Discrimination of grass-fed and grain-fed frozen beef using hyperspectral imaging

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Introduction: The labelling of beef as grass-fed or grain-fed cannot be inherently trusted, with food fraud possible and occurring (Logan et al., 2020). Consequently, there is a need to develop practical methods to identify the origin of meat products. Methodologies such as near-infrared reflectance (NIR) and Raman spectroscopies have been used to identify meat origin in recent years, with promising results (Liddle et al., 2020; Logan et al., 2020). Hyperspectral (HS) imaging, consisting of visible (VIS) and short-wave infrared (SWIR) factions, has also shown great potential in determining chemical composition and quality of meat (Elmasry et al., 2012). The HS imaging system used in the present study is contactless and provides high spatial resolution with reflectance values for every pixel. This could allow on-site measurements at chain speed in the abattoir with improved accuracy.

Materials and methods: One hundred and eight frozen beef steaks (54 grass-fed and 54 grain-fed) were sourced as per Liddle et al. (2020). A Rapiscan 6040DV prototype scanning system fitted with VIS (Basler Ace GigE, Photonic Science, East Sussex, UK) and SWIR (Snake A/C GigE v3 AK081, Photonic Science, East Sussex, UK) HS cameras with a conveyor (189.8 m/s) to carry samples across the system was trialled in the present study. Generated images were marked-up (6 to 8 regions of interest, ROI) of 7 × 7 pixels across the lean surface using ImageJ, and reflectance values extracted from the ROI using GIMP software.

Reflectance data were converted into absorbance (log(1/R)), centred, scaled and cleaned from outliers using principal components analysis in R. One grain-fed SWIR sample was removed from the study as it was deemed an outlier. Data were split into calibration (75% = 40) and validation (25% = 14) stratified by feed origin. Three statistical discrimination methods were compared: partial least squares (PLS-DA), linear (LDA) and random forest (RF).

Results and Discussion: The use of PLS-DA on VIS data showed the greatest accuracy of all models on the validation dataset (92.9%), successfully predicting 13 of the 14 grass- or grain-fed steaks. Both PLS-DA and LDA on SWIR data gave 85.7% accuracy on the validation dataset, correctly classifying 24 out of 28 steaks. However, this model had the lowest accuracy on the calibration dataset (96.3%), whereas the RF models showed 100% accuracy for both VIS and SWIR. This finding was similar to another study using RF compared to PLS-DA for SWIR (Kong et al., 2013). The accuracy found for the VIS in the present study was comparable to NIR spectroscopy (88-93%) (Liddle et al., 2020) and SWIR to Raman spectroscopy (96.5-98.5%) (Logan et al., 2020).

Conclusion: The use of a non-invasive, non-contact HS scanning system trialled in the present pilot study provided very high accuracy and the RF method performed best. Results should be confirmed with a larger sample size before such a technology can be deployed in the meat industry.

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