Prediction of physico–chemical and texture characteristics of beef by near infrared transmittance spectroscopy

Mamen Oliván, Begoña de la Roza, Mercedes Mocha and María Jesús Martínez

Servicio Regional de Investigación y Desarrollo Agroalimentario (S.E.R.I.D.A.), Apdo 13, 33.300 Villaviciosa, Asturias, Spain

Introduction

Physico–chemical and texture characteristics of meat determine nutritional, technological and sensory quality. However, the accurate analysis of meat quality requires expensive, laborious and time-consuming analytical methods.

Near infrared (NIR) spectroscopy has become a rapid and effective analytical tool for estimating chemical composition of foods, including meat and meat products.[1–5] It has also been studied for its ability to predict other meat quality attributes such as water holding capacity[6,7] and instrumental and sensory texture.[8–10]

There are some reports on the use of near infrared (NIR) spectroscopy transmittance for determining the composition of ground meat,[11] the composition and shear value of raw beef cuts[8] and the sensory quality of meat sausages.[12] The objective of this work was to evaluate the use of NIR using transmittance for determining physico–chemical characteristics of ground beef, including moisture, fat, protein, total pigment content, water holding capacity and instrumental texture.

Materials and methods

A total of 318 ground beef samples were scanned using an Infratec 1265 Feed Analyzer. The samples were obtained from the *Longissimus thoracis* muscle of the 10th rib of yearling bulls from two local breeds in Northern Spain, "Asturiana de los Valles" and "Asturiana de la Montaña". The meat samples were ground with an electrical chopper, vacuum packed, aged for seven days and frozen at –24°C until the analyses were done.

Moisture content was measured by oven drying at 102°C (ISO 1442-1973), fat content was determined by Soxhlet extraction (ISO 1443-1973) and protein content was estimated from nitrogen content using the Kjeldahl analysis (ISO 937-1978). The total pigment content was determined by using the Hornsey method,[13] showing the results as the absorbance at 512 nm. The water-holding capacity (WHC) was analysed using the method of Grau and Hamm,[14] modified by Sierra.[15]

The instrumental evaluation of texture was conducted on an Instron 1011 with a Warner–Bratzler shearing device. This analysis was performed on a thick chop obtained from the *longissimus* muscle of the 8th rib, aged for seven days and cooked in a hot bath at 75°C for 40 minutes. The results were expressed as maximum load (WB), maximum stress (MS) and toughness.

The NIR transmittance analysis was performed on an Infratec 1265 Feed Analyzer which operated from 850 to 1050 nm at 2 nm intervals. The samples were placed into a glass cup 130 mm in diameter.

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Table 1. Physico–chemical and texture characteristics of the sample population.

Component	*n*	mean	range	*SD*
Moisture (%)	114	74.49	70.68 – 76.44	1.42
Fat (%)*	58	2.66	0.56 – 6.65	1.72
Protein (%)*	126	22.43	20.78 – 24.06	0.61
Pigments (absorbance)	318	0.504	0.21 – 0.87	0.13
WHC	318	19.68	6.41 – 28.68	4.43
WB	250	5.01	2.72 – 9.62	1.33
MS	250	5.10	2.67 – 10.59	1.37
Toughness	250	2.49	1.33 – 4.97	0.70

*in fresh matter

The average spectra of each sample was obtained from 15 scan locations and recorded as log 1/*T* (*T* = transmittance).

Calibrations were performed with the WinISI software v. 1.02 (Infrasoft International, Port Matilda, PA, USA) using the modified partial least squares method.[16] To examine the effect of scatter correction or derivation of spectra on the calibration performance, calibrations were calculated with the crude spectra or pretreated with different mathematical treatments like inverse multiplicative scatter correction (inverse MSC), standard normal variate detrending (SNVD) and/or second derivative operation.

Results

Means, standard deviations (*SD*) and ranges for physico–chemical and texture characteristics of samples are presented in Table 1. The crude spectra of meat obtained by transmittance in the region from 850 to 1050 nm showed a wide peak located from 930 to 1000 nm, covering bands mainly related with water (934 to 960 nm and 984 to 996 nm) and fat (962 to 968 nm) (Figure 1).

