Visible spectroscopy and redox potential as alternatives of ultimate pH for cooking yield prediction

A. Vautier[1*], A. Bozec[1], E. Gault[1], T. Lhommeau[1], JL. Martin[2], and JL. Vendeuvre[2]

1 IFIP – French institute for pig and pork industry. La motte au Vicomte, BP 35104, 35561 Le Rheu Cedex, France.

2 IFIP – French institute for pig and pork industry. 7 avenue du Général de Gaulle, 94704 Maisons-Alfort Cedex, France.

*Corresponding author (phone: +33(0)2-99-60-98-57; fax: +33(0)2-99-60-93-55; e-mail: antoine.vautier@ifip.asso.fr)

Abstract— **The opportunity to use redox potential and visible spectroscopy for cooking yield prediction was investigated in processed meat. Whereas the relationship between ultimate pH (pHu) and cooking yield is well documented, the redox potential may help to understand the meat quality response in processed meat. Visible spectroscopy was tested as a more reliable alternative to pHu. Two experiments were run on cooked cured hams (SM) and loins (LD). To increase the meat quality variability, processing was performed with deboned and bone-in hams, and with loins stored under modified atmosphere or vacuum. Redox potential determination was carried out according to Rödel study [1] and visible spectra were collected with a spectrocolorimeter. The meat was processed following industrial standards and materials. Individual traceability was maintained from brine injection to slicing. For the 2 experiments, a strong relationship was confirmed between pHu and cooking yield (r=0.79, r=0.70) while the correlations with redox potential was not significant (r=-0.21, r=-0.24, SM and LD respectively). PLS cross-validation treatment of visible spectra showed high prediction level for the cooking yield of hams (r=0.70 and rmsec=2.1) and loins (r=0.67 and rmsec=2.0), not far from the pHu prediction level (rmse=1.8 and rmse=1.9, for SM and LD respectively). Redox potential measurements did not explain cooking yields variations for cured hams and loins, but a strong relationship was confirmed with pHu. PLS results suggest that visible spectroscopy might be considered as an alternative to pHu for cooking yield prediction.**

Keywords— **cooking yield, pH, spectroscopy, pork**

I. INTRODUCTION

Ultimate pH relationship with cooking yield of industrial processed ham is well documented and correlation levels from r=0.58 to r=0.84 are reported [2], [3], [4]. Ultimate pH is also considered as one of the best indicators for the risk level of the “PSE-like zones” defect occurrence on raw hams [5]. However, a lot more research is needed to explain some of the variability in process yield results (cooking and slicing yields). As the post mortem oxidation level of muscle proteins could be one of the factors implicated in the “PSE-like zone” defect origin, the present study focuses on the possibility to predict meat quality with redox potential measurements. Its relationship to processing yields has been investigated for cooked ham and also for cooked loin that recently showed increasing production ratios in the meat processing sector in France. The use of visible spectroscopy for processing yields prediction was investigated too, considering some reliable aspects of the technique (versus the relative versatility of pH measurements under industrial conditions).

II. MATERIAL AND METHODS

Eighty hams and loins were studied from the primary cutting of the carcasses (24 hours post mortem) to the end of the process in a French industrial factory. To produce contrasted oxidative environments, hams were alternatively deboned or not, and loins were alternatively stored under modified atmosphere or vacuum. The delivery time to the factory varied from 3 to 6 days post mortem for both hams and loins. Measurements were performed at the end of the storage time. Ultimate pH was measured in the *Semimembranosus* (5cm from the coxal bone edge) and *Longissimus* (last rib) muscle with a pH+ pH-meter (Sydel, France) and a Xerolyt® electrode (Mettler Toledo, Schwitzerland). Redox potential was measured according to Rödel protocol [1] with a platinum pT6140 electrode (Schott, Germany) introduced in the same muscle areas that were used for pH measurements. With no calibration needed, redox curves were stable after an inconsistent waiting period (from 30 min. to hours), but in order to collect a representative number of data, we standardized this time to 90 min. Visible spectroscopy measurements (400-700nm) were performed with a CM 600D spectrocolorimeter (Konica-Minolta, Japan) on the *Gluteus Medius* (primary cutting) and on the *Longissimus* (last lumbar vertebrae) muscle after 90 minutes of blooming (D65 illuminant). After deboning (3 to 6 days post mortem), “PSE-like zone” defect quotation was performed on raw hams according to the IFIP scale [6].

Hams and loins were calibrated to the same weight at the factory, then individually brine injected and vacuum packed to maintain individual traceability during the tumbling. After cooking and a 7 day long resting period, each bag was opened and cooking yields were determined. Standard automatic slicing lines were used to determine the slicing yields. For hams, the defected slices frequency was estimated in line with a unique operator. The quotation of loin slices was performed in the IFIP laboratory, focusing on 2 major defects (“paste-like” texture, and slice cohesion).

Chemometric data analysis was performed with the 7.8.0 version of Matlab (R2009a, The Math Works Inc., USA) and using the Saisir package developed for Matlab by D. Bertrand (http://easy-chemometrics.fr). The effect of “pse-like zones” defect class on meat quality parameters and industrial process yields were estimated with the 8.02 version of SAS (SAS Institute, USA), using the GLM and LSMeans procedures.

