Les Cahiers de l'IFIP
Revue R&D de la filière porcine française
Vol 2 - N° 2 - 2015

Technological quality of pork loin for meat-curing:

the main predictors of technological yield and sliceability

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Cooked-and-sliced off-the-shelf pork loin is primed for growth. The meat processing industry need technical references. The cooked ham model may well be transposable to processing loin muscle, but the loin has specific features that warrant a re-assessment of the impact of technological meat quality criteria on processing yields and meat defects. The IFIP studied the correlations between loin quality measurements and cooking yields, tested the ability of visible/near-infrared spectroscopy to predict meat quality, and proposed an anatomical map of these relationships. Ultimate pH shows predictive correlations with technological yield but near-infrared spectroscopy out-predicts pH for technological yield. This study found that around 30% of loins carried the same kind of "paste-like" muscle structure as cooked ham, essentially localized to the shoulder-end third of the loin.

Aptitude technologique de la longe pour une transformation en salaison : identification des principaux prédicteurs du rendement technologique et tranchage

La longe cuite tranchée en libre service est un produit à potentiel de croissance. Les transformateurs ont besoin de références techniques. Le modèle du jambon cuit est peut-être transposable à la transformation de la longe, mais les spécificités de celle-ci impliquent de réévaluer l'impact des critères de qualité technologique sur les rendements de transformation et les défauts musculaires. L'IFIP a étudié les relations entre les mesures de qualité de la longe et les rendements de fabrication. L'aptitude à prédire la qualité de la viande par spectroscopie visible proche infrarouge a également été testée. Une cartographie anatomique de ces relations a été proposée. Le pH ultime montre des relations permettant de prédire le rendement technologique et la spectroscopie proche infrarouge a montré une meilleure aptitude à la prédiction du rendement technologique que le pH. Cette étude a révélé qu'environ 30% des longes portaient un défaut de structure musculaire de type « pommade » comme sur jambon cuit, surtout localisé dans le tiers antérieur de la longe.

Keywords: loin, technological meat quality, pH, visible/near-infrared spectroscopy
Mots clés : longe, qualité technologique, pH, spectroscopie visible proche infrarouge

Introduction

As the fresh meat market continues to lose ground (pork has been shedding -0.5 to -1.0% a year in the last few years), an option could be **to develop a whole new range of processed meat products based on loin**. As the loin has always been almost exclusively sold fresh, the bulk of research is focused on drip loss and cooking loss (Pinochet *et al.*, 1988; Van Laack *et al.*, 1994; Otto *et al.*, 2004; Kurt *et al.*, 2007), appearance issues (colour, intermuscular and intramuscular fat factors, purchase intentions; Dransfield *et al.*, 2005) and texture changes after cooking (Honikel *et al,* 1987, 1994; Chiavaro *et al.*, 2009; Moeller *et al.*, 2010). The development of a potential market for processed loin as cooked-and-sliced off-the-shelf products hinges on gaining new knowledge on the **technological quality of the loin.**

For superior-grade cooked ham—the flagship cool-aisle off-the-shelf product—the impact of pork meat biochemical parameters on the technological quality and processing yields has been intensively investigated in France over the last fifteen years. Of several quality parameter metrics identified for ham, **ultimate pH is currently the most reliable predictor of technological yield** (Alviset *et al.*, 1995; Boutten *et al.*, 2003, Vautier *et al.*, 2009), with correlation levels varying from r=0.79 to r=0.84 and a prediction error of 1.8 points. Ultimate pH is also **a good risk marker for the "PSE-like" defect that affects around 17% of hams** (Minvielle *et al.*, 2001) and results in reduced slicing yield (Vautier *et al.*, 2011). An ultimate pH-based predictive model was found to add **84% concordance** on predicted occurrence of the defect (Vautier *et al.*, 2008). Another recent study reported that it was possible to **calibrate a visible/near-infrared spectrometer** to fresh ham (bone-in or bone-out) probing sites to predict cooking yield with a high correlation level (r=0.87) and a prediction error of 3.0 points (Vautier *et al,* 2009).