The results of the calibration statistics are shown in Table 2 (chemical attributes) and Table 3 (texture attributes). Generally, for chemical composition the use of the inverse MSC or SNVD pre-treatments provided better calibration statistics for most of the variables. This is in accordance with the

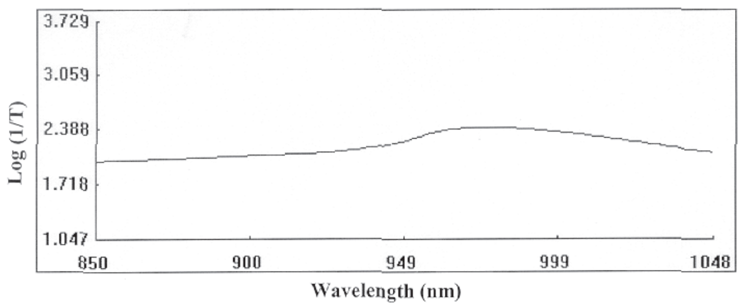

Figure 1. Average crude spectrum of the sample population.

Table 2. Statistics of calibration for chemical composition.

Component	Pretreatment	*SEC*	R^2	*SECV*	r^2	*RER*
Moisture	None	0.409	0.915	0.443	0.901	13.00
	None - D	0.321	0.922	0.364	0.899	15.82
	InvMSC	0.316	0.952	0.340	0.945	16.94
	InvMSC - D	0.317	0.948	0.349	0.938	16.50
	SNVD	0.322	0.951	0.344	0.943	16.74
	SNVD - D	0.293	0.952	0.317	0.944	18.17
Fat	None	0.602	0.880	0.676	0.853	9.00
	None - D	0.352	0.949	0.462	0.913	13.18
	InvMSC	0.424	0.939	0.528	0.909	11.53
	InvMSC - D	0.332	0.961	0.449	0.929	13.56
	SNVD	0.591	0.887	0.682	0.852	8.92
	SNVD - D	0.344	0.958	0.443	0.931	13.75
Protein	None	0.501	0.265	0.505	0.255	6.50
	None - D	0.447	0.378	0.476	0.299	6.89
	InvMSC	0.497	0.269	0.506	0.259	6.48
	InvMSC - D	0.455	0.396	0.481	0.331	6.82
	SNVD	0.445	0.432	0.475	0.353	6.91
	SNVD - D	0.460	0.385	0.483	0.320	6.79
Pigments	None	0.043	0.848	0.045	0.835	14.67
	None - D	0.048	0.829	0.050	0.818	13.20
	InvMSC	0.032	0.918	0.034	0.913	19.41
	InvMSC - D	0.033	0.915	0.034	0.910	19.41
	SNVD	0.032	0.925	0.033	0.922	20.00
	SNVD - D	0.032	0.921	0.034	0.914	19.41

D: 2nd derivative

reports of Ding *et al*.[17] and Ding and Xu,[18] who showed that the SNVD correction improved the classification accuracy of minced meat of beef and kangaroo. The use of the 2nd derivative also improved the predictions, mainly when combined with the SNVD treatment. It is known that the use of derivative

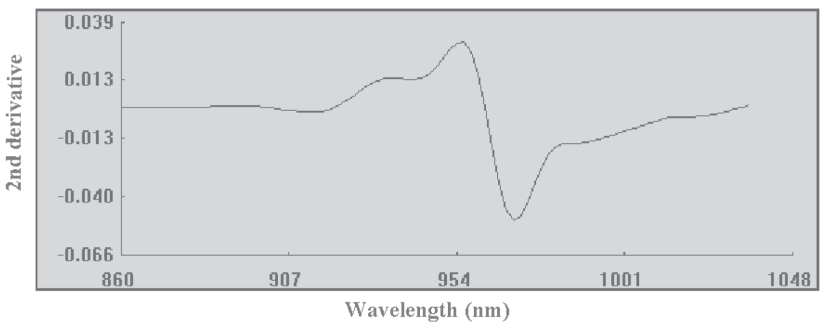

Figure 2. Average spectrum of the sample population after application of scatter correction and 2nd derivative.

Table 3. Statistics of calibration for texture traits.

