MicroNIR SPECTROSCOPY FOR THE AUTHENTICATION OF SOUTH AFRICAN LAMB

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Abstract – The use of a portable MicroNIR (Viavi Solutions, formerly JDSU, USA) device was explored to determine the potential of using Near-infrared spectroscopy (NIRS) as an analytical tool for the authentication of fresh South African lamb meat. Meat of the *Longissimus thoracis* muscle of lambs (n=159) from five different regions (four Karoo and one Non-Karoo) was assessed. Spectral measurements were made on fresh meat steaks, 24hrs post-mortem. Principal component analysis (PCA) of the spectral data show that the Non-Karoo Rûens (RU) lamb grouped separately from that of the Karoo lamb, known as Central Karoo (CK), Northern Karoo (NK), Hantam Karoo (HK) and Bushmanland (BL). Within the Karoo, CK was partially separated from the other Karoo regions. Sufficient classification was achieved using partial least square discriminant analysis (PLS-DA) and support vector machines (SVM). Using PLS-DA, standard normal variate (SNV) and multiplicative scattering correction (MSC) combined with Savitzky-Golay second derivative gave 98% and 83% correct classification for Karoo and Non-Karoo, respectively. For SVM, overall SNV performed better correctly classifying 71% of BL, 87% of CK, 67% of HK, 43% of NK and 58% of RU. Using the MicroNIR it is possible to obtain suitable spectral data for the classification of lamb meat. However, a larger samples size might yield a more satisfactory classification in terms of the exact origin.

Key Words – Region of origin, Authenticity, Near-infrared spectroscopy

I. INTRODUCTION

The determination of the origin of food products are becoming increasingly important as consumers want to know where their products comes from as well as the verification of its authentic nature [1]. This is especially vital for food products sold at a premium price, due to the quality characteristics associated with it through its method of production in a defined region of origin. In South Africa, most of the lamb meat produced in the Northern parts of the country is known as *Karoo lamb* [2]. The meat is appreciated for its unique sensorial quality (e.g. herbaceous aroma and flavour attributes), attributable to the diet of the sheep, which mainly consist of the indigenous, herbaceous Karoo bushes and shrubs [3]. As a result of the quality and value associated with the meat, there is a risk that the name may be misused by entities not even remotely linked to the region. Another concern is lamb sold as Karoo lamb when in actual fact it had been produced in a feedlot or a Non-Karoo region. Therefore, it is vital that a method for the authentication of South African lamb, with special reference to Karoo lamb, is developed. Not only would such a method be able to distinguish Karoo from Non-Karoo lamb, but it would also provide scientific evidence to verify the unique nature of the product.

The hand-held MicroNIR was used to explore the classification of origin of lamb meat samples (n=159) from five regions in South Africa. The vast Karoo region is made up of different biomes which form the sub-regions [4]. The four selected for this study are known as the Hantam Karoo (HK), Central Karoo (CK), Northern Karoo (NK) and Bushmanland (BL). It is widely argued whether some of these should be included as part of the Karoo and whether the lamb produced from these regions can be classified as Karoo lamb. HK lamb mainly comprise the unique Karoo bushes of the region and fall within the succulent Karoo biome, while CK, NK and BL fall in the Nama-Karoo biome, comprising a combination of Karoo bush and savanna-type grasses [3]. The other region, known as the Rûens (RU), lies in the southern part of the country, where lambs are raised on lucerne (*Medicago sativa*) pastures [5]. The Rûens are known for their lamb produced on

these pastures however, depending on season, lamb may also be raised on stubble after the grain harvesting period (usually December-February) [5].

Previous research of descriptive sensory analysis and stable isotope ratio analysis [6] revealed distinct sensory and isotopic differences of lamb meat obtained from different farms within the mentioned regions. The differences found were related to diet linked to the origin. Given the time-consuming and costly nature of these analyses, the aim of the current work was to investigate NIRS as a potential tool for rapid and effective classification of lamb meat. The portable MicroNIR was used for this purpose as it enables easy, fast and non-destructive monitoring of the lamb meat. The work is also the first of its kind in South Africa, investigating the use of NIRS for the authentication of regionally unique lamb.

