Speciation of raw homogenised meats by visible and near infrared reflectance spectroscopy

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Introduction

With regard to meat, a significant authenticity issue is that of species identification.[1,2] Given the particularly high value of certain meats, adulteration with cheaper species has the potential to yield considerable financial rewards. Species identification is generally not problematic when the meat is seen as whole cuts but it does become impossible to identify meats visually once they have been minced or even chopped. A need exists for a rapid and reliable procedure to determine whether a comminuted meat sample is of the species declared. Infrared spectroscopic techniques possess the necessary speed and, in a previously published communication,[3] the potential of mid- and near infrared spectroscopy combined with factorial discriminant analysis to confirm the identity of chicken, turkey and pork meats was demonstrated. In a separate study,[4] the use of near infrared (NIR) reflectance spectroscopy on dry extract of homogenised meat as a means of discriminating between beef, pork, mutton and mechanically-recovered poultry meat and predicting the degree of substitution of homogenised beef by other species, has been reported. This paper reports the results of attempted discrimination between chicken, turkey, pork, beef and lamb meats using visible near infrared reflectance spectral data.

Materials and methods

Meat samples

Two hundred and thirty (230) homogenised meat samples were utilised in this study. They comprised 55 chicken, 54 turkey, 55 pork, 32 beef and 34 lamb. Chicken and turkey were purchased as breast meat, pork as loin chops, beef as round steak and lamb as side loin chops; all were stored overnight at +4°C following purchase and prior to preparation and spectral collection. Individual samples were cut into cubes of manageable size and homogenised (Robot Coupe SA, Vincennes, France).

Spectral collection

Combined visible and near infrared spectra were collected in reflectance mode using an NIRSystems 6500 instrument (NIRSystems Inc., Maryland, USA) over the wavelength range 400–2500 nm at 2 nm intervals. Spectrophotometer control and spectral file management were performed using NIRS3 software (version 3.10; ISI International, Port Matilda, USA).
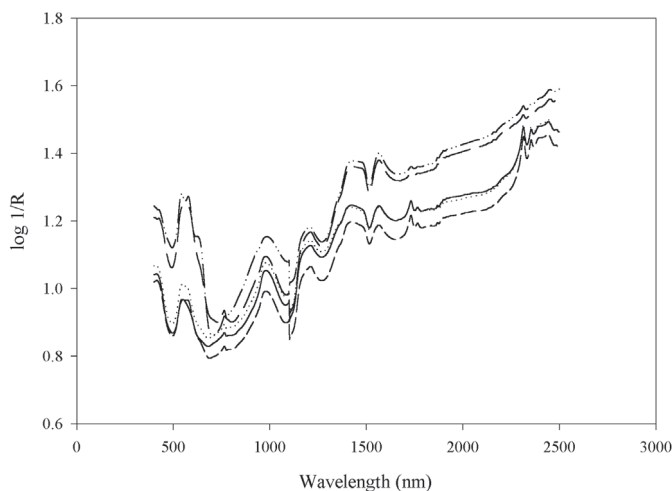
Figure 1. Mean reflectance spectra of each of the five meat groups.

Chemometric procedures

Individual mean sample spectra were exported from the spectrophotometer as JCAMP.DX files. These were then transferred into SAISIR software (D. Bertrand, INRA, Nantes, France) for principal component analysis and factorial discriminant procedures. Soft independent modelling of class analogy (SIMCA) and partial least squares (PLS) regression analyses were performed using The Unscrambler (CAMO A/S, Trondheim, Norway). For PLS regression models, all meat of a given species was arbitrarily ascribed a value of 1.0 for the dummy variable "species" with all other meats being given the value 0; following model development and prediction on a separate sample set, those samples with a predicted value greater than or equal to 0.5 were identified as being of the species being modelled. All samples with a predicted value less than 0.5 were identified as not being of the species in question. *K*-Nearest Neighbours analyses were programmed in MATLAB with the Euclidean distance between spectra being used as the distance function. Two thirds of samples of each meat type were selected arbitrarily for calibration development. The remainder were used for model evaluation (prediction set).

Results and discussion

A mean spectrum of each of the five meat groups is shown in Figure 1. While the lean meat composition of beef and lamb is relatively constant, a major source of variation relates to lipid; differences in total lipid and lipid composition also exist between the other meats studied in this work. Such compositional differences relate especially to C14:0, C16:0, C18:0 and C18:1 moieties.[5] With regard to colour, myoglobin is the basic pigment in fresh meat and is found in three forms, i.e. reduced myoglobin, oxymyoglobin and metmyoglobin. Meat myoglobin content varies with species and also with age, sex and physical activity.[6,7]

Factorial discriminant analysis

Summary results for the factorial discriminant models developed for the five species of homogenised raw meats are shown in Table 1. The most successful models were obtained using spectral data in

Table 1. Optimum factorial discriminant models for meat speciation using five groups.

