NIRS PREDICTION OF INTRAMUSCULAR FAT CONTENT OF PORK LOINS: EFFECT OF THE ACQUISITION SURFACE

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Abstract – The objective of this study was to develop calibrations for the prediction of intramuscular fat content of pork loins, based on visible + near infrared spectroscopy (350-1800nm) measured on ungrounded muscle. A total of 100 loins were randomly selected, intramuscular fat level was graded using the NPPC scale and spectrums were acquired at the center of the sample (bone in pork chop located at the last rib level). Two kind of spectrums were acquired on loins and included in the calibration data sets: single spectrums and averaged spectrums (4 adjacent spectrums). The reference intramuscular fat content of the samples was determined by chemical analysis. Calibration by cross-validation showed a satisfying accuracy for the single spectrum database ($R^2c=0.74$) and more precise results for averaged spectrums ($R^2c=0.85$). External validation results (n=26) revealed a sharp decrease in the correlation between observed/predicted intramuscular fat (r=0.46, single spectrum database), but a better accuracy was obtained with averaged spectrums (r=0.58). These data are consistent with the strategy of developing a dedicated probe with a larger measurement window.

Key Words – NIR spectroscopy, intramuscular fat, pork meat.

I. INTRODUCTION

The French pork production is mainly intented to a meat processing market, and in this market the “jambon cuit supérieur” is a major product. An important number of research has been conduct in the past to develop robust methods in order to select meat on its technological quality. The ultimate pH has been identified as good predictor of the cooking yield and is used nowadays as a routine technique to select hams in slaughterhouses. Recently visible+NIR spectroscopy has been presented as an alternative for the prediction of the cooking yield [1]. On the other hand, no selection is practiced on the loin when intended to the fresh meat market. For this consumer market, a selection on the intramuscular fat content should be useful, regarding its strong relationship with sensory traits of the meat [2]. The sorting of pork meat on the intramuscular fat content using a subjective quotation has been well studied in the past [2] [3] [4], but some recent work showed promising results with objective methods like NIR spectroscopic calibrations [5] [6]. The models developed in these publications with cross validation procedure indicated a satisfying accuracy with R^2c from 0.49 to 0.61 and rmsev from 1.3 to 0.6.

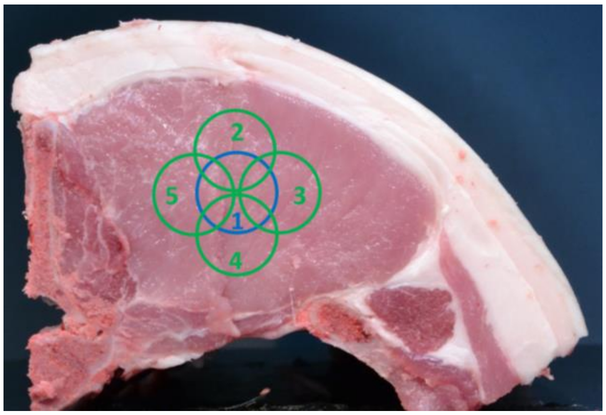
The aim of the present work is first to confirm the feasibility of the NIRS prediction of the intramuscular fat content on ungrounded *Longissimus* muscle, and second to develop specific calibrations that would allow slaughterhouses to select loins in standard production conditions. The size of the measurement area has also been studied to estimate the improvement of accuracy that could be expected if a probe with a larger measurement window would be designed.

II. MATERIALS AND METHODS

A randomly selected batch of loins (n=100) was used in this study. Loins were coming from standard production pork carcasses (Piétrain sire crossbreed) and were cut in commercial bone-in pork chops (20mm average thickness). The chop located at the last rib was immediately measured after the cutting with an ASDI Labspec4 visible and near infrared spectrometer. The reflection probe from ASDI was used to collect spectrums (ref.A111206, 2cm diameter measurement window). Spectrums were collected with one second measurement time (10 spectrums averaging).

Two protocols were used to collect visible + NIR spectrums (350-1800nm): a single spectrum taken at the center of the *Longissimus*, or an averaging of 4 adjacent spectrums (figure 1). This second option was performed in order to estimate the accuracy improvement that might be observed with a twice wider window probe. Subcutaneous fat, intermuscular fat and connective tissue were removed from chop samples before chemical analysis of the free fat content (NFV-04-403).