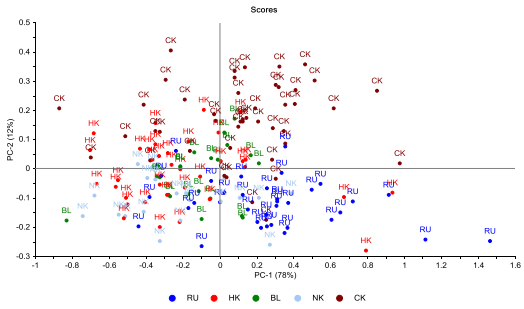
II. MATERIALS AND METHODS

Lamb meat was collected from three registered abattoirs in South Africa. Each abattoir was located in a distinct region, where lambs are raised extensively on the natural vegetation. Lambs (three per farm), classed A2 [(A) no permanent incisor teeth; (2) fat depth of 1.0-4.0 mm measured between the 3rd and 4th lumbar vertebrae] of any breed and gender, and a carcass weight of approximately 18 kg were sourced. In total, 159 lambs were used for the study. Twenty four hours after slaughter, meat steaks (1.5-2 cm thick) were cut perpendicular to the grain of the left *Longissimus thoracis* muscle of the carcass at the T_{13} position. The steaks were layed down on one side, while the other side was exposed to the air and left to bloom for 30 min after which the NIR scans were acquired. Samples were scanned (triplicate) in diffuse reflectance mode between 950-1650 nm by placing the MicroNIR spectrometer (Viavi Solutions, formerly JDSU, USA) on the exposed surface of the meat. Mean spectra (per sample) were used for data analysis. The full NIR wavelength range (950-1650 nm) was used. Unscrambler X 10.3 (Camo Software) was used for pre-treatment and chemometric analysis of the NIR spectral data. Three pre-treatments: standard normal variate (SNV), multiplicative scattering correction (MSC) and a combination of SNV and MSC, respectively with Savitzky-Golay second derivative (15 points) (SG) were used. Principal component analysis (PCA) was used to visualize sample grouping, while the partial least square discriminant analysis (PLS-DA) (±0.5 cutoff criteria) and support vector machine (SVM) (C=1, Gamma=10) methods were applied for classification of origin. A calibration (n=106) and validation (n=53) sample set were used.

III. RESULTS AND DISCUSSION

PCA revealed grouping of samples based on origin (Fig. 1). The Karoo samples tended to group separately from the Non-Karoo (RU). However, within the Karoo group CK were more partially separated from the other Karoo samples, while HK, BL and NK grouped closer.

Figure 1. PCA scores plot of the spectral data (SNV pre-processed) for the different lamb types



Overall, the highest absorptions were observed at 930-960 nm (Ar-OH second overtones), 1070-1100 nm (Ar-CH second overtones), 1120-1190 nm (C-H second overtones), 1380 nm (Ar-OH first overtones) and 1470-1520 (N-H first overtones). Differences in chemical components of lamb meat (caused by different diets) are likely the reason for discrimination between samples. It is widely known that diet affects the growth rate of the animal, the level and type of fat deposition and the chemical composition of the meat. These differences are what distinguish certain types of meat from others and in the case of Karoo lamb, what makes the meat more desired than lamb meat produced with other types of extensive practices. A key characteristic distinguishing Karoo lamb from other lamb meat is its herbaceous aroma and flavor, due a diet which includes fragrant plants. This explains the high absorptions of aromatic

(Ar-) overtones as many terpenes (fragrant components produced by plants) exist as cyclic structures. Preliminary data (exploring the volatile profile of the meat and fat) have shown that some cyclic monoterpenes, such as limonene (monocyclic) and pinene (bicyclic) play a dominant role in the sensory profile of Karoo lamb. The Karoo samples associated with strong absorptions in the 1380 nm range, possibly as a result of the presence of these phenolic compounds, which can be deposited in the meat through the consumption of herbaceous Karoo plants.

