

Fast and simultaneous prediction of animal feed nutritive values using near infrared reflectance spectroscopy

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Abstract. Feed plays an important factor in animal production. The purpose of this study is to apply NIRS method in determining feed values. NIRS spectra data were acquired for feed samples in wavelength range of 1000 – 2500 nm with 32 scans and 0.2 nm wavelength. Spectral data were corrected by de-trending (DT) and standard normal variate (SNV) methods. Prediction of in vitro dry matter digestibility (IVDMD) and in vitro organic matter digestibility (IVOMD) were established as model by using principal component regression (PCR) and validated using leave one out cross validation (LOOCV). Prediction performance was quantified using coefficient correlation (r) and residual predictive deviation (RPD) index. The results showed that IVDMD and IVOMD can be predicted by using SNV spectra data with r and RPD index: 0.93 and 2.78 for IVDMD ; 0.90 and 2.35 for IVOMD respectively. In conclusion, NIRS technique appears feasible to predict animal feed nutritive values.

1. Introduction

In animal production and livestock enterprise, feed plays an important role and spends about 70% of production cost [1]. Sago starch can be utilized to become animal feed which are readily in an abundant number in Indonesia. As stated by [2], it contains around 28. 27% crude fibres, and approximately 1. 359 % crude protein. Moreover, according to [3] sago residues may contain starch (57.9%), cellulose (23.1%), hemicellulose (9.19%) and lignin (3.89%) after starch extraction.

Generally, crude fibre in high amount will cause slow and limited ruminal degradation of carbohydrates. Further, lower content nitrogen is one of the main factors deficiencies from residues causing the low value of residues as feed for ruminants [4]. Fermentation technique by using microbial seems to be a practical method to improve nutritional value of agro residues. It is crucial to evaluate nutritive value of animal feed before being fed to animals mainly feedstuff quality for feed formulation to obtain high production of animals. Recently, to determine feed quality, several methods were employed. Yet, most of them were used based on standard laboratory analysis with complicated procedures, time consuming and using of hazardous chemical solutions, from which may cause environmental pollutions.

Therefore, alternative methods should be found to alter chemical analysis at laboratories to evaluate the nutritive values of feed stuff. Near infrared reflectance spectroscopy (NIRS) has been developed as rapid, direct, non-destructive and non-invasive bioanalytical technique. By this technique, the quantity, composition, structure and distribution of chemical constituents and functional groups in a tissue can be revealed.



Based on advantages and excellence of NIRS as novelty method to measure feed quality, this study is truly required. Thus, the main purpose of this present study is to apply NIRS as a rapid and simultaneous method in determining feed nutritive values in form of digestive organic materials (KCBK and KCBO). The prediction models were developed using raw untreated spectra data and enhanced one.

2. Materials and Methods

2.1. Material

Sago residues were used as a model feed to measure feed quality after fermentation. Sago from agro industry by product was fermented with 40% water content. commercial fermentation products (Saus Burger Pakan[®] (SBP) was used to fermented with different day fermentation as follow control (without fermentation), 7d, 14d, 21d and 28d.

2.2. Spectra data acquisition

Near infrared (NIR) spectra data of feed samples were obtained using Fourier transform infrared instrument. The basic measurement chosen for this spectra data measurement is high resolution with integrated sphere. Absorbance spectra data in form of diffuse reflectance in wavelength range from 1000 to 2500 nm were obtained 20 scans and averaged. Spectra data were recorded and saved in local computer with three different file formats (*.SPA, *.JDX and *.CSV) [5].

2.3. Measurement of feed nutritive values

After collecting and recording infrared spectra data, all feed samples were analyzed in Animal Feed Laboratory, Syiah Kuala University to measure its relevance quality parameters: protein, digestive organic materials (KCBK and KCBO), crude fiber, crude lipid and minerals. The method used for these measurements were standard laboratory methods.

2.4. Spectra data correction

Spectra data analysis were firstly performed to inspect spectra visualization and noise recognition. Noise, caused by light scattering were enhanced and corrected using de-trending (DT) and standard normal variate (SNV) methods. All spectra enhancement methods were processed using The Unscrambler X 10.3 software.

2.5. Prediction model

Prediction models were established for each quality attributes (KCBK and KCBO) based on untreated raw and enhanced spectra data (DT and SNV). Prediction models were developed using principal component regression (PCR) with full leave one out cross validation (LOOCV).

