TOWARDS AN ONLINE ASSESSMENT OF MEAT QUALITY IN PORK

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Abstract – The quality of pork is quite variable. A common deviation in pork is PSE, characterized by pale colour, soft and exudative meat along with a low pH_{45}. Presently, differences in meat quality cannot be detected online during the production process. However, in view of an increasingly automatized process of dissection, an early determination of quality could be of great importance. Therefore, we evaluated Raman spectroscopy as a fast and non-invasive method to assess meat quality, suited for online application. For a sample of 156 hams, pH_{45}, pH_{24}, colour, drip loss, and shear force were determined as quality parameters for the *semimembranosus* muscle. These parameters allowed to sort hams unambiguously into eight quality classes. Almost 60% were sorted as "normal", but as many as 35% as "exudative". The correlation between reference parameters and Raman spectra was determined with PLS regression. Spectra measured 24 h p.m. produced promising regression models for pH_{24} and drip loss, with R^2=0.87 and R^2=0.82, respectively. Prediction model for shear force with Raman spectra measured 24 h p.m. was not possible, but with Raman spectra measured 1 h after slaughter. This PLS model gave the overall best correlation, with R^2=0.95.

Key Words – Drip loss, Rapid method, pH, Raman spectroscopy, Shear force

I. INTRODUCTION

The quality of pork is quite variable. Important parameters to describe meat quality are pH-value (pH), drip loss (DL), colour (in particular, L*), and tenderness (shear force, SF).

The pH characterizes the post mortem glycolysis and thus differentiates between "normal" RFN (reddish-pink, firm, non-exudative), PSE (pale, soft, exudative) and DFD (dark, firm, dry) meat [1]. Tenderness and colour are very important criteria for consumer acceptance.

The usual laboratory methods to determine these parameters are time consuming and require destructive sampling. Thus, it is not possible to measure all these quality parameters directly online during the slaughter process. Therefore, at present, the only sorting criteria are lean meat content of the carcass or weight of different cuts. The project outlined in this paper evaluates Raman spectroscopy as an analytical method for fast online determination of quality parameters without compromising the carcass.

II. MATERIALS AND METHODS

In total, a field sample of 156 hams was collected. Quality parameters and Raman measurements were taken on the *M. semimembranosus* (SM). The pH was measured 45 min (pH_{45}) and 24 h (pH_{24}) p.m. in duplicate with a puncture electrode (Portamess 913XpH, Knick, Berlin, Germany). For determination of DL, a 2 cm slice of SM was stored at 4°C for 72 h [2]. Drip loss was expressed as the percentage difference between initial and final weight. To characterize tenderness, SF of cooked meat samples was measured with a Warner-Bratzler shear blade (Instron Series 5564, Instron Deutschland GmbH, Pfungstadt, Germany) [3]. Colour was measured in the L*a*b* system with a Minolta CR400 (Konica Minolta Optics, Inc., Tokio, Japan) 24 h p.m. on a fresh cut. Only L* was used for data analysis. Afterwards, the Raman spectra were measured using a hand-held 671 nm Raman probe described earlier [4]. Ten Raman measurements were performed at different sites of the SM with 80 mW laser power, an integration time of 5 s per spectrum and 5 accumulations. For further analysis, all meat spectra per sample were averaged.

For statistical analyses, partial least squares regression (PLSR) was performed with the PLS toolbox 6.2 (Eigenvector Research Inc.,

Wenatchee, WA, USA) based on MATLAB 7.9.0 R2009b (The Mathworks Inc., Natick, MA, USA). Cross-validation was applied for random blocks with 9 data splits and 20 iterations.

III. RESULTS AND DISCUSSION

The slaughter weight of animals sampled ranged between 76 and 122 kg, with an average lean meat content of 58% ± 4.2%-points standard deviation (SD). The weight of hams ranged between 11 and 18 kg. Quality parameters varied in a usual range, with variation coefficients between 5% for ph_{45} and 48% for DL (cf. Table 1).