Component	Pretreatment	*SEC*	R^2	*SECV*	r^2	*RER*
WHC	None	3.124	0.354	3.164	0.340	7.04
	None - D	2.806	0.578	2.935	0.539	7.59
	InvMSC	2.743	0.356	2.861	0.301	7.78
	InvMSC - D	2.797	0.435	2.895	0.395	7.69
	SNVD	2.800	0.360	2.854	0.335	7.80
	SNVD - D	2.801	0.490	2.887	0.463	7.71
WB	None	0.844	0.428	0.885	0.372	7.80
	None - D	0.893	0.362	0.939	0.295	7.35
	InvMSC	1.002	0.306	1.040	0.253	6.63
	InvMSC - D	0.857	0.364	0.898	0.300	7.68
	SNVD	0.928	0.294	0.969	0.233	7.12
	SNVD - D	0.863	0.371	0.904	0.311	7.63
MS	None	0.873	0.405	0.900	0.369	8.80
	None - D	0.889	0.360	0.923	0.309	8.58
	InvMSC	1.098	0.249	1.108	0.233	7.15
	InvMSC - D	0.915	0.298	0.957	0.230	8.28
	SNVD	1.007	0.212	1.021	0.192	7.76
	SNVD - D	0.843	0.367	0.887	0.300	8.93
Toughness	None	0.560	0.265	0.580	0.213	6.28
	None - D	0.493	0.362	0.514	0.308	7.08
	InvMSC	0.560	0.265	0.580	0.213	6.28
	InvMSC - D	0.487	0.306	0.518	0.215	7.03
	SNVD	0.549	0.169	0.557	0.145	6.54
	SNVD - D	0.455	0.386	0.487	0.303	7.47

D: 2nd derivative

treatments not only reduces scattering effects but also increases the resolution of spectrum peaks.[19] In this work, the application of scatter correction and second derivative increased the resolution of peaks and revealed distinct peaks related with moisture (934 to 960 nm and 984 to 996 nm), fat (962 to 968 nm) and pigments (960 nm),[8] as shown in Figure 2. Thus, the use of the SNVD treatment and the second derivative provided the best prediction results for moisture (r^2 = 0.944, *SECV* = 0.317) and fat (r^2 = 0.931, *SECV* = 0.443) and the application of the SNVD treatment gave the best prediction of total pigments (r^2 = 0.922, *SECV* = 0.033).

The coefficients of determination for the total pigment content, both for calibration (R^2=0.925) and cross-validation (r^2 = 0.922) were higher than those reported by Mitsumoto *et al.*[8] who obtained a determination coefficient of R^2 = 0.895 between the total pigment content and the optical density determined in transmittance mode from beef cuts. The relationship between reference and predicted data for pigment content is shown in Figure 3.

The low coefficients of determination for the estimation of the protein content in meat (r^2< 0.35) must be noticed. Most of the earlier reports on NIR or transmittance prediction for meat composition[2,3,5,8,20] gave lower predictions for protein than for any other constituent. This has been related to analytical errors in the Kjeldahl analysis or a low correlation between the Kjeldahl method which measures nitrogen and the NIR method which measures protein.[2] In this work, the lower prediction of protein could be related to the lack of spectral peaks in the overtone bands for protein (at 910

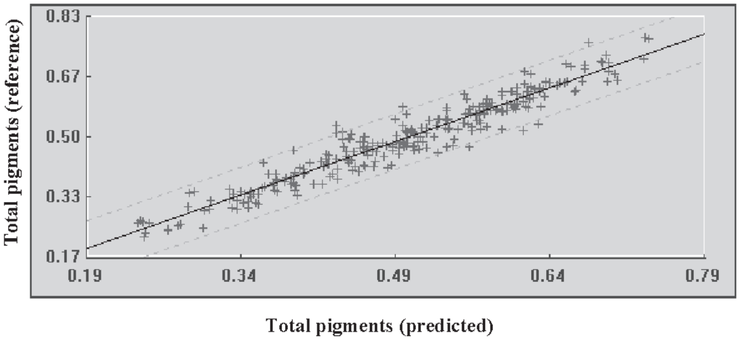

Figure 3. Relationship between reference and predicted data for pigment content.

and 1020 nm)[21] and also due to the relatively large error in the reference method compared with the sample standard deviation for protein, as indicated by Togersen *et al*.[5]

For texture traits, the best estimation was obtained from the crude spectrum (WB and MS) and the 2nd derivative of the crude spectrum (toughness and WHC). The best prediction of the WHC gave better statistics ($r^2 = 0.539$) than the calibrations reported by Brondum *et al*.[7] when determining the WHC of porcine meat estimated with the filter paper method in the NIR range from 802 to 2500 nm ($r = 0.62$).