Figure 1: NIRS measurements location for single spectrum (1) and multiple spectrum averaging (2+3+4+5) – Longissimus muscle, last rib.



Chemometric data analysis was performed with the 7.10.0 version of Matlab (R2010a, The Math Works Inc., USA) and using the Saisir package developed for Matlab by D. Bertrand and C. Cordella (http://www.chimiometrie.fr/saisir_webpage.html). Calibration models were determined with a cross-validation based selection of the number of PLS factors as described previously [1]. The calibration and cross-validation procedure was performed on a randomly selected data set (n=65). In a second step, the accuracy of prediction models was estimated by external validation (n=34). A dedicated software Ma_guit41 based on Saisir functions [7] was used for the needs of automation of the cross-validation procedures.

III. RESULTS AND DISCUSSION

Samples population revealed after chemical analysis a relatively poor amount of fat content, and a low variability (m=1.6%, sd=0.95). These results are in agreement with our NPPC quotation centered on the second grade and showing no chop with a class 4 grading (table 1).

Table 1: calibration samples data set characteristics

NPPC grading	1	2	3	p.=
n=	28	47	25	
Intramuscular fat (%)	0.77_a	1.48_b	2.37_c	< 0.0001

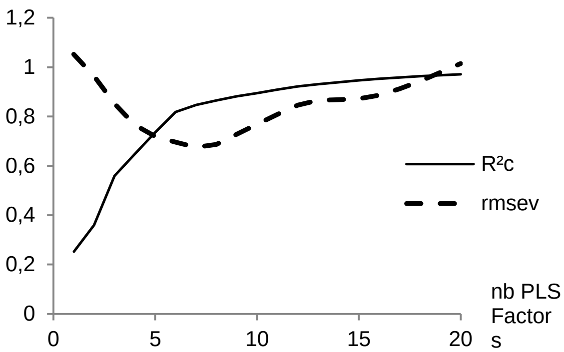
On this basis, calibration may have been difficult to determine in comparison with previous work data sets [5] [6]. Nonetheless, the calibration obtained in similar conditions (single spectrum data set) showed satisfying characteristics (R^2_c=0.74 and rmsev= 0.81 for 1^{st} derivative single spectrum data set, table 2). These results obtained for ungrounded pork meat revealed more precise calibrations than some previous paper (R^2_c=0.49 [5], R^2_c=0.61 [6]), but calibrations developed by Bastianelli *et al.* [8] were found to be better for poultry meat (R^2_c from 0.77 to 0.86) with a very close protocol and material.

When averaged spectrums were used for the prediction of intramuscular fat content, calibration results were quite logically better. After the cross-validation procedure (figure 2) the PLS model including 7 PLS factors showed indeed a nice accuracy (R^2_c=0.85 and rmsev= 0.68, for 1^{st} derivative averaged spectrum data set, table 2). These results are in agreement with the project of developing a more specific probe to predict the intramuscular fat content on loin. In a sort of way, calibration results of averaged spectrums indicate us that a twice larger probe would probably allow to measure a more representative part of the *Longissimus* muscle.

Table 2: visible+NIR calibration and cross validation results (n=65) for the prediction of the intramuscular fat content based on single spectrums or averaged spectrums

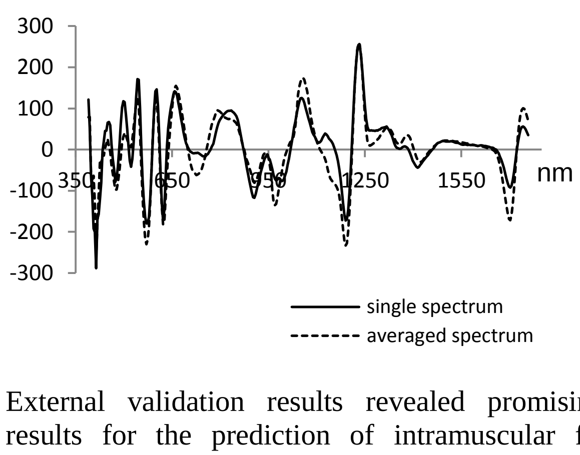
Spectrum	treatment	Nb PLS factors	R^2_c	Rmsev
Single spectrum	None	6	0.65	0.86
	SNV	4	0.58	0.89
	1^{st} derivative	7	0.74	0.81
4 spectrum averaging	None	9	0.88	0.70
	SNV	6	0.79	0.72
	1^{st} derivative	7	0.85	0.68