However, there is still no available literature on predictors of cooked-loin processing and cooking yields. An IFIP-led study on using redox potential as a parameter brought a number of early pointers on well-determined measurement sites of the loin (Vautier *et al.*, 2011) and found that ultimate pH measured at the 13th rib again showed good correlations with cooking yields (r=0.70). Visible spectroscopy data confirms the cooking yield prediction levels previously obtained with visible/near-infrared spectroscopy on ham, whereas **redox potential data was uninformative.** Observations led here on sliced loins identified two slice structure defects: the first, **a sliceability defect**, that appears reasonably correlated to ultimate pH, and the second, a paste-like defect, that looks substantially like the similar defect encountered in cooked ham but emerging through apparently different mechanisms (as unrelated to ultimate pH measurement). These preliminary findings prompted us to set up a specific study on the state of the art in knowledge on technological quality in pork loin. The objective is (i) to determine which of the current meat quality criteria (pH1, pHu, L*a*b* colour profile, visible/near-infrared spectrometry, conductivity) are relevant variables for technological yield prediction, and (ii) to identify **the reference-measurement probing sites** for pork loin.

The aim of this study is to profile the processability of pork loin by determining the big predictors of process yields and identifying the big end-product defects. Here, strong similarities with the "cooked ham" model can be noticed—recent studies led by the IFIP (Vautier *et al.*, 2011) have demonstrated that cooked-and-sliced pork loin is exposed to much the same kind of "paste-like" texture problems as cooked-and-sliced ham. Another equally important objective is to determine the most appropriate measurement sites for applicability across the charcuterie industry.

Material & Methods

Loin selection — sampling scheme

Over the course of the study, 80 carcasses sourced from standard pork batches were selected at slaughter (by Cooperl, Montfort-sur-Meu slaughterhouse facilities). An ear tissue sample was taken from each selected carcass using special-purpose ear punches (photo 1). The selected sample was then sent to Certagen DNA services (Rheinbach, Germany) to determine **halothane genotype**.

Photo 1

After identification, and for each replicate series, the 20 left-side and right-side half-carcasses were butchered down at D+1 and the loins deboned into 'boneless half-chain false-lean-off' cuts (reference 213 in the INAPORC export catalogue—–see Frenchporkcuts.com, photo 2) sufficiently early in the morning to enable quality parameter data to be acquired later the same day.

Photo 2

At the end of the day of measurement (at the IFIP's meatcutting facilities, Romillé), the right-side and left-side racks were transported to big industry charcuterie firm Fleury Michon (Pouzauges) for salt-curing and processing into superior-grade cooked-and-sliced roast pork. The right-side racks were processed through a standard-added-salt protocol while the left-side racks went through a low-salt (-25%) protocol. Processing followed the standard industrial procedure but with some minor amendments, with the aim of keeping an unbroken chain of unit-by-unit traceability through each processing step, as in the earlier trial by Vautier *et al.* (2011). The pork loin racks were thus ID-numbered, individually brine-injected (18%) and vacuum-packed into bags, then tumbled with a non-test batch of racks of pork in an industrial-scale tumbler, and finally moulded separately ready for subsequent cooking. Technological yields of each sample were individually measured on-site by Fleury Michon. Slicing yield losses were then estimated on the shelf-ready pre-sliced cooked loin packs as and when they were received back at the IFIP's Romillé-based meatcutting facilities. Presence of major defects was estimated for each loin in relation to anatomic location of the slice (shoulder end/ham end) as each slice pack had been pre-code-numbered in relation to anatomic position in the whole-rack slicing sequence.

