BEEF TENDERNESS PREDICTION BY NIR? - NOT IN REALITY YET

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***Abstract*—Information on the tenderness of beef at an early stage after slaughter will be of value in the distribution chain and increase chance of obtaining more satisfied beef consumers. NIR measurement has recently shown results indicating potential as relevant measuring technology and was therefore tested in a commercial meat plant on loin steaks from a total of 149 cows and young bulls representing the market variation in stock groups supplied for slaughter. The day after slaughter NIR spectra were measured in the centre of bloomed steaks cut at 13th rib and at 5th rib - 6th rib respectively. The sirloin was aged two weeks at 5°C for sensory tenderness profiling by a trained panel assessing tenderness attributes on an intensity scale from 0-15. The mean tenderness value was 6.7 with a standard deviation of 2.8. Unscrambler PLS1 models were established on selected individual wavelengths to predict the sensory tenderness score. Best models obtained for predicted tenderness from NIR wavelengths at day one after slaughter resulted in a correlation to sensory tenderness of aged beef of 0.52 and SEP/RMSEP of 2.4. Thus it was concluded that measurements with the used NIR technology on the day after slaughter did not seem adequate for commercial sorting of beef according to a prediction of sensory tenderness.**

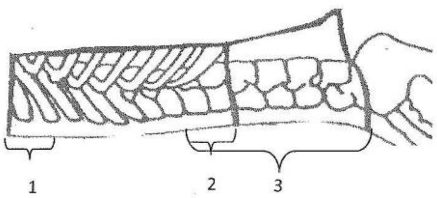
***Index Terms*—Beef, NIR, Tenderness.**

I. INTRODUCTION

Tenderness has long been considered the most important beef palatal attribute. It is also the most variable attribute and it strongly affects consumer satisfaction with beef (Montgomery *et al.*, 2004). Furthermore, investigations have shown that the consumer is willing to pay for guaranteed tender beef (Boleman *et al.*, 1997). As a consequence the perspectives for tools for measuring and sorting beef according to tenderness seem obvious. Over time several instruments and methodologies have been tested with variable success and so far systems in commercial use are few. Recently NIR as a method has been readdressed as on line method showing some potential (Bowling et al., 2009; Rosenvold et al., 2009). Since the tenderness variability is often claimed as a major challenge for beef in the Danish market is was decided to test if a recent NIR system had sufficient potential for accurately measuring tenderness variation in major Danish beef product sources from either young bulls or cows.

II. MATERIALS AND METHODS

A total 85 cows and 64 young bulls, all of Holstein Friesian origin were selected at a commercial slaughter plant for NIR measurement on the day after slaughter. The animals were selected to represent a realistic sample of two of the larger groups of stock provided for slaughter in the market with respect to age, weight and EUROP classification, table 1. Carcasses had been low voltage electrically stimulated 15 min. after sticking for 30-35 s with a setting of pulse width 6 ms – break 78 ms – voltage 78 V – duration 35 s. Ten of the cows were not electrically stimulated due to technical reasons. The carcasses were selected for NIR measurement the day after slaughter and thereby equalized to app. 4°C in the loin muscle at the time of measurement. pH and temperature were measured at 5-6 lumbar vertebra using a Knick Portamess pH-meter equipped with a Mettler-Toledo Lot 406-M6-S7/25 electrode and a Testoterm thermometer. The measurements were carried out in the chilling room the day after slaughter. Hence min. 18 h post mortem.



1 = 2 cm steak for NIR measurement   2 = 2 cm steak for NIR measurement, pH and tempature   3 = Sirloin sample for sensory panel evaluation

Figure 1. Measuring and sample locations

NIR-measurements - It was decided to measure with the NIR instrument both at the end of the pistol at 5th rib - 6th rib, which will be convenient for commercial use of the method, and also on the sirloin cut at 13th rib, which will ensure a measure near to the reference sample taken for sensory analysis. pH/temperature measurements were carried out before NIR measurements with a equipment from ADS Inc., USA QualitySpec® BT (QSBT). Two steaks were cut at respectively 5th rib - 6th rib and at 13th rib and bloomed for 1 hour, figure 1, and one NIR measurement was conducted placed in the center of each cut steak surface. The NIR instrument was adjusted to measure from 350 to 2500 nanometer, and had a measuring head aperture diameter of 28mm, after screening the head from external light with a black plastic screen.

