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Detection of Minced Beef Adulteration by Means of UV-VIS Spectrometer

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INTRODUCTION

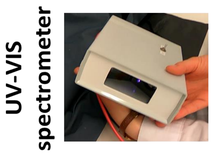
Food fraud has been an emerging food protection issue. Specifically, intentional substitution of minced meat with different animal tissues than the one claimed can be practiced for economic gain. Hence, the rapid detection of minced meat adulteration is a major issue in terms of food protection. The aim of this study was to assess the potential of spectroscopic data coupled with machine learning approaches to detect minced beef adulteration with beef offal.

METHODS

Purchase of meat: Beef and bovine offal were purchased from four different butcher shops (b1, b2, b3, b4).

Preparation of samples: Meat was minced and appropriate portions of the two bovine tissue types were mixed so that different levels of adulteration were attained with 25% increment. For each level of adulteration, six samples were prepared (i.e., sample replicates).

Acquisition of spectral data: The UV-VIS spectrometer sensor (Hamamatsu C12880MA) was employed for:
- visible range spectroscopy (VIS) measurement and
- fluorescence signal (FLUO) detection.



Data analysis: The acquired spectral data from three batches (b1, b2, b3, *n*=90) were used for model training and one batch (b4, *n*=30) for external validation.
- Partial Least Square Discriminant Analysis (PLSDA) and
- Support Vector Machines (SVM)

were implemented to the acquired data in R version 3.6.1. and Rstudio version 1.1.456, using the packages 'mixOmics', 'e1071' and 'caret'.

RESULTS

Three-class classification

The metrics of precision, recall, F1-score and accuracy were calculated for the external validation set considering three classes. The 3-class classification referred to the discrimination of pure samples (i.e., pure beef) from the adulterated ones (i.e., adulterated, pure offal). The results are presented in Table 1 and the main findings are briefly provided below:

- The accuracy scores attained with the applied algorithms were over 53.33% and the highest score (i.e., 80.00%) was accomplished using SVM on VIS data.
- In the case of SVM for both spectral data (VIS, FLUO), beef samples were totally discriminated with F1-scores=1.00, which equals to total discrimination of pure class, although accuracy scores were lower than 100%.
- When the collected spectral data (VIS and FLUO data) were comparatively evaluated, better results in terms of accuracy were attained when VIS data were used.

Table 1. Precision, recall, F1-score and accuracy results for PLSDA and SVM of external validation using visible (VIS) and fluorescence (FLUO) data with three classes, namely 0% beef-100% offal, adulterated and 100% beef-0% offal. (*NaN=Not a Number)

		True class		
Data type		100% beef (0% offal)	Adulterated	100% offal (0% beef)
VIS (b4, *n*=30)				
PLSDA	Precision (%)	100.00	72.00	100.00
	Recall (%)	66.67	100.00	16.67
	F1-score	0.80	0.84	0.29
	Accuracy (%)		76.67	
SVM	Precision (%)	100.00	75.00	NaN*
	Recall (%)	100.00	100.00	0.00
	F1-score	1.00	0.86	NaN*
	Accuracy (%)		80.00	
FLUO (b4, *n*=30)				
PLSDA	Precision (%)	75.00	83.33	31.25
	Recall (%)	100.00	27.78	83.33
	F1-score	0.86	0.42	0.45
	Accuracy (%)		53.33	
SVM	Precision (%)	100.00	100.00	40.00
	Recall (%)	100.00	50.00	100.00
	F1-score	1.00	0.67	0.57
	Accuracy (%)		70.00	

CONCLUSIONS

Spectroscopic data (VIS, FLUO) coupled with appropriate algorithms exhibit potential for the rapid detection of minced beef adulteration.

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