Meat quality mapping of the loin: pH vs NIR spectroscopy to predict the cooking yield

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Abstract – Cooked loins for self service shelves is a recent use for pork loins that are traditionally intended to the fresh meat market. Therefore, the prediction of the meat quality for a processing purpose is still poorly documented. A previous study revealed a close relationship between the cooking yield of the loin and its ultimate pH and described strong problems of slicing. The aim of this work is to explore other meat quality predictors such as visible+NIR spectroscopy and conductance, and to study the texture problems occurring during the slicing of cooked loins. The ultimate pH of the *Longissimus* shows good correlation level with the cooking yield whatever the measurement site (from r=0.60 to r=0.69), but conductance can't be considered as a meat quality predictor in this study. External validation results for visible+NIR spectroscopy prediction of the cooking yield (r=0.65) let us consider this technique as a reliable alternative to ultimate pH for cooking yield prediction, but only if applied at the caudal end of the *Longissimus*. The "paste-like" defect location is specific of both cranial and caudal end of the loin, and is not linked with the halothane genotype.

I. INTRODUCTION

In the growing market of cooked ham displayed in the self service shelves, the cooked loin is a recent but rising product in France (+11.5% in 2012). Cooking yield and slicing yield problems and their relationship with meat quality parameters has been well documented for cooked ham in the past. Ultimate pH especially is well known for its strong relationship with the cooking yield (from r=0.58 to r=0.84; [1] [2] [3]). The meat quality of the loin is also well known in the fresh meat context, but studies focusing on its suitability for the processed meat industry are not frequent. In a previous work, Vautier et al. [3] have studied the relationship between the cooking yield of loins and meat quality parameters such as ultimate pH or color. Cooking yield was found to be highly correlated with ultimate pH (r=0.70) and visible spectroscopy appeared to be a pH alternative candidate for the prediction of the meat quality of the loin on the cutting line. The objective of this study was to confirm determinant meat quality parameters for processed loins, including the conductance and early post mortem measurements, and to test the accuracy of a visible+NIR spectroscopy calibration for cooking yield prediction. Slicing yields were analyzed focusing on structure defects.

II. MATERIALS AND METHODS

Eighty carcasses from Piétrain Sire pigs were randomly selected at the slaughterhouse (day 0, D0). pH (pH1) and conductance (cond1) were measured on line at 30 minutes post mortem on the *Longissimus* muscle (last thoracic vertebrae) with a Sydel pH-meter equipped with a Mettler Toledo Lot406 electrode, and a Matthäus LF-Star, respectively. Core temperature of the *Longissimus* muscle (T30) was registered just before entering the chilling tunnel and an ear sampling was performed at that time to determine the halothane genotype with DNA test [4]. After deboning and trimming, bacon-style loins were transferred to our cutting room where a meat quality mapping was performed at a minimum of 24 hours post mortem (D1). Eighteen ultimate pH measurements were practiced from cranial to caudal end, in two rows (medial and lateral), every 5 cm with the help of a grid. Meat color was measured at both cranial (4th thoracic vertebrae) and caudal end (last lumbar vertebrae) of the loin with a Konica-Minolta Cr-300 (D65 illuminant), and conductance was also measured at the last thoracic vertebrae level (Cond24). Visible + Near InfraRed Spectroscopy (NIRS) was performed on 9 *Longissimus* sites, every 5cm in a single central row with an ASDI Labspec 5000 (350-1800 nm). A two way optic fiber probe (7 mm diameter, insertion probe) was used to practice NIRS acquisitions at the center of the muscle in the same axis than the loin main axis. At D2, loins were transported to a meat processing company that was in charge of the “Rôti Cuit Supérieur” processing (no phosphate or carraghenan allowed). Loins were individually processed following the same protocol than described by Vautier et al. [3]. Cooking yield was recorded and slicing yield was individually measured at the IFIP laboratory focusing on the two major defects of the processed loins, the “paste-like” and “cohesion” defect of slices. The slices ordering was maintained allowing anatomic evaluation of defects for the processed loins, from cranial to caudal end.