Figure 2: cross validation procedure for the determination of the appropriate number of PLS factors – prediction of the intramuscular fat content based on averaged and 1st derivative spectrums data set (n=65)



Interestingly, PLS models developed on 1st derivative single spectrum data set or 1st derivative averaged data set showed very similar characteristics. PLS loading factor curves could almost be overprint (figure 3). Such noticeable observation should considerably increase the robustness of the models developed.

Figure 3: PLS loading factors for prediction models of the intramuscular fat content based on single spectrum or averaged 1st derivative spectrums



External validation results revealed promising results for the prediction of intramuscular fat content based on a single spectrum acquisition, but the overall accuracy of this prediction model is still poor (r=0.46, error=0.72, figure 4). Part of the reason probably comes from the low variability of intramuscular fat content in the external validation data set. Another reason could be the lack of representativity of a 2 cm diameter NIRS measurement regarding the average diameter of the longissimus muscle (about 5.5 cm). This could possibly explain the better results for external validation of the model developed on averaged spectrums (r=0.58, error=0.65, figure 5) that get a noticeably identical characteristics than the single spectrum based model.

Such data suggest a larger probe (circa 5cm diameter) would probably be the next development needed to perform on line a more accurate selection of loin based on the prediction of intramuscular fat content.

Figure 4: external validation results for the prediction of the intramuscular fat content performed with calibration based on 1st derivative data set of single spectrums (1) – n=34

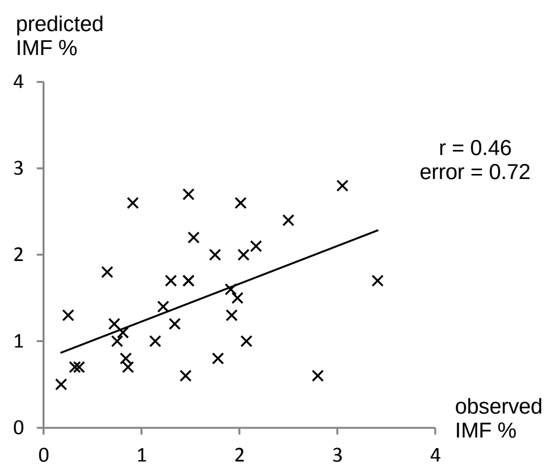
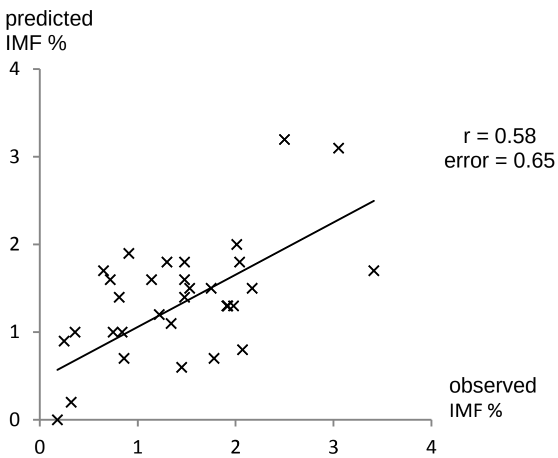


Figure 5: external validation results for the prediction of the intramuscular fat content performed with calibration based on 1st derivative data set of averaged spectrums (2+3+4+5) – n=34



IV. CONCLUSION

This study confirmed that it is possible to select loin on their intramuscular fat content with visible and infrared spectroscopy. The calibrations developed in this work revealed promising characteristics in comparison to previous works using also visible + NIRS measurements on ungrounded pork meat. Nevertheless, external validation results revealed the limits of the use of a reduced diameter probe (2 cm). The next step would certainly be to design a dedicated probe with an increasing window diameter (5 cm) and perhaps including a transflectance option for the spectrums acquisition as it was described by Wold *et al*. [9] as a more precise technique for the prediction of fat content.

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