The prediction of the Instron measurements from the transmittance spectra were low, as expected, when comparing data obtained from different sample matrix. The analyses of the instrumental texture were performed on meat cubes removed from cooked steaks while the transmittance spectra were obtained from fresh ground meat. Probably the best estimation of the instrumental texture of meat should be calculated on the spectrum obtained from meat cuts, as shown by Park *et al*.[9]

Conclusions

The near infrared transmittance from 850 to 1050 nm provided excellent predictions of moisture, fat and total pigment content in ground beef, with r^2 being higher that 0.9. However, the prediction of protein was low, due to the lack of peaks in the bands of protein and the prediction of texture traits (WB, MS, toughness) was poor, due to the low relationship between the texture characteristics of cooked steaks and the transmittance spectra of fresh ground beef.

References

1. W.G. Kruggel, R.A. Field, M.L. Riley, H.D. Radloff and K.M. Horton, *Journal of the Association of Official Analytical Chemists* **64,** 692 (1981).
2. E. Lanza , *J. Food Sci.* **48,** 471 (1983).
3. T. Isaksson, B.N. Nilsen, G. Togersen, R.P. Hammond and K.I. Hildrum, *Meat Sci.* **43,** 245 (1996).
4. R. Sanderson, S.J. Lister, M.S. Dhanoa, R.J. Barnes and C. Thomas, *Anim. Sci.* **65,** 45 (1997).
5. G. Togersen, T. Isaksson, B.N. Nilsen, E.A. Bakker and K.I. Hildrum, *Meat Sci.* **51,** 97 (1999).
6. J.R. Andersen, C. Borggaard and T. Nielsen, *Proceedings ECCAMST meeting.* Roskilde, Denmark (1995).
7. J. Brondum, L. Munck, P. Henckel, A. Karlsson, E. Tornberg and S. Engelsen, *Meat Sci.* **55,** 177 (2000).
8. M. Mitsumoto, S. Maeda, T. Mitsuhashi and S. Ozawa, *J. Food Sci.* **56,** 1493 (1991).

9. B. Park, Y.R. Chen, W.R. Hruschka, S.D. Shackelford and M. Koohmaraie, *J. Anim. Sci*. **76,** 2115 (1998).
10. C.E. Byrne, G. Downey, D.J. Troy and D.J. Buckley, *Meat Sci.* **49,** 399 (1998).
11. W.R. Windham, F.E. Barton, II and K.C. Lawrence, in *"Leaping ahead with near infrared spectroscopy"*, Ed by G.D. Batten, P.C. Flinn, L.A. Welsh and A.B. Blakeney. Royal Australian Chemical Institute, Victoria, Australia, p. 287 (1995).
12. M.R. Ellekjaer, T. Isaksson and R. Solheim, *J. Food Sci.* **59,** 456 (1994).
13. H.C. Hornsey, *J. Sci. Food Agric.* **7,** 534 (1956).
14. R. Grau and R. Hamm, in *"Muscle as Food"*, Ed by P.J. Bechtel. Food Science and Technology. A series of Monograph. 1985. Academic Press. New York. USA (1953).
15. I. Sierra, Instituto de Economía y Producciones Ganaderas del Ebro (IEPGE) **16,** 48 (1973).
16. J.S. Shenk and M.O. Westerhaus, *Analysis of Agricultural and Food Products by Near Infrared Reflectance Spectroscopy.* Monograph. Infrasoft International, Port Matilda, USA.(1993).
17. H.B. Ding, R.J. Xu and D.K. Chan, *J. Sci. Food Agric.* **79,** 1382 (1999).
18. H.B. Ding and R.J. Xu, *J. Food Sci.* **64,** 814 (1999).
19. A.M.C. Davies and A. Grant, *Int. J. Food Sci. Technol.* **22,** 191 (1987).
20. K.I. Hildrum, M.R. Ellekjaer and T. Isaksson, *Meat Focus International* **4,** 156 (1995).
21. B.G. Osborne and T. Fearn, *Near Infrared Spectroscopy in Food Analysis.* Longman Scientific & Technical, Harlow, Essex, UK (1986).