Relationship between meat quality parameters (pH, temperature, conductance, color) and cooking and slicing yields was estimated with the SAS software, using the REG and the FREQ procedures. Chemometric data analyses were performed on visible+NIR spectrums with the 7.8.0 version of Matlab (R2009a) and using the Saisir package (http://easy-chemometrics.fr). CROSSPLS and BASIC_PLS procedures were used to determine prediction models of the cooking yield. Fifty six loins were randomly selected to build the calibration sample and to determine the number of PLS factors by cross validation (70/30 calibration/cross validation ratio). The remaining loins (n=24) were used to evaluate the accuracy of the prediction by external validation.

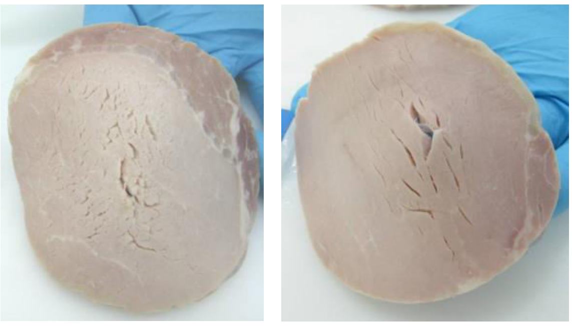
III. RESULTS AND DISCUSSION

Cooking yields are lower than previous results with a similar protocol [3] (89.6% vs 93.8%, respectively, table 1). The ultimate pH (pH24) level explains in itself the yield difference (5.47 vs 5.61) and confirms that the process was performed following standard settings. Cohesion defect rate is very high (63%) but its consequence on taste is far less important than the effect of paste-like defect (30%) (figure 1).

Table 1: overall meat quality results

n=80	m	sd
T30 (°c)	38.1	1.1
pH1	6.34	0.19
Cond1(mS/cm)	3.68	0.40
pH24	5.47	0.15
Cond24(mS/cm)	7.52	2.74
Cooking Yield (%)	89.6	3.7
Slices with cohesion defect (%)	63	37
Slices with paste-like defect (%)	27	28

Figure 1: paste-like defect (left) and cohesion defect (right) on processed loin



Ultimate pH results show limited anatomic variations considering the size of the entire *Longissimus* muscle (+/-0.10 except pH value n°2 from *Spinalis Thoracis*, table 2). pH values are very close within a 10 cm distance (+/-0.02) that indicates a lower site precision is needed to measure the ultimate pH of loin. On the other hand, pH mapping of the ham’s *Semimembranosus* presented strong anatomic differences in a previous study [5] and needs a higher precision when measuring (+/-0.13 within 5cm at the reference site). The relationship between ultimate pH and the cooking yield is very close with a high correlation level (from r=0.60 to r=0.69, except pH n°2), confirming previous results on processed loin (r=0.70) [3].

Table 2: ultimate pH mapping of the loin and correlation with cooking yield (n=80)

site	m	Corr./cooking yield		*Site*	m	Corr./cooking yield
1	5.53	0.69		*2*	5.58	0.30
3	5.51	0.69		*4*	5.52	0.62
5	5.48	0.68		*6*	5.52	0.66
7	5.47	0.64		*8*	5.53	0.67
9	5.46	0.69		*10*	5.53	0.63
11	5.46	0.66		*12*	5.54	0.61
13	5.48	0.61		*14*	5.54	0.60
15	5.52	0.60		*16*	5.56	0.65
17	5.55	0.61		*18*	5.55	0.61
Lateral side				*Medial side*		

Correlation between ultimate pH alternatives and the cooking yield showed lower levels (table 3). Conductance (30 min. or 24 hours post mortem) seems not to be an accurate predictor of the cooking yield but L*value may be a second choice predictor after ultimate pH (from r=0.41 to r=0.55) confirming previous results [3].

Table 3: linear regression results for the prediction of the cooking yield

	Area of the measurement	Corr./cooking yield
T30	Last thoracic vertebrae	0.26
pH1		0.39
Cond1		0.01
Cond24		0.00
L*	4th thoracic v.	0.55
L*	Last lumbar v.	0.41

External validations of PLS based predictions of the cooking yield using visible+NIR spectroscopy pattern show contrasting results (table 4). Somehow, the best results are similar to those obtained with a pH based prediction. Spectrums taken at the caudal end of the *Longissimus* gives the highest correlation level (r=0.65, figure 2). The external validation error is high (2.9) considering the standard deviation of cooking yield (3.7), but the correlation is better than other pH-alternatives like the muscle L*value (r=0.55, table 5). These data are in agreement with external validation results obtained previously for the prediction of the cooking yield of “jambon cuit supérieur” cooked ham by visible+NIR spectroscopy (r=0.82, rmsep=1.62) [6].