Measurements on the fresh source meat

At the slaughterhouse (D0, 30 minutes post-mortem) on right half-carcass

- pH1 / SYDEL pH meter + Mettler Toledo LoT406-M6-DXK-S7/25 electrode probe, measurement practiced on *Longissimus* muscle at the reference site near the last rib (IFIP, 2000).
- Temperature of the *Longissimus* muscle
- Ear sampling to determine halothane genotype (Certagen).

Table 1: Organizational breakdown of measurement phases between slaughterhouse/meatcutting facility/salt-curing

LOT	MONDAY	TUESDAY	WEDNESDAY	THURSDAY
Lot 1 (L1) **IFIP measurements**	• pH1 • conductivity 30min. • sampling for halothane screening • loin temperature	• pHu (map) • conductivity 24h (map) • colour (2 sites) • NIRS acquisitions (9 sites)	-	-
Lot 2 (L2) **IFIP measurements**	-	• pH1 • conductivity 30min. • sampling for halothane screening • loin temperature	• pHu (map) • conductivity 24h (map) • colour (2 sites) • NIRS acquisitions (9 sites)	-
Delivery to Fleury Michon	-	-	7 a.m. Lot L1 (n=40 loins)	7 a.m. Lot L2 (n=40 loins)
Processing by Fleury Michon	on each delivery of 40 loins • 20 right-side loins singled out for processing into standard-salt ready-cooked individual loin packs • 20 left-side loins singled out for processing into low-salt ready-cooked individual loin packs			

At the IFIP's meatcutting facilities (D1, 24–30h post-mortem) on right half-carcass

- **ultimate pH** / SYDEL pH meter + Mettler Toledo LoT406-M6-DXK-S7/25 electrode probe,
  - pH map covering 18 sites gridded cros-sways at 5-cm intervals,
  - two series of 9 ventral and 9 dorsal mea-surements,
  - measure in the middle of the *Longissimus* muscle.

- **Colour (L*, a*, b* space)** / Minolta CR-300 colorimeter, standard illuminant D65 Two probing sites
  - Site 1: *Longissimus* at the
  - 5th thoracic vertebra
  - Site 2: *Longissimus* at the
  - last lumbar vertebra

- **Conductivity** / Matthaus LF-Star conduc-tivity meter
  - conductivity at 24h post-mortem, map covering 9 sites gridded at 5-cm intervals,
  - one axial series,
  - measure in the middle of the *Longissimus* muscle.

- **Visible**/near-infrared spectroscopy / ASDI LabSpec 5000
  - acquisitions on 18 sites gridded cros-sways at 5-cm intervals,
  - one axial series,
  - measure in the middle of the *Longissimus* muscle.

Measurements on processed end-product

At salt-curing (D2) – process steps: injection, tumbling and cooking

- weight of each individual loin
- calculation of the amount of brine to inject to guarantee a set calibrated injection rate (18%)

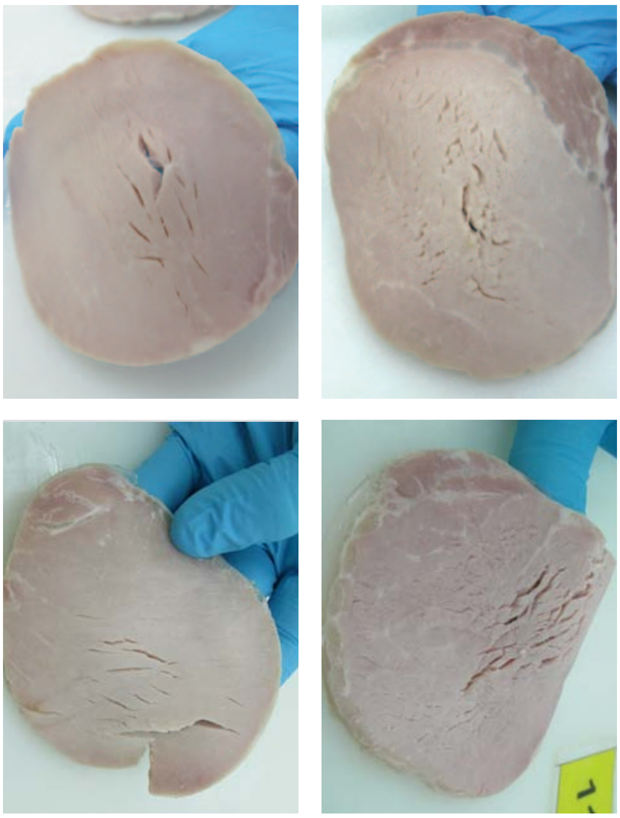
At salt-curing (D8) – process steps: demoulding and slicing