Sensory analysis - The sirloin was cut at 13th rib for sensory analysis, figure 1. Samples were vacuum packed and aged at app. 5°C for 14days and then frozen at minus 18°C. The meat was thawed at 6°C for 20 h prior to cooking and sensory analysis. Steaks 20 mm thick were cut and equalized to 15°C at room temperature until cooking on a pan at 170°C to a core temperature of 63°C. From the center of each steak two to three slices were cut, 2.5 cm x 4 cm. Each assessor was served one slice on a preheated plate. The sensory panel had received basic training based on ISO 4121, ASTM-MNL 13, DIN 10964 and the assessors were all familiar with meat assessments and descriptive analyses. Prior to the analysis the panel was trained on samples presented in the experiment, samples from cows and young bulls were analyzed in the same session. Cooking loss was recorded by weighing steaks before and after cooking.

The sensory analysis was carried out as a conventional profiling. The attributes assessed comprised tenderness, juiciness, hardness at first bite, crumbliness, chewing time, chewing remains, roasted beef flavour. The attributes were assessed on a continuous scale from 0 (no intensity) to 15 (high intensity).

Statistical analysis - The comparison of sensory data of cows vs. young bulls was carried out with the Statistical Analysis System version 9 (SAS Institute, Cary, NC, USA) with the following model attribute = animal group.

Models for prediction of tenderness from recorded NIR spectre by selecting several individual wavelengths was carried out with PLS1 in Unscrambler version 9.8 (Camo, 2008). In the analysis a full cross validation was used to obtain a stable model and uncertainty test to evaluate the robustness of regression coefficients. The uncertainty test points to wavelenghts significantly contributing to the tenderness prediction model by the so called ”jack-knifing” method and thereby limiting model overfitting (Esbensen, 2002).

III. RESULTS AND DISCUSSION

The characteristics of selected animals/carcasses are given in table 1.

Table 1. Average, Standard deviation (SD), minimum and maximum of carcass weight, EUROP conformation & fat class, pH and temperature in sirloin at time NIR measurement, (N=149)

All carcasses (n=149)	Avg.	SD	Min	Max
Age (month)	37.8	22.2	13	100
Carcass weight (kg)	295.6	57.6	152	442
EUROP Conformation	4.0	1.8	1	10
EUROP Fat class	2.8	0.9	1	5
Temperature (°C)	3.7	1.1	1.4	7.9
pH	5.7	0.2	5.5	7.0
Cows (n=85)				
Age (month)	55.2	12.4	22	100
Carcass weight (kg)	315.2	60.1	152	442
EUROP Conformation	3.2	1.3	1	7
EUROP Fat class	2.9	1.0	1	5
Temperature (°C)	3.7	1.2	1.4	6.9
pH	5.7	0.3	5.5	7.0
Young bulls n=64				
Age (month)	14.7	2.0	13	20
Carcass weight (kg)	269.5	42.1	196	381
EUROP Conformation	4.9	1.9	3	10
EUROP Fat class	2.5	0.5	1	3
Temperature (°C)	3.6	1.1	1.6	7.9
pH	5.7	0.1	5.5	6.3

Sensory panel evaluations and cooking loss is given in table 2. The 10 cows that were not electrically stimulated did not differ in sensory quality or other characteristics to the other cows in the data set and have therefore been included in the full dataset.The high Chronback α indicates a very reliable reference for the tenderness value. The cows with higher age had as expected a lower tenderness than the young bull, but the variation in the groups were at the same level.