Wavelength range (nm)	Data pre-treatment	No. of principal components	% Correct classification[a]
400–2498	2nd derivative	10	94.3
400–1100	2nd derivative	8	94.8
400–750	2nd derivative	8	93.4
1100–2498	None	8	81.7

[a] mean of calibration and prediction percentages

Table 2. Optimum factorial discriminant models for meat speciation using four groups.

Wavelength range (nm)	Data pre-treatment	No. of principal components	% Correct classification[a]
400–2498	None	10	97.8
400–1100	2nd derivative	9	98.7
400–750	None	9	97.8
1100–2498	None	8	94.3

[a] mean of calibration and prediction percentages

the wavelength range 400–1100 nm; neither the visible (400–750 nm) nor the near infrared (1100–2498 nm) ranges contained sufficient information alone to match the performance of the combined visible–near near infrared spectral region. The most successful model used spectral data in the range 400–1100 nm, a 2nd derivative pre-treatment and eight components (nos 1,6,3,2,7,9,4,5 in order of incorporation); the correct classification accuracy of this model was 97.39% in the calibration sample set and 92.17% in the prediction set.

The main problem in these models is the accurate discrimination between chicken and turkey meats; to this end, the above work was repeated after combining these two meat types into a single cat-

Table 3. Optimum *K*-nearest neighbour models for meat speciation.[a]

Wavelength range (nm)	Number of groups	% Correct classificationb
400–2498	5	87.0
	4	91.2
400–1100	5	90.5
	4	96.5
400–750	5	93.1
	4	96.5
1100–2498	5	58.4
	4	83.5

[a] $k = 3$; 2nd derivative using 15 point filter
[b] mean of calibration and prediction percentages

Table 4. Best results of SIMCA models for meat speciation.[a]

Wavelength range	Model	Number of predictions samples	% Correct classification
400–750	Chicken	18	93.8
	Turkey	18	82.4
	Pork	17	95.9
	Beef	10	93.2
	Lamb	11	94.6
	Poultry	36	86.5

[a] raw spectral data input to SIMCA process

egory of poultry meat. Summary results for the discriminant models using four groups thus resulting are shown in Table 2. Once again, the best model was developed using spectral data in the 400–1100 nm range after a 2nd derivative pre-treatment.

K-Nearest Neighbour analysis

Best results utilised a 2nd derivative with a 15-point Savitsky–Golay filter (Table 3). Using values of $k = 1$ to 6 revealed little sensitivity to the magnitude of this parameter, with a value of 3 being judged optimal. The information being used by this technique is found chiefly in the visible spectral region; extending the range up to 1100 nm neither improved nor impaired predictive accuracy, although this lack of improvement argues against the use of this extended wavelength range. Using spectral data beyond 1100 nm reduced classification accuracy rates.

SIMCA

The results summary for SIMCA analysis are shown in Table 4. The best overall results were obtained using the visible wavelength region only, echoing the K-NN analysis reported above. In general, the use of spectral data above 1100 nm degraded the models (Table 4).

Partial least squares regression

Summary data for the results of discriminant PLS regression are shown in Table 5. In the case of turkey, pork, beef and lamb, there is little to choose between the five wavelength ranges examined, al-

Table 5. Optimum PLSR results for meat speciation.

Wavelength range (nm)	Meat model (% correctly classified)					
	C + T	C	T	P	B	L
400–750	100	90.9	88.7	93.5	99.2	98.3
750–1100	93.1	74.8	87.4	93.5	99.2	98.3
400–1100	98.3	86.1	82.6	92.2	99.2	97.4
1100–2498	91.7	78.3	85.2	90.0	98.7	97.4
400–2498	97.0	82.6	84.8	93.9	98.7	96.1

though spectral data below 1100 nm produced the most accurate models. When chicken and turkey are combined into a single class, visible radiation was again most accurate.

Conclusions

On the basis of results reported above, the combination of visible and near infrared reflectance spectroscopy appears to have potential for species identification in the unblended, homogenised meats examined. With all of the chemometric strategies examined, the differentiation of turkey from chicken was difficult and the greatest source of mis-classification. It seems that either of the three most accurate classification methods (PLS, FDA, KNN) may be suitable for rapid analysis of homogenised meats for confirmation of identity.

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