- weight of each cooked roast loin, determination of tech-nological yield, as: yld = (weight of the cooked roast loin minus cooking juice / weight of raw meat + brine= × 100
- sliceability on the in-line slicer
- numbering the order of arrival of shelf-ready packs exiting the in-line slicer (serves to assign an anatomical region to each pack of slices)
- transfer of the entire batch of slices produced from the racks originally butchered at the IFIP's meatcutting facility

At the IFIP's meatcutting facilities (D15) – observation of slice integrity defects

- opening up each 4-slice pack of shelf-ready cooked loin
- visual integrity defects quality control-graded (yes/no) using an IFIP-defined scoring system developed in a pre-vious study (Vautier *et al.*, 2011):

"Sliceability" defect | ***"Paste-like" defect***



Statistical processing and analysis

The now-standard quantitative meat quality data (pH1, ultimate pH, colour, conductivity) were successively introduced as explanatory variables for technological yield in the REG procedures bundled with S.A.S V8.02 (SAS Institute).

The visible/near-infrared spectra were processed using MATLAB release R2009a and the SAISIR toolbox available at http://easy-chemometrics.fr/index.htm (D.BERTRAND). In an effort to improve the accuracy of the models, the raw spectra were run through two separate pre-processing steps, i.e. SNV (Standard Normal Variate) correction and first-order derivation. The criteria used to assess accuracy of the predictive models were R^2 (coefficient of determination), RMSEC (error of calibration) and RMSEV (error of validation). Partial Least Squares (PLS) regression was used for the prediction of technological yield. As the wider objective was to define models offering enhanced robustness, cross-validation was applied to help determine the optimal number of PLS factors to include in the models—an increase in RMSEP (mean RMSEP for ten random segments of the validation sample) translates as extra messy noise compromising prediction quality and thus dictates the number of PLS factors to include in the models. The prediction of presence/absence of post-slicing integrity defects ("sliceability" and "paste-like") was performed using PLS discriminant analysis (PLS–DA) classification. Percentage of slices classed correctly in the cross-validation served to determine optimal number of PLS factors, in much the same way as RMSEP served for the prediction of technological yield.

Results & Discussion

Mean results: meat quality and yields

Despite not filtering out the carcasses on genetic origin and pH1 level, none of the carcasses showed the kind of sudden pH drop characterizing PSE meat. Note however that 11.3% of the carcasses had a pH30min post-mortem < 6.1 (PSE-tendency meat). Level of ultimate pH in the loins tested was relatively low (m=5.47) compared to average reported values (Frotin *et al.*, 2007, m=5.65 for *Semimembranosus* measured in 15 different slaughterhouses) but with good variability (SD=0.15). Conductivity measured at the last rib was very low here compared to the results reported by Boutten *et al.* (2003) for *Semimembranosus* (between 36 and 59 mS/cm), a muscle that is equally glycolytic but which Boutten *et al.* found was highly variable on post-mortem time-range (from 1 to 7 days). Boutten *et al.* measured conductivity