III. RESULTS

General meat quality results are reported in the table 1. Ultimate pH level and variability correspond to standard meat quality data [5].

Table 1: general meat quality and processing yield results (mean, standard deviation) for hams and loins.

Item	Hams	Loins
n=	80	80
pH u	5.71 (0.19)	5.61 (0.15)
Redox Potential (mV)	-63.5 (25.8)	-92.3 (32.7)
Cooking yield (%)	89.7 (3.0)	93.8 (2.7)
Slicing yield (%)	92.4 (7.8)	55.6 (22.9)
L*	49.6 (4.1)	55.1 (3.5)

The correlations between pHu and cooking yields are strongly significant ($p<0.0001$, table 2) for both hams and loins. Muscle lightness L* and cooking yields correlations are significant but their levels are lower. Redox potential measurements relationship with cooking yields are only significant for loin processing ($p<0.05$) with low correlation values.

Table 2: linear regression results and relationship between meat quality parameters and cooking yield for hams and loins.

cooking yield of hams				
	R²	rmse	Y=	r=
pH u	0.62	1.8	Y=0.200+0.122*pHu	0.79^{***}
Redox Pot.	0.04	3.0	-	-0.21^{ns}
L*	0.39	2.3	Y=1.126-0.005*L*	-0.63^{***}
cooking yield of loins				
	R²	rmse	Y=	r=
pH u	0.48	1.9	Y=0.230+0.126*pHu	0.70^{***}
Redox Pot.	0.06	2.6	-	-0.24^{*}
L*	0.24	2.3	Y=1.140-0.004*L*	-0.49^{***}

Variance analysis results shows for hams a significant effect of the “PSE-like zones” defect grade on *Semimembranosus* pHu, *Gluteus medius* lightness, cooking and slicing yields (table 3). Redox potential results do not differ between the 4 grades.

Table 3: meat quality results by “PSE-like zones” defect class for hams.

	Defect class				p.=
	1	2	3	4	
n=	48	16	10	6	
pH u	5.77_a	5.66_{ab}	5.57_b	5.58_{ab}	0.003
Redox Pot. (mV)	-64.1	-62.5	-52.0	-79.0	ns
Cooking yield (%)	90.9_a	89.4_b	87.4_{bc}	85.5_c	<0.0001
Slicing yield (%)	94.2_a	93.6_{ab}	89.2_{abc}	80.9_c	0.0003
L*	48.3_a	50.4_{ab}	52.1_b	54.4_b	0.0003

PLS cross validation treatments of the *Gluteus Medius* visible spectra revels an accurate prediction for hams cooking yield ($R^2=0.49$, rmsec=2.1) with 2 PLS factors (table 4), the rmsev values are increasing with extra PLS factors included in the model (figure 1). *Longissimus* spectra treatments with a number of 6

PLS factors (figure 2) shows similar prediction level for the cooking yield of loins (R^2=0.45, rmsec=2.0).

Table 4: results for visible spectroscopy calibration and cross-validation sets of PLS regression of cooking yields (average results based on 10 random cross validations)

cooking yield of hams				
	nb. PLS factors	spectra sampling	R^2	rmse
calibration	2	78/78	0.49	2.1
validation		26/78	0.50	2.3
cooking yield of loins				
	nb. PLS factors	spectra sampling	R^2	rmse
calibration	6	80/80	0.45	2.0
validation		27/80	0.41	2.2

Figure 1: selection curves of the number of PLS factors for the hams cooking yield prediction by visible spectroscopy.

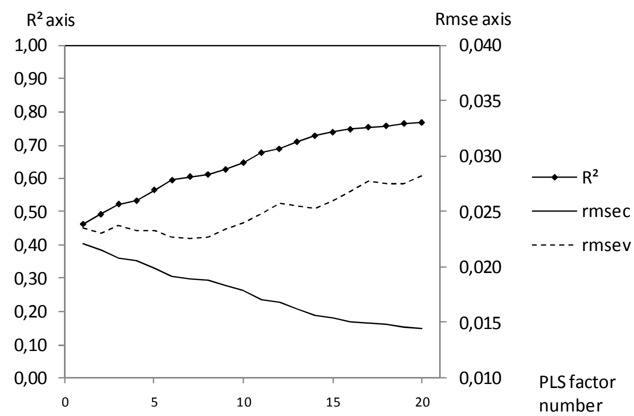
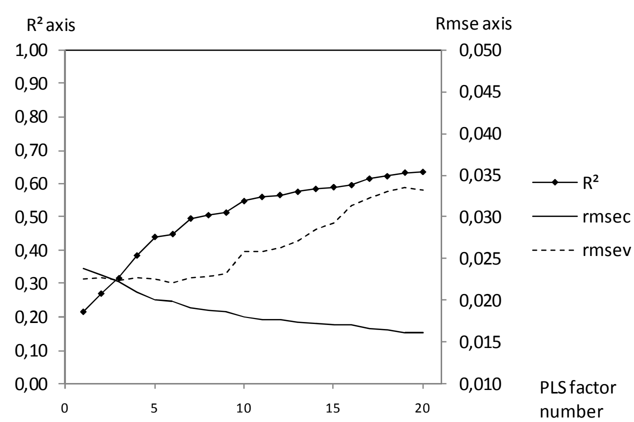


Figure 2: selection curves of the number of PLS factors for the loins cooking yield prediction by visible spectroscopy



IV. DISCUSSION

Hams cooking yields were about 10 points lower (m=89.7, table1) than the usual results for this meat quality level (pHu m=5.71) and one reason could be the reducing of the tumbling effect when the meat is individually vacuum packed. The slicing yield is very low for loins (m=55.6%, IFIP quotation) but it does not represent the same commercial acceptance notion as for hams.