Table 2. Sensory evaluation of sirloin steaks. Lsmeans and standard deviations in (). Scale 0-15. (N=149)

Trait	Cows n=85	Young bulls n=64	P	All carcasses	Chronback's
Tenderness	6.2^{a} (2.7)	7.3^{b} (2.8)	0.02	6.7 (2.8)	0.91
Juiciness	9.8^{b} (1.1)	9.2^{a} (1.2)	<0.0001	9.6 (1.2)	0.74
Hardness at first bite	7.1^{b} (1.9)	6.1^{a} (1.9)	0.0007	6.7 (2.0)	0.86
Crumbliness	3.2^{a} (1.9)	4.2^{b} (2.2)	0.003	3.6 (2.1)	0.88
Chewing time	9.7 (2.3)	9.0 (2.4)	0.06	9.4 (2.4)	0.91
Chewing remains	9.2 (2.7)	8.4 (2.7)	0.07	8.8 (2.8)	0.91
Roasted beef flavour	8.0^{b} (1.2)	6.9^{a} (0.7)	<0.0001	7.5 (1.1)	0.64
Cooking loss	15.1 (0.3)	15.4 (2.4)	0.3	15.2 (2.2)	-

The selected carcasses for measurement appear to have a variation in tenderness that represents sufficiently what may traditionally occur in the population of the two groups, figure 2.

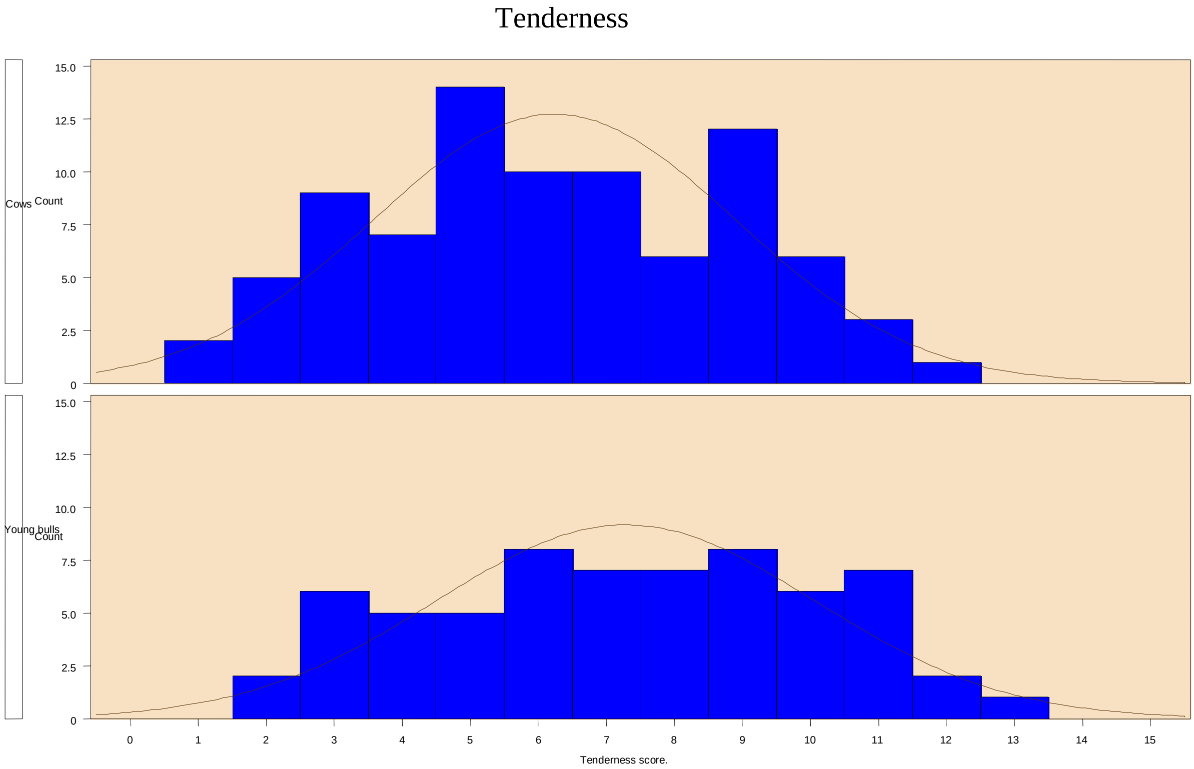


Figure 2. Distribution of tenderness scores of the 85 cows and 64 young bulls

NIR spectra were especially noisy outside the area of 450nm to 2350nm, see figure 4. A pls1 model was made with in this range to establish the best fit to the sensory tenderness value. The model included wavelenghts from the regions following regions 450-1403, 1554-1557 and 1559-1859 nm respectively.