***Table 2:** Mean meat quality results at the reference site (Longissimus muscle at the last rib) and mean processing yields*

n=80		mean	SD
Temp1 (°C)		38.1	1.1
pH1		6.34	0.19
Cond1 (mS/cm)		3.68	0.40
pHu		5.47	0.15
Cond24 (mS/cm)		7.52	2.74
Normal salt content*	Technological yield (%)	89.6	3.7
	% slices w/ "sliceability" defect	62.8	37.0
	% slices w/ "paste-like" defect	26.8	28.0
Low salt content (-25%)*	Technological yield (%)	89.2	3.4
	% slices w/ "sliceability" defect	51.2	38.0
	% slices w/ "paste-like" defect	36.0	34.0

** effect of salt level on end-product results estimated analysis of variance: Technological yld p=0.453, % paste-like, p=0.029, % sliceability, p=0.004*

perpendicular to muscle fiber direction, as was also practiced here.

The results for technological yield are fairly logically 3 to 4 points lower than in Vautier *et al.* (2011) where mean ultimate pH of processed loins was 5.61. Note that technological yield of standard-salt-content processed loins (right-side loins) was substantially comparable to technological yield of low-salt-content processed loins (left-side loins). A higher ultimate pH level may have produced more of a gap between the two types of product. Percentage of slices scored as "paste-like" was significantly higher for the low-salt processed loins (36.0 vs 26.8, p=0.029), which further underlines how **meat muscle quality is a crucial factor when working with low-added-salt processes.** Conversely, proportion of slices presenting "sliceability" defects was found to be higher in standard-salt products, which does not fit with the other processing results. However, there is every reason to downplay the technological impact of this defect, as even though the IFIP singled it out as a slice integrity problem, industry processors tend to consider it far less of an issue for sensory quality of the end-product than the "paste-like" defect.

Mapped profile of ultimate pH

***Table 3:** pHu per site and mean per-site to all-sites correlations*

Measurement series—lateral		Measurement series—medial	
mean (SD)	Corr. / i sites	mean (SD)	Corr. / i sites
5.53 (0.16)	0.85	5.58 (0.17)	0.55
5.51 (0.14)	0.87	5.52 (0.13)	0.82
5.48 (0.14)	0.88	5.52 (0.14)	0.88
5.47 (0.15)	0.84	5.53 (0.16)	0.88
5.46 (0.13)	0.87	5.53 (0.17)	0.89
5.46 (0.13)	0.87	5.54 (0.18)	0.87
5.48 (0.14)	0.88	5.54 (0.18)	0.88
5.52 (0.15)	0.87	5.56 (0.17)	0.89
5.55 (0.17)	0.86	5.55 (0.17)	0.88

The amplitude of variation in ultimate pH according to loin measurement site was high (0.12 pH units) and affected not just the measurements in the *Spinalis thoracis* (site #2) but also the variations along the *Longissimus*. These factors reconfirm the benefits of having a precisely-defined in-loin ultimate pH measurement reference site.
The mean of the individual site-to-site correlations with each of the 18 measurement sites successively serving as reference was, in the main, fairly high, at between 0.82 and 0.89, with the exception of measurement site #2 (r=0.55) which corresponds to measurements performed not in the *Longissimus* but in the *Spinalis thoracis*. At this point in the study, the evidence suggests that with the exception of measurement site #2, all the measurement sites tested here would make good candidates as loin pH measurement reference site, with site-to-site cross-referencing being entirely feasible given the inter-site correlations.

Correlation between technological yield and pHu map

***Table 4:** Results of linear regressions between technological yield and ultimate pH for each of 18 loin measurement sites (R^2=coefficient of determination; RMSE=error) – standard-salt process end-products*

Measurement series—lateral		Measurement series—medial	
R^2	RMSE	R^2	RMSE
0.47***	2.7	0.09ns	3.5
0.48***	2.7	0.39***	2.9
0.46***	2.7	0.43***	2.8
0.41***	2.8	0.45***	2.7
0.47***	2.7	0.40***	2.9
0.44***	2.8	0.37***	2.9
0.37***	2.9	0.36***	2.9
0.36***	3.0	0.42***	2.8
0.37***	2.9	0.37***	2.9