The cooking yield of hams is strongly related to the *Semimembranosus* pHu (r=0.79, table2) and the *Gluteus Medius* lightness L* (r=-0.63), as reported in previous work on cooking yields [2], [3], [4]. The same results are observed for cooked loins with a lower correlation level (r=0.70 and r=-0.49, respectively). Redox potential measurements explained a reduced part of cooking yield variability (r=-0.21 and r=-0.24 for hams and loins respectively). A high standard deviation level for redox potential results (25.8 and 32.7mV for hams and loins respectively), as reported by Pichner [7] (standard deviations from 29 to 94mV) may introduce the difficulties to get stable redox potential measurements in meat, even with a 90 minutes stabilisation period.

Semimembranosus pHu and *Gluteus Medius* lightness variations with "PSE-like zones" defect class are similar to previous research [5], but the overall severe defect frequency (class 3+4) is 4 to 5 times higher than in this study (table 3). This is consistent with the non controlled fasting time and resting time prior to the slaughtering of pigs, such experiment settings were determined in order to increase the meat quality variability. Significant gaps in cooking and slicing yields for extreme "PSE-like zones" defect class confirm the relationship between the raw meat defect and the structure problems occurring on processed meats.

Cross-validation PLS treatments carried out on 400-700nm spectra produced a high prediction level for the cooking yield of hams (r=0.70, rmsec=2.1). The determination of the number of PLS factors was proceed according to Bertand recommendations [8] focusing on robustness and the rmsev results. With such a method, PLS prediction is slightly less precise than pHu linear regression (r=0.79, rmse=1.8), but the improved reliability of the visible spectra measurement is an important point for industrial purpose, compared to the environment sensitivity of pH measurement (electrostatic forces and electromagnetism). In addition, cross-validation PLS treatment of visible spectra from *Longissimus* showed a prediction level (r=0.67, rmsec=2.0) very close to pHu regression results for cooking yields of loins (r=0.70, rmse=1.9).

V. CONCLUSIONS

This study confirms the strong relationship between ultimate pH and cooking yields for processed pork hams and loins. Redox potential data did not explain cooking yields results. For stabilisation time concerns and because of the high variability level of the measurement, redox potential is not an accurate method to predict cooking yields on raw meat. After all, visible spectroscopy may be considered as an alternative to ultimate pH when predicting cooking yields. The prediction levels are similar, and the high reliability of spectroscopic methods is a criterion that meat industry companies are looking for.

ACKNOWLEDGMENT

We are grateful to the Fleury Michon meat processing company for their dedication in this special meat process.

This work has been supported by FranceAgriMer.

REFERENCES

1. Rödel W. und Scheuer R. (1998). Das redoxpotential bei fleisch und fleischerzeugnissen, 1- beteutung, messung und berechnung des redoxpotentialwertes. Fleischwirtschaft 78(9):975-981.
2. Jacquet B., Sellier P., Runavot J.P., Brault D., Houix Y., Perrocheau C., Gogué J., Boulard J. (1984). Prédiction du rendement technologique de la fabrication du jambon de Paris à l'aide de mesures prises à l'abattoir. Journées de la recherche porcine en France, vol. 16, p. 49-58.
3. Gueblez R., Le Maitre C., Jacquet B., Zert P. (1990). Nouvelles équations de prédiction du rendement technologique de la fabrication du jambon de Paris. Journées de la Recherche Porcine en France, vol. 22, p. 89-96.
4. Alviset G., Braud J., Vidal E. 1995. Influence du pH ultime et de trois génétiques sur la qualité du tranchage des jambons Label Rouge commercialisés en libre service. Bulletin de Liaison du CTSCCV, vol.5(1), p.10-24.
5. Vautier A., Boulard J., Bouyssière M., Houix Y., Minvielle B. 2008. Prediction level of meat quality criteria on « pse-like zones » defect of pork's ham. 54th International Congress Of Meat Science And Technology. Cape Town, SA.
6. IFIP. 2005. Grille de notation du défaut « déstructuré » des muscles de la cuisse de porc.
7. Pichner R. (1999). Untersuchungen am frischem und gelagertem schweinefleisch zur evaluierung geeigneter frischeparameter. Vet. Med. Dissertation, München.
8. Bertrand D. et Dufour E. (2006). La spectroscopie proche infrarouge et ses applications analytiques. 2éme édition. Tech et Doc, Lavoisier. p.466-467.