Table 1 Overview of parameters analysed. Mean, standard deviation (SD), and range (Min–Max) are for n=156.

	pH_{45}	pH_{24}	L*	DL[%]	SF[N]
Mean	6.3	5.5	49.6	4.2	48.7
SD	0.3	0.2	3.4	2.0	6.9
Min	5.4	5.3	41.0	0.7	35.7
Max	6.8	6.1	57.9	10.7	68.7

Table 2 Quality parameter values to differentiate meat quality classes (PSE – pale, soft, exudative; s-PSE – slightly PSE; RSE – reddish-pink, soft, exudative; AM – acid meat; PFN – pale, firm, non-exudative; RFN – reddish-pink, firm, non-exudative; DFD – dark, firm, dry; s-DFD – slightly DFD)

	pH_{45}	pH_{24}	L*	DL	main trait
PSE	<5.8			>5%	
s-PSE	>5.8		>50	>5%	exudative
RSE	>5.8		<50	>5%	
AM	>6.3	<5.4		<5%	
PFN	>5.8	>5.4	>50	<5%	normal
RFN	>5.8	>5.4	<50	<5%	
s-DFD		5.7-6.0		<2%	dry
DFD		>6.0		<2%	

When rating the hams according to the parameters pH_{45}, pH_{24}, DL, and L*, not all samples could be assigned to the standard meat-quality classes RFN, PSE and DFD. A finer differentiation into intermediate quality classes was required to differentiate clearly all 156 hams (Table 2).
According to the criteria in Table 2, 89 hams (57%) were assigned to normal DL classes, only 7 PSE and 4 DFD hams were identified (Figure 1). However, 48 hams were assigned to the intermediate classes slightly PSE (17%) and RSE (14%). All exudative classes together added up to 35%, which was an unexpected high percentage.

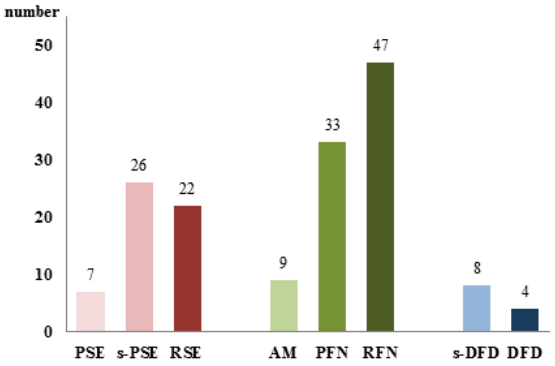

Figure 1. Distribution of hams into the quality classes of Table 2 (n=156)

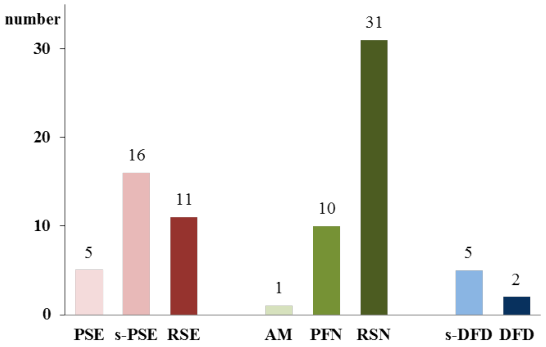

Figure 2. Distribution of hams into quality classes for the subsample used for PLSR (n=96)

All quality parameters were analysed in the laboratory. They are not suited for online measurements because methods are time consuming (DL) or invasive (pH). Hence, Raman spectroscopy was used as a fast and non-invasive method with potential for online measurement. For the evaluation of its suitability to predict selected quality parameters (namely, pH_{24}, DL and SF), Raman spectra were measured 24 h after slaughter. PLSR was used to predict the reference data. Raman measurements were restricted to a subsample of the data set. The distribution into quality classes is largely the same for this subsample (Figure 2) as for the overall sample (Figure 1).

Raman spectra could best predict pH_{24} (Figure 3). The coefficient of determination for the prediction model was R^2=0.87, with a cross validation error RMSECV=0.15. As the prevalence of DFD hams was rather low in this random sample, the distribution of the pH values was unbalanced. To obtain a more balanced distribution, more DFD samples should be included. However, such extra DFD hams would have to be selected from a much larger sample. Nevertheless, the two DFD hams are clearly separated from all other samples, and even the slightly DFD hams with a pH between 5.7 and 6.0 are clustered (Figure 3).