Table 5: *Results of linear regressions between technological yield and ultimate pH for each of the 18 loin measurement sites (R^2=coefficient of determination; RMSE=error) – low-salt process end-products*

Measurement series—lateral		Measurement series—medial	
R^2	RMSE	R^2	RMSE
0.37***	2.7	0.09ns	3.2
0.41***	2.6	0.33***	2.8
0.42***	2.6	0.42***	2.6
0.36***	2.7	0.42***	2.6
0.43***	2.6	0.40***	2.6
0.42***	2.6	0.36***	2.7
0.35***	2.7	0.37***	2.7
0.37***	2.7	0.45***	2.5
0.39***	2.7	0.38***	2.7

The coefficients of determination for the prediction of technological yield for standard-salt process end-products were, in the main, fairly similar (from R^2=0.36 to R^2=0.48), with the exception of measurement site #2 (R^2=0.09). Mirroring the analysis of the inter-site pH results, site #2 holds no relevance for technological yield prediction. Site #3 and site #5 posted some of the highest R^2 values (0.48 and 0.46, respectively) but remain far enough from site #2 to minimize the risk of error when measuring pH in real-world industry-scale conditions. Sites #3 and #5 thus make good candidates as loin pH measurement reference sites and confirm the **loin technological yield–loin ultimate pH correlation** found in 2011 by Vautier *et al.* (R^2=0.49). The results of the regressions reported in Table 5 show a significant correlation between **pHu and technological yield for low-salt process end-products,** on a par with the level found for standard-salt process end-products (R^2=0.41 to 0.42 for sites #3 and #5 shortlisted as candidate reference sites). These correlations do not look quite as good in the R^2 values, but it is important to bear in mind that in Table 5, the pH measurements taken on right-side loins serve to predict the post-processing technological yields of left-side loins, which could naturally let a degree of inaccuracy creep in.

Correlation between technological yield and other quality metrics (pH1, conductivity1, conductivity24, colour)

Table 6: *Results of linear regressions between technological yield and meat quality parameters measured at just one loin measurement site (R^2=coefficient of determination; RMSE=error) for standard-salt and low-salt process end-products*

Variable	Site	Normal salt		Low-salt	
		R^2	RMSE	R^2	RMSE
pH1	Last rib	0.07*	3.6	0.06*	3.3
Temp. 1		0.15**	3.4	0.09**	3.3
Cond. 1		0.00^{ns}	3.7	0.00^{ns}	3.4
Cond. 24		0.00^{ns}	3.7	0.00^{ns}	3.4
L*	4th thoracic vertebra	0.30***	3.1	0.16**	3.1
a*		0.06*	3.6	0.04^{ns}	3.3
b*		0.20***	3.3	0.10**	3.2
L*	Last lumbar vertebra	0.17***	3.4	0.17**	3.1
a*		0.02^{ns}	3.7	0.01^{ns}	3.4
b*		0.06^{ns}	3.6	0.05*	3.3

pH1 of the loin explained only a negligible proportion of variability in technological yield (7% for standard-salt process end-products and 6% for low-salt process end-products), while conductivity—whether at 30 minutes or 24 hours post-mortem—failed to show any correlation with technological yield, regardless of measurement site (data not shown).

Only reflectance (L*) of *Longissimus* muscle measured at the 4th thoracic vertebra presented some relative value for technological yield prediction, explaining 30% of variability for standard-salt process end-products.

Prediction of technological yield by visible/ near-infrared spectroscopy

After the preliminary cross-validation step (n=10) required to determine the optimal number of PLS factors to include in each model (a procedure that helps increase model robustness; Dufour *et al.*, 2006), the PLS-based calibration plots showed contrasting performances on technological yield prediction according to anatomical site. These models explained 18% to 65% of yield variability for sites C and K, respectively (Table 7). In contrast to prediction by pHu measurement, it was the most posterior sites that posted the best results. Applying the first-order derivative signal pretreatment to the spectral data tangibly increased prediction performances for sites J and K but not for any of the other measurement sites.

