B24

CLASSIFICATION OF BEEF TENDERNESS FROM NIR REFLECTANCE MEASUREMENTS OF *M. LONGISSIMUS DORSI* SAMPLES BY DISCRIMINANT ANALYSIS

HILDRUM, K.I., NÆS, T. AND FRØYSTEIN, T.*
MATFORSK, Osloveien 1, N-1432 Ås, Norway
*Norwegian Meat Cooperative, P.O. Box 60 Refstad, 0513 Oslo, Norway

Keywords
Classification, tenderness, sensory analysis, near infrared spectroscopy

Background
The meat tenderness problem recognized in many countries has led to an increased interest in developing efficient methods for tenderness assessment. By efficient methods is here meant rapid, nondestructive and reliable measurement techniques. One such technique is near infrared (NIR) spectroscopy, which has proven useful in the proximal analysis of meat, and has also shown promise in assessing tenderness of beef (Hildrum *et al.*, 1994). A beef manufacturer will usually be more interested in whether a meat cut is unacceptably tough, acceptable or very tender, -than in the exact tenderness value of the cut. Classification methods are therefore more relevant for this purpose than quantitative calibration methods. Recently results from the classification of beef sensory attributes using ultrasonic spectral features as input data was reported (Park *et al.*, 1995). Using 2 tenderness subgroups and a sensory score of 5.0 as threshold between the groups, a 75.0 % accuracy for muscle fiber tenderness and overall tenderness classification was obtained by neural-network modelling.

Purpose
The purpose of this study was to examine classification techniques in predicting sensory tenderness of beef from NIR spectroscopic analysis by 2 different classification methods.

Materials and Methods
M. longissimus dorsi muscles from 30 Norwegian Red Cattle were removed 45 min after stunning. Loins from 20 carcasses were conditioned for 26 hours at 15 °C, chilled and aged for 7 days at 4 °C. The remaining 10 loins were chilled at 4 °C right after excision and aged for 7 days at 4 °C. After 2, 7 and 14 days samples were taken for NIR and sensory analysis according to procedures described by Hildrum *et al.* (1994). NIR reflectance spectra (InfraAlyzer 500, Bran & Luebbe Gmbh, Norderstedt, Germany) were obtained both on fresh, raw samples and on samples that had been frozen and thawed. Samples for sensory analysis were heat treated at 70 °C for 50 min (30 samples) or 75 min (60 samples) and kept frozen at - 40 ° C until the time of analysis. The samples were classified in 3 subgroups according to the sensory analysis, - one group with tenderness values 1.0-5.0 (tough), the second 5.0-6.5 (intermediate) and the third 6.5-9.0 (tender). Also a two-group classification was used, - tough below 5.0 and tender above 5.0. The sensory intensity scale was from 1 (tough) to 9 (tender). The two classification methods used were based on 1; principal component regression (PCR) and 2; Mahalanobis distances in principal component subspaces (MDC) (Mardia *et al.*, 1979). For method 1, two different allocation rules were used, "normal" and "bias reduced". For method 2, the distances for each sample to each of the subgroup means were computed and the sample allocated to the closest subgroup. Membership values for each sample for each of the subgroups were computed from the distances as described by Næs and Hildrum (1995). Validation of the methods was done by full cross-validation and by segmented cross-validation with all samples for each animal in one segment. Data analysis was performed in the UNSCRAMBLER (Version 5.5, Camo AS, Trondheim, Norway) and in SAS (SAS Institute Inc. Cary, NC, USA).

Results and discussion
pH_{24} in the loins ranged from 5.36 to 5.73, while sensory tenderness scores ranged from 1.85 to 8.24. PCR prediction of sensory tenderness from NIR analysis of 90 fresh or frozen samples yielded multivariate correlation coefficients of 0.65 (6 PC) and 0.70 (4 PC), respectively (Fig. 1). The root mean square error of prediction (RMSEP), were 1.20 and 1.13, for the fresh and frozen sample models, respectively. The strong overlap between the 3 subgroups is evident from Fig. 1, which shows the PCR predicted versus measured sensory tenderness values for fresh samples. Using the allocation rule indicated by the dotted lines ("normal"), the number of correct classifications were on average 63 % (random probability 33 %) both for fresh and frozen sample measurements (Table 1). The percent correct classifications for the extreme subgroups (tough/tender) were very low, but very high for the intermediate group. The 3 subgroups classification using the "normal" allocation rule was thus of little use. However, it is important to note that there was no overlap between the two extreme groups, which means that the chance of misclassifying a tender sample as tough was very small and vice versa.

One reason for the low percent correct classifications above in the extreme groups is that PCR did shrink all predictions towards the center of the data set (Martens and Næs, 1989). This effect can be reduced by changing the allocation rule ("reduced bias") so that the group intervals of the ordinate axis in Fig. 1 are determined by the intersections between the dotted lines parallel to the abscissa and the regression line. This makes the percent correct classifications in the different subgroups more even (Table 1).