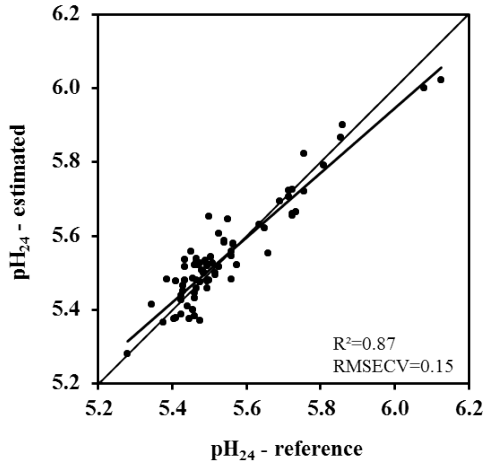

Figure 3. PLSR prediction of pH_{24} from Raman spectra measured 24 h p.m., with regression and identity lines

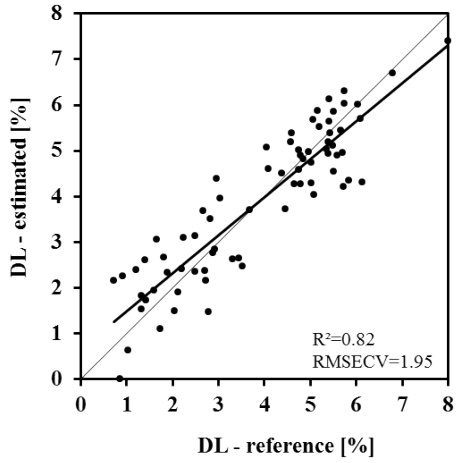

Figure 4. PLSR prediction of DL (72 h p.m.) from Raman spectra measured 24 h p.m., with regression and identity lines

The estimation of DL also achieved promising results with R^2= 0.82 and RMSECV= 1.95 (Figure 4). However, the prediction of DL alone is not sufficient for sorting into quality classes because the error of nearly 2%-points is still too high.

Furthermore, we tried to predict SF from Raman spectra measured 24 h p.m. (Figure 5A). But this was not successful, yielding a far too low R^2=0.17. As an alternative, we could use Raman spectra that were measured 1 h p.m. on the same subsample as part of a parallel study [5]. These Raman measurements provided an astonishing better prediction model with R^2=0.95 and RMSECV=3.35 (Figure 5B). Obviously, information to predict SF is available from early p.m. Raman measurements, but this information has been lost over time from the spectra by 24 h after slaughter.

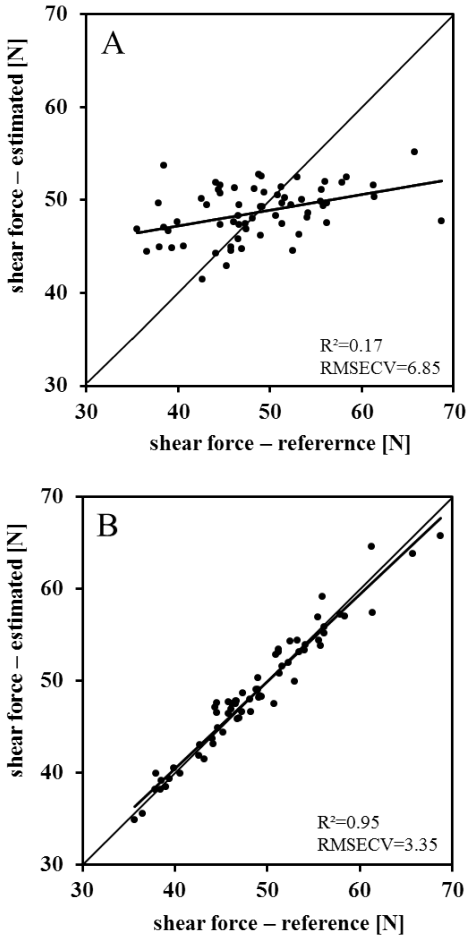

Figure 5. PLSR prediction of SF (72 h p.m.) from Raman spectra measured 24 h p.m. (A) or 1 h p.m. (B)

IV. CONCLUSION

Based on the reference parameters pH_{45}, pH_{24}, L* and DL, we achieved an unambiguous and differentiated sorting of a large sample of hams into eight quality classes. Both, pH_{24} and DL could be predicted with Raman spectra taken 24 h after slaughter. These results indicate that recognition of s-DFD and DFD hams should be possible online by means of Raman spectroscopy. SF could not be predicted by Raman spectra taken 24 h p.m., but by spectra taken 1 h p.m.. Consequently, timing of measurements appears to be an important issue for practical application. Overall, prediction of relevant quality parameters by Raman spectroscopy provides good potential as a non-invasive method to sort meat during the production process.

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