Near-infrared spectroscopy demonstrated outstanding predictive power for loin technological yield, with accuracy far outperforming pHu measurement, both on coefficient of determination (0.65 vs 0.48, respectively) and error of calibration (2.2 vs 2.9). These results confirm the findings reported in Vautier *et al.* (2009) for ham technological yield predicted using the same type of visible/near-infrared spectroscope (R^2=0.60).

Visible/near-infrared spectroscopy showed much less powerful performances for technological yield prediction on low-salt-content processed loins. The likely explanation resides not in a process effect but almost certainly in a measurement site-specific effect that is much sharper for spectroscopy than pHu. Informative here is the fact that with pH measurement, it is possible to observe slight variations in pH between the right-side and left-side loin from the same pig without this variation causing any real loss of predictive performance when using right-side loin measurements to predict left-side loin technological yields post-processing. Spectroscopy measurement does not appear to be immune to this 'sidedness' as it is probably more measurement site-side specific and consequently appears to be **far less robust than pHu measurement at predicting yields** obtained on the opposite side.

Table 7: *Results of PLS regressions for calibration between near-infrared spectra calibration set on the Longissimus and technological yield after selecting number of PLS factors included in the model by cross-validation (n=10) – standard-salt process end-products*

Probing site	Cross-validation (n=10)	Calibration			
	RMSEP mini	Nb fact. PLS	Pretreated spectra	R^2	RMSEC
C	3.8	3	No	0.18	3.3
D	3.7	3	No	0.11	3.5
E	3.4	4	No	0.36	2.9
F	3.8	4	No	0.23	3.2
G	3.5	4	No	0.33	3.0
H	3.6	3	No	0.19	3.3
I	3.5	4	No	0.24	3.2
J	3.4	6	first-ord. deriv	0.49	2.6
K	3.2	10	first-ord. deriv	0.65	2.2

***Table 8:** Results of PLS regressions for calibration between near-infrared spectra calibration set on the Longis-simus and technological yield after selecting number of PLS factors included in the model by cross-validation (n=10) – low-salt process end-products*

Probing site	Cross-validation (n=10)	Calibration			
	RMSEP mini	Nb fact. PLS	Pretreated spectra	R^2	RMSEC
C	4.0	2	No	0.09	3.2
D	3.4	1	No	0.01	3.3
E	3.2	1	No	0.12	3.1
F	3.4	2	No	0.12	3.1
G	3.4	1	No	0.12	3.1
H	3.4	3	No	0.20	3.0
I	3.3	1	No	0.11	3.2
J	3.3	3	No	0.24	2.9
K	3.5	1	No	0.03	3.3

Anatomical variation of structural defects in processed loin slices

***Table 9:** Results for processed loin slice scores using the IFIP scoring scheme ("sliceability" and "paste-like" defects) and by anatomic location – standard-salt and low-salt process loin samples*

Probing site	Normal salt		Low-salt	
	% slices w/ "paste-like" defect	% slices with "sliceability" defect	% slices w/ "paste-like" defect	% slices with "sliceability" defect
C	40	35	40	23
D	49	48	57	37
E	41	49	51	37
F	26	59	36	52
G	11	71	26	62
H	11	74	26	60
I	17	70	30	61
J	27	72	32	56
K	26	69	28	62

Whether on standard-salt process or low-salt process end-products, the "paste-like" slice defect is far more frequently found in the shoulder-end third of the loin (43% and 49% of slices on average against 20% and 30% on the two posterior thirds for standard-salt and low-salt loin, respectively). Our results thus confirm Fleury Michon's reports of **recurrent textural problems with slices from shoulder-end pork loin.** The defect that the IFIP records as a **"sliceability"** problem cropped up repeatedly in both the low-salt and standard-salt processed loin, at higher frequency in the ham-end half (4% and 37% for the shoulder-end half against 71% and 60.2% for the ham-end half). Fleury Michon claims this defect is not damaging to product retailability or sensory acceptability, **which makes it a less important determinant of loin meat technological quality.**

Correlations between quality measures and slicing defects

The "sliceability" defect is significantly more common **when loin pHu is low**, whether on standard-salt or low-salt process end-products. The paste-like defect does not vary with ultimate pH regardless of process salt level, which points to non-homology with the paste-like defect found in cooked ham which varies significantly with ultimate pH (Vautier *et al.*, 2011).