Table 4: PLS regression results for visible+NIRS prediction of the cooking yield

	Calibration (n=56)		Cross validation (n=56/3)	External validation (n=24)	
Site	R²	Nb. pls factors	Rmsec mini	r	Rmsep
C	0.26	3	3.8	0.28	3.7
D	0.09	1	3.8	-	-
E	0.66	6	3.5	0.26	3.7
F	0.05	1	3.8	-	-
G	0.08	1	3.8	-	-
H	0.02	1	3.9	-	-
I	0.29	3	3.9	0.31	3.6
J	0.78	9	3.8	0.65	2.9
K	0.15	4	3.9	0.49	3.3

Subjective notation of the cooked loins defects after slicing reveals specific anatomic occurrences. The cohesion defect is more frequent in the caudal part of the loin and the paste-like defect shows its highest rate in both caudal and especially cranial end of the loin (table 5).

Figure 2: *Longissimus* external validation results for the prediction of the cooking yield by visible+ NIRS (site J)

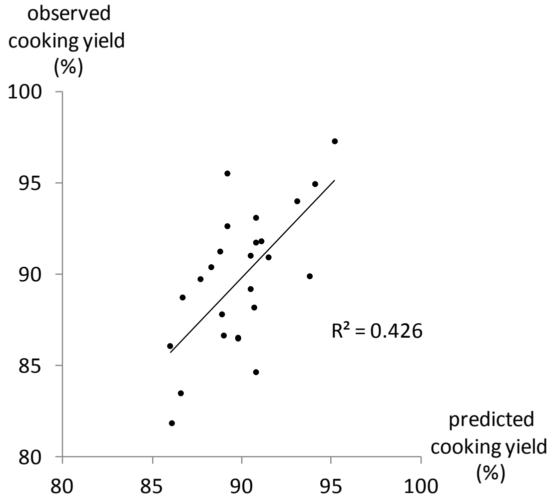


Table 5: defect mapping of the processed loin after slicing

Site	Slices with paste-like defect (%)	Slices with cohesion defect (%)
C	40	35
D	49	48
E	41	49
F	26	59
G	11	71
H	11	74
I	17	70
J	27	72
K	26	69

The halothane genotype is not considered, in this experiment, as a major risk factor for both paste-like and cohesion defect (table 6). None of the meat quality parameters tested here (pH1, pH24, cond1, cond24, L*) have shown a significant relationship with the paste-like defect rate (table 7).

Table 6: slicing results by halothane genotype

	Halothane genotype		p.=
	NN	Nn	
n=	22	58	
Paste-like defect (%)	23	28	ns
Cohesion defect (%)	54	66	ns

Table 7: paste-like defect rate by meat quality class (pH1 and pH24)

		n=	Paste-like defect (%)	p.=
pH1	< 6.0	2	15	ns
	6.0 < pH< 6.3	33	29	
	> 6.3	45	26	
pH24	< 5.4	22	25	ns
	5.4 < pH < 5.5	31	25	
	5.5 < pH < 5.6	16	38	
	> 5.6	11	21	

IV. CONCLUSION

This study focusing on the meat quality of loin for an industrial processing purpose confirms that the ultimate pH is considered as the best predictor of the cooking yield (r=0.65). Its measurement on the *Longissimus* needs a far less precise site than the precision needed to measure the ultimate pH in the ham (*Semimembranosus*). Early post mortem meat quality parameters (pH1, T30, cond1) show lower correlation level with cooking yield (r=0.01 to r=0.39). The visible+NIR spectroscopy practiced in the caudal part of the *Longissimus* gave good external validation results (r=0.65) and confirms results obtained previously for the prediction of the cooking yield of ham. This technique could probably be improved with the help of a dedicated probe with a larger optic window than the actual insertion probe. The “paste-like” slicing defect is not related to meat quality parameters or halothane genotype. Histological studies may help to understand its occurrence and specific anatomical localization on the loin.

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