Compared to the "normal" allocation rule based on PCR, MDC behaved differently as % correct classifications were lower for the intermediate group than for the extreme subgroups. The membership values for the fresh samples are presented in the triangle in Fig. 2, where the allocation regions for the three subgroups are separated by solid lines. Considerable overlaps existed between neighboring groups, but almost all misclassified extreme samples were close to the border of the

correct group. There were no tough samples in the "tender" sector, while two tender samples are to be found in the "tough" sector of the figure.

Classification in 2 tenderness groups by PCR was examined using 5.0 as threshold value for tenderness (random probability 50 %). The average correct classifications now increased to 80 % using the "reduced bias" allocation rule with a higher correct classifications percentage for tender (83-85 %) than tough (66-76 %) samples.

Conclusions

Classification of beef sensory tenderness from NIR reflectance measurements on fresh or frozen meat samples has been studied by classification techniques based on PCR and MDC. There was considerable overlaps between neighbor groups, but seldom overlaps between extreme groups for the 3 group classifications. Average % correct classifications for models with 2 or 3 tenderness groups were in the ranges 78-81 % and 49-63 %, respectively. The percent correct classifications for the tender group (2 subgroups) were in the range 83-87 %. The classification results are highly dependent on the rules for allocation of samples into subgroups.

Acknowledgments

The authors appreciates the valuable contributions from Bjørg Narum Nilsen, Laura Blümlein, Anne-Kari Arnesen and Siv Siri Gulbrandsen in this study.

References

Hildrum, K. I., Nilsen, B. N., Mielnik, M. and Næs, T. (1994). Prediction of sensory characteristics of beef by near-infrared spectroscopy. Meat Science, **38**, 67-80.

Mardia, K.V., Kent, J.T. and Bibby, J. M. (1979). Multivariate Analysis. Academic Press. London. UK.

Martens, H. and Næs, T. (1989) Multivariate Calibration. John Wiley and Sons. Chichester, UK.

Næs, T. and Hildrum, K.I. (1995). A comparison of multivariate calibration and discriminant analysis for determining tenderness of meat by NIR spectroscopy. Appl. Spec. (submitted).

Park, B. Chen, Y.R., Whittaker, A.D., Miller, R. K. and Hale, D.S. (1995). Neural-network modeling for beef sensory evaluation. Transact. of the ASAE, **37**, N5, 1547-1553.

No of subgroups	State of NIR samples	Classification method	Allocation rule	PC's in model	% correct classification			
					Tender	Intermed.	Tough	Average
3	Fresh	PCR	Normal	6	9	92	40	63
	Frozen/Thawed			4	18	94	20	63
	Fresh		Bias corr.	6	55	47	67	52
	Frozen/Thawed			4	67	63	67	64
	Fresh	MDC	Normal	3	62	35	80	49
	Frozen/Thawed			3	62	37	73	49
2	Fresh	PCR	Normal	6	87	-	66	78
	Frozen/Thawed			4	88	-	71	81
	Fresh		Bias corr.	6	85	-	74	80
	Frozen/Thawed			4	83	-	76	80

Table 1. Classification of 90 *M. Longissimus dorsi* bovine samples in tenderness groups based on NIR measurements and sensory analysis (PCR: Principal Component Regression; MDC: Mahalanobis Distances Classification)

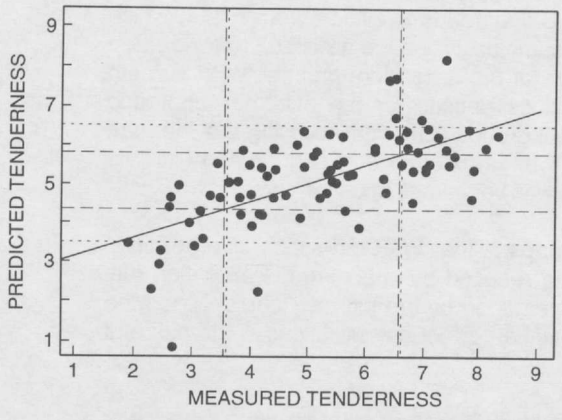

Figure 1. PCR predicted versus measured tenderness for 90 fresh beef samples; with allocation into 3 subgroups (..... «normal» allocation rule; _ _ _ _ _ «bias corrected» allocation rule; _____ regression line)

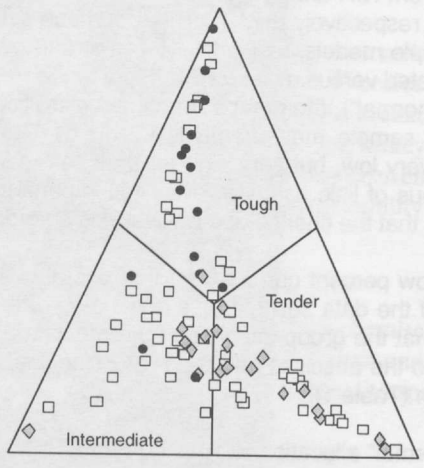

Figure 2. Membership map for 90 fresh beef samples in the MDC tenderness classification (● tough; ❑ intermediate, ▨ tender)