The pH1 measurement does not look a good indicator of level of sliceability defect (no effect of pH1 class on percent occurrence of "sliceability" and "paste-like" defects). There was also no halothane genotype effect on frequency of the paste-like defect, whereas a halothane genotype effect is observable on fresh ham muscle in frequency of the "structureless ham" defect.

Conclusion

Of several now-standard meat quality measurements, whatever the anatomic site measured, **only ultimate pH** shows a satisfactory prediction level for technological yield: **for the best site identified (10 cm in from the very tip of the shoulder-end),** the ultimate pH measurement explains 48% of technological yield variations with a prediction error of 2.7 points.

Signal pretreatment on the visible/near-infrared spectra revealed a clearer relationship between yield prediction by spectroscopy and actual technological yield than for prediction by ultimate pH: the best-performing model explains up to 65% of variability in technological yield, with an error of calibration of 2.2 points (after using cross-validation to select the model). The data found here confirm **near-infrared spectroscopy as a powerful predictor of technological yield on pork loin,** as previously found by Vautier *et al.* (2009) investigating the cooked ham model.

***Table 10:** Frequency of "paste-like" and "sliceability" defects compared by ultimate pH class (pH24 class: 1<5.4 / 5.4<2<5.5 / 5.5<3<5.6 / 4>5.6)*

		pH24 class				p.=
		1	2	3	4	
n=		22	31	16	11	
% Paste-like	Normal salt	0.25	0.25	0.38	0.21	ns
% Sliceability		0.79_a	0.64_a	0.60_{ab}	0.31_b	0.0073
% Paste-like	Low-salt	0.40	0.36	0.43	0.20	ns
% Sliceability			0.56_{ab}	0.37_{bc}	0.20_c	0.0013

***Table 11:** Frequency of "paste-like" and "sliceability" defects compared by pH1 class (1<6.0 / 6.0<2<6.3 / 3>6.3) and halothane genotype (NN vs Nn)*

		pH@1 class			Hal		p.=
		1	2	3	NN	Nn	
n=		2	33	45	22	58	
Paste-like	Normal salt	0.15	0.29	0.26	0.23	0.28	-
Sliceability		0.34	0.61	0.65	0.54	0.66	-
Paste-like	Low-salt	0.06	0.43	0.32	0.30	0.39	-
Sliceability			0.53	0.49	0.29_a	0.59_b	Hal**

This study also found that cooked loin suffers a high occurrence **(i.e. around 30% of loins) of a structural defect** similar to the **"paste-like"** defect in cooked ham. The defect is essentially localized to the **shoulder-end third of the loin,** and we were unable to find any clear-cut correlations between percentage of "paste-like" slices and standard meat quality parameters (colour, conductivity at 30 minutes, conductivity at 24 hours, pH at 1 hour, ultimate pH, halothane genotype). Over and above predicting technological yield, the ability to predict this "paste-like" defect in cooked-and-sliced pork loin—and implement countermeasures to reduce its occurrence—is the next big **challenge for the meat curing and packing industry.**

Acknowledgements

France AgriMer provided financial support.
This study was financed under the French national programme for rural and agricultural development.

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How to cite

- *Vautier A., Gault E., Lhommeau T., 2015. Aptitude technologique de la longe pour une transformation en salaison : identification des principaux prédicteurs du rendement technologique et tranchage. Cahiers IFIP, 2(2), 41-52.*