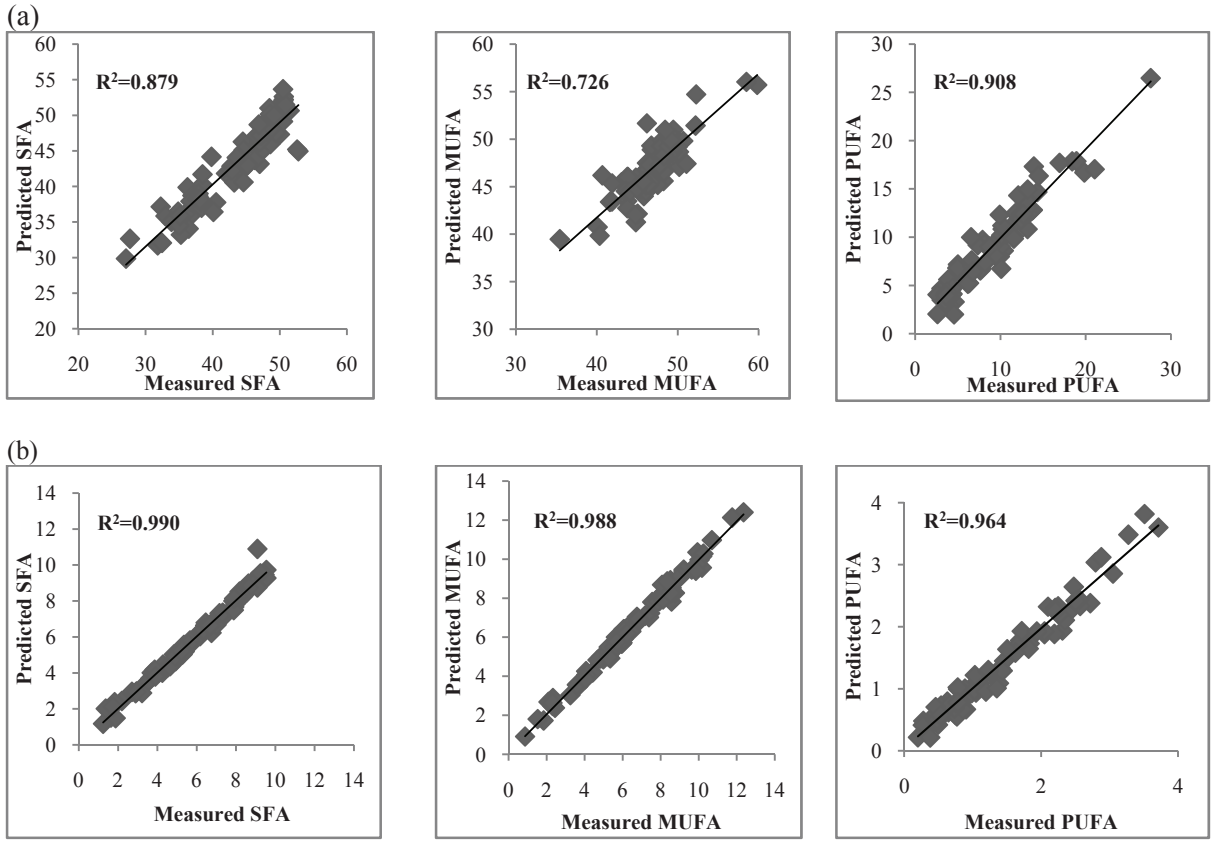

Figure 1. Relationship between reference and predicted SFA, MUFA and PUFA expressed on % of total FA (a) and g/100g of fresh meat (b) of minced meat. The coefficient of determination of calibration is included for each trait

CONCLUSION

The present study underlined the ability of NIT spectroscopy to predict FA groups in commercial ground meat products. Better predictions were obtained for SFA, MUFA and PUFA expressed on fresh meat than on the total FA. This study confirmed the positive effect of mincing the samples on the development of robust prediction models. The calibration models developed in this study can be used by meat industry to address the requirements of EC Regulation 1169/2011.

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