USE OF NEAR-INFRARED SPECTROSCOPY TO PREDICT BIOCHEMICAL AND STRUCTURAL COMPONENTS OF BOVINE MEAT

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Abstract – The aims of the study were 1) to determine biochemical and structural components content using a near infrared spectroscopy (NIRS) and 2) to compare the use of different NIR spectrometers. Four muscles were selected (*Longissimus thoracis* (n=52), *Rectus abdominis* (n=52), *Semimembranosus* (n=40), *Semitendinosus* (n=40)), on different type of cattle from several rearing systems. NIRS spectra were measured at wavelengths between 350 and 2500 nm on portable, industrial and laboratory spectrometer. The NIRS prediction models obtained for total collagen (expressed in mg OH-prol/g of dry matter) showed a coefficient of determination of cross-validation (R^2_{CV}) of 0.82. Others biochemical and structural components showed a R^2_{CV} from 0.4 to 0.7. Laboratory devices gave better predictive models than industrial and portable equipment.

Key Words – connective tissue, myosin heavy chain, meat quality, NIRS.

I. INTRODUCTION

The tenderness is one of the most important characteristics by which consumers judge meat quality [1]. Factors such as muscle fiber and connective tissue characteristics are involved in beef quality variations [2, 3]. Muscle connective tissue is composed of cells and extracellular matrix, consisting of collagen fibrils linked by cross-links (CLs) both embedded in a matrix of proteoglycans (PGs) [4]. The reference methods for the analysis of muscle biochemical components are quite destructive, time-consuming and expensive. A rapid quantification of these components, at lower cost, is of particular interest for meat sector to attempt to easily determine the tenderness potential of a muscle and thus ensure a level of tenderness for the consumer. The preliminary work of Listrat *et al.* [5] suggested that the development of near infrared spectroscopy (NIRS) calibration model is possible for predicting beef collagen content but need more development both for collagen content and for CLs and PGs. The present study was designed to evaluate the prediction of muscle fiber and connective tissue characteristics using different NIRS equipment, from a portable NIRS system to a laboratory NIRS device.

II. MATERIALS AND METHODS

Fifty-two samples of *Longissimus thoracis* (LT), 52 of *Rectus abdominis* (RA), 40 of *Semimembranosus* (SM) and 40 of *Semitendinosus* (ST) were collected from 52 carcasses of cattle from different genetic types (milk (n=23), meat (n=29)) and different types of animal (young bulls (n=15), cows (n=22), heifers (n=9), steers (n=6)). After sampling, freezing grinding for muscle fiber and additionally freeze-drying for connective tissue, analysis and spectral measurements were carried out. Total and insoluble collagen (in mg of hydroxyproline per g of dry matter) were measured according to the norm NF V 04-415 (2002). CLs (in nM of pyridinoline per mole of collagen) and PGs (in mg of chondroitin-4-sulphates (C4S)-GAGs equivalents per g of collagen) were measured using the method described by Dubost *et al.* [2]. Muscle fiber type were analysed using electrophoretic separation and quantification of myosin heavy chains according to Picard *et al* [6]. The spectra were acquired using a portable spectrometer ASD LabSpec 4, an industrial spectrometer FOSS DS2500 and a laboratory spectrometer FOSS NIRSystems 6500. Spectra were processed mathematically using the SNV and Detrend pretreatment and first derivative. The models were developed by PLS and validated by cross-validation, with the WinISI software for 1100-2500 nm range spectrum. Predictions of model performance for different biochemical components were evaluated on the basis of the following criteria: standard error of cross-validation (SE_{CV}) and R^2_{CV}.

III. RESULTS AND DISCUSSION

The descriptive statistics, as well as results of biochemical and structural parameters prediction performances of the 3 NIR spectrometers are presented in Table 1. The great variability for collagen, proteoglycan, cross-links and type I fibers are due to the mixing in our database of several muscles and different animal types which have different properties on these parameters in agreement with data of the literature [2].

Table 1 Prediction models for biochemical parameters of intramuscular connective tissue and muscle fiber (unit: see § II) by NIRS for the 3 infrared spectrometers

	Mean	CV (%)	ASD LabSpec 4		FOSS DS2500		FOSS NIRS6500	
			SE_{CV}	R^2_{CV}	SE_{CV}	R^2_{CV}	SE_{CV}	R^2_{CV}
Total collagen	3.9	33.3	0.63	0.61	0.58	0.68	0.43	0.82
Insoluble collagen	2.5	32.8	0.43	0.62	0.39	0.71	0.37	0.74
Cross-links	0.3	23.8	4.93	0.54	5.11	0.55	4.31	0.67
Total proteoglycans	7.1	37.6	1.75	0.51	1.64	0.59	1.48	0.65
Slow oxidative fibers (type I)	24.6	49.2	8.69	0.41	8.27	0.47	8.16	0.54

Abbreviation: SE_{CV}: standard error of cross validation; R^2_{CV}: coefficient of determination of cross-validation.

The prediction equations for collagen showed a R^2_{CV} from 0.6 to 0.8 according to the spectrometer used. These calibrations confirm the satisfactory results of the preliminary study (R^2_{CV}=0.88) of Listrat *et al.* [5]. The few authors who have been interested in the prediction of collagen by NIRS have not obtained as much precision. According to Gonzalez-Martin *et al.* [7], this would be due to the variability of the population used that would not be wide enough. Other factors such as sample preparation could have an effect. Indeed, we worked with lyophilized minced frozen samples while the majority of authors worked with fresh ground meat. We chose this method because it allows us to homogenize the collagenic and myofibrillar fraction of samples. To our knowledge, there are no results concerning the prediction of insoluble collagen, PG, CL and muscle fiber type I by NIRS. Those obtained in this study are not wholly satisfactory but show a potential that could be exploited in the future.

The comparison of the prediction models of the different spectrometers shows a slightly higher potential of the laboratory and industrial devices compared to the portable NIR equipment. The loss of performance with the portable spectrometer may be explained by a loss of signal information at the level of the optical fiber that connects the probe to the sensors [8]. The surprising difference in performance between the industrial and laboratory spectrometers (DS2500 and NIRSystems 6500), may probably be explained by different technical characteristics.

IV. CONCLUSION

The results of this study confirm the encouraging results of the preliminary study without claiming to use them for routine analyzes. Further studies are needed to try to improve NIRS prediction models. Alternative strategies must be implemented to achieve this objective, such as increasing the number of samples with more varied origins. This study shows the potential of using three different NIRS instruments on the calibration models for some biochemical and structural parameters of muscles.

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