The PLS-DA results is shown in Table 1. In order to prevent over-fitting of the calibration model, the number of PLS factors were reduced from 7 to 6 for MSC and SNV, and from 6 to 4 for MSC+SG and SNV+SG. Although the Pearson R^2 value decreased, a satisfactory classification of Karoo vs Non-Karoo was still achieved with 95% and 98% correct classification for Karoo and 67% and 83% for Non-Karoo. As seen in Table 1, MSC+SG and SNV+SG pre-processing produced the best results.

Table 1 Correct classification rates of external validation set by PLS-DA analysis

Pre-processing	Calibration model		% Correct	
	R^2	RMSEP (‰)	Karoo (41)	Non-Karoo (12)
MSC[1]	0.74	0.59	95	67
MSC+SG[2]	0.76	0.56	98	83
SNV[1]	0.75	0.58	98	67
SNV+SG[2]	0.76	0.57	98	83

[1]Six factors used; [2]Four factors used; (R^2) Pearson determination coefficient; (RMSEP) Root-mean-squared error of prediction (test set validated); (MSC) Multiplicative scattering correction; (SNV) Standard normal variate; (SG) Savitzky-Golay (2^{nd} derivative, 2^{nd} order polynomial, 15 points).

SVM was used for the classification of the samples according to class (Karoo vs. Non-Karoo) and region of origin (RU, HK, CK, NK, BL). Overall the best SVM classification for class was achieved with MSC and SNV pre-processing of the spectral data. MSC provided a 95% correct classification for Karoo (39 out of 41) and 25% for Non-Karoo (3 out of 12). SNV gave 88% correct for Karoo (36 out of 41) and 67% correct for Non-Karoo (8 out of 12). In terms of SVM classification of the region of origin, MSC (C=10, Gamma=10, 83 SVs) and SNV (C=1, Gamma=10, 81 SVs) gave the overall best results (Table 2).

Table 2 Correct classification rates of external validation set by SVM for lamb meat origin

Pre-processing	% Accuracy[1]	% Correctly classified [2]				
		BL	CK	HK	NK	RU
MSC*	88	71	87	75	29	67
MSC+SG	72	29	67	75	0	67
SNV	89	71	87	67	43	58
SNV+SG	75	86	80	67	14	67

[1]Training model; [2]Classification of external validation set; *C adjusted to 10; (MSC) Multiplicative scattering correction; (SNV) Standard normal variate; (SG) Savitzky-Golay (2^{nd} derivative, 2^{nd} order polynomial, 15 points).

Through inspection of the external validation results it was noted that the SVM classification of CK lamb samples, from two farms, were consistently misclassified as Non-Karoo. This could suggest that these lambs were not raised extensively or that they received a large amount of supplementary feed. It was decided to exclude the two farms, re-build the SVM calibration models (for both class and region of origin classification) and re-test the model with the external validation set. Overall there was no great improvement seen for the classification of the validation set. In fact the samples excluded were not available to be misclassified for CK (as before), while the classification results of the other samples were the same. However, for the MSC+SG and SNV+SG pre-processing for SVM of origin, there was a large decrease in the percentage accuracy of the calibration models. There was also an increase in misclassifications for the validation set. This could signify the importance of having outliers in a robust classification model.

IV. CONCLUSION

NIRS can be used for the classification of South African lamb in order to verify its authentic nature. Classification using PLS-DA and SVM was sufficient to distinguish between Karoo and Non-Karoo, as well as region of origin. Discrimination within the Karoo is weak, nevertheless it is strong between Karoo vs. Non-Karoo. The results also

confirm that the portable MicroNIR is a suitable instrument to use for authenticating fresh meat. There is a great need to extend the database by including more sheep samples from different regions in order to develop a robust classification model which can be used to detect the origin of the meat. By increasing the sample size the variation is also increased. Ultimately, the wider the differences in sheep samples, the more accurate the model becomes. The results presented also serve as baseline data for future work.

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