The best models obtained for predicted tenderness from NIR wavelengths measured at 13th rib at day one after slaughter resulted in a correlation to sensory tenderness of aged beef of 0.52 and SEP/RMSEP of 2.4, figure 5. Models with very few wavelengths were also tried, but in all cases the models predicted tenderness less accurate, even when modeling within the cow and young bull groups separately.

The measurements from 5th rib - 6th rib resulted in models with poorer results, results not shown. Since the model prediction error for tenderness in magnitude is not very different from the standard deviation of tenderness on the measured carcasses the used NIR technology does not seem adequate for commercial sorting of Danish beef according to a NIR measure on day one after slaughter used for a prediction of sensory tenderness after two week aging.

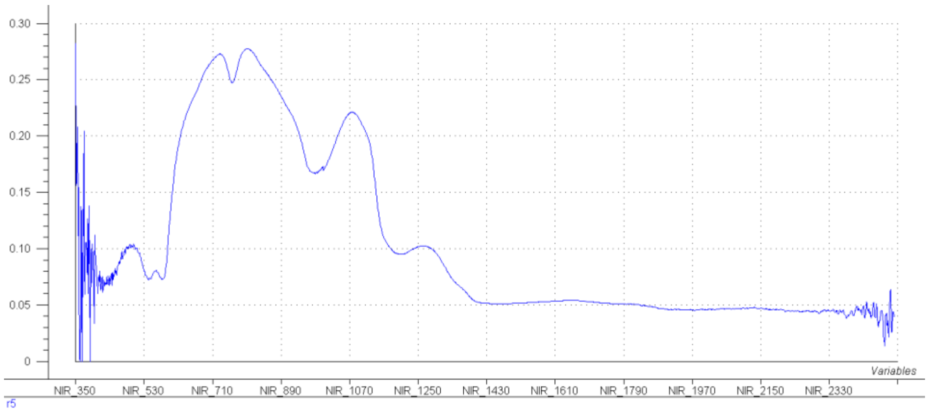


Figure 4. Typical NIR spectre of bloomed sirloin steak surface

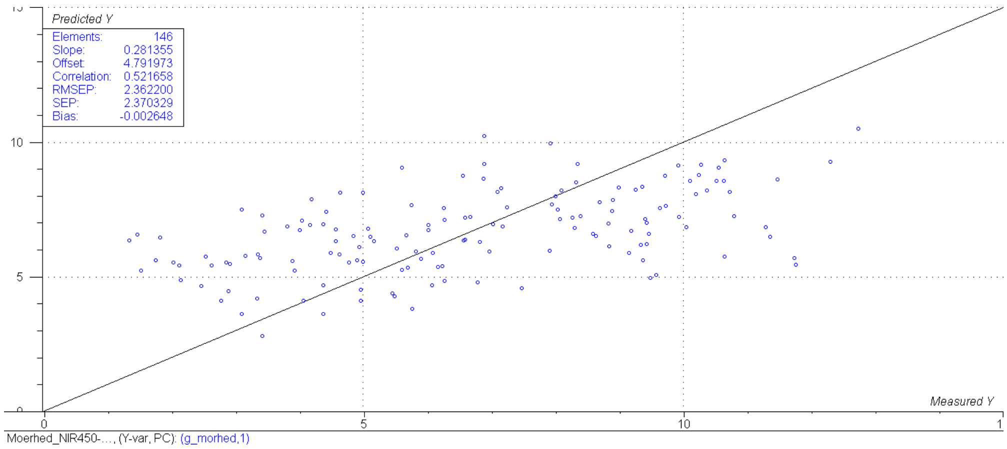


Figure 5. PLS1 model prediction of sensory tenderness based on NIR measurement of bloomed sirloin steak surface at 13th rib. N=146, as 2 animals were considered outliers.

IV. CONCLUSION

NIR-spectra measured on day one after slaughter on bloomed beef steaks cut at 13th rib showed insufficient information when used in PLS1 model for prediction of sensory tenderness after two week aging.

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