2.6. Evaluation performance

Prediction models performances were judged for their accuracies and robustness using these following indicators: the coefficient of correlation (r), root mean square error (RMSE) and the residual predictive deviation (RPD) defined as the ratio between the standard deviation and the RMSE. The higher the RPD, the greater and robust the model to predict KCBK and KCBO of animal feed samples [6].

3. Result and discussion

3.1. Spectra features

Typical diffuse reflectance spectrum for feed samples in wavelength range from 1000 to 2500 nm is shown in Fig.1. this spectra data shows the absence o nutritive values of animal feed samples which is derived from the absorbance bands that result from the vibration of molecular bonds of O-H, C-H, C-O and N-H with the IR radiation.

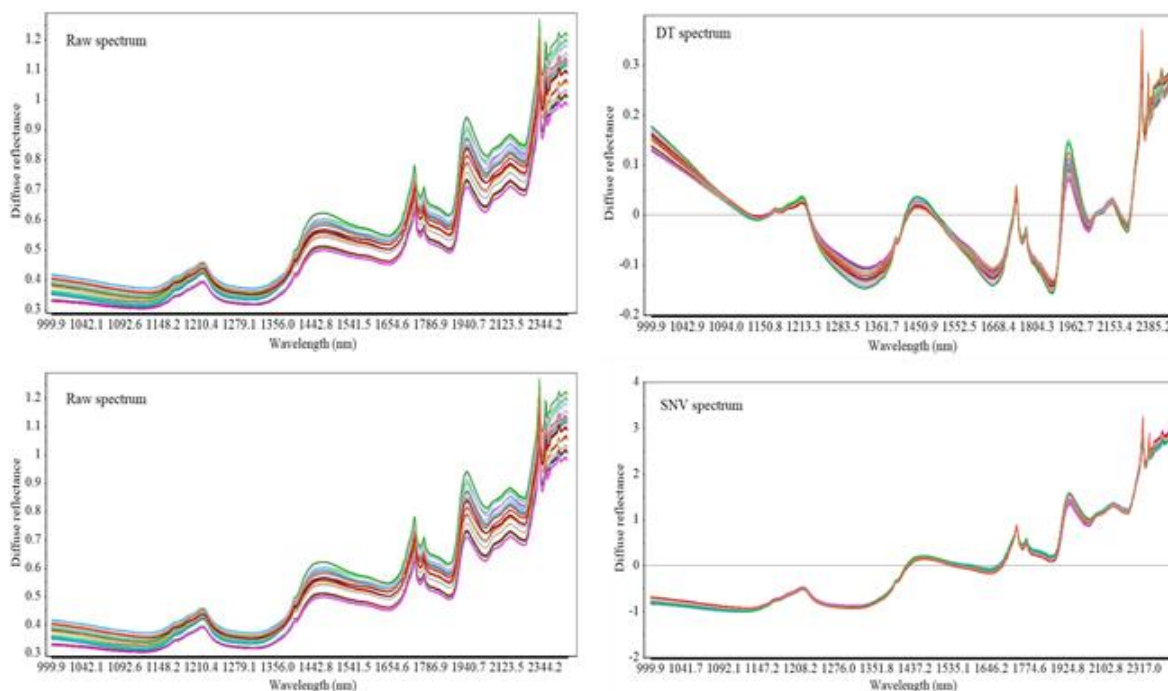


Figure 1. Spectra data of feed samples and corrected data using DT and SNV method.

Animal feed samples are scattered with the infrared radiation and their reaction including reflectance, absorbance and transmittance are captured and recorded. The different reaction of this specular data are depend on composition, cell structure and other chemical or physical properties of the feed samples. A captured near infrared spectra of biological object consists the response of the molecular bonds O-H, C-H, C-O and N-H. These bonds are subject to vibrational energy changes when irradiated by NIR frequencies [7].

As shown in Fig.1, spectra data were corrected using DT and SNV method. DT enhanced peak and valley by multiplying polynomial order while SNV spectra corrected spectra data by scaling spectra to its ideal one which normally mean spectra. These three spectra data (Raw, DT and SNV) were then used to develop prediction model used to predict feed nutritive values.

3.2. Prediction models

The main part of near infrared spectroscopy application is building a calibration model used to predict quality attributes or chemical constituents of this feed samples to be observed. The models were established using principal component regression is a two-step procedure; first decomposes the X-variables by a principal component analysis (PCA) and then fits a MLR model, using a small number of principal components (PCs) or latent variables (LVs) instead of the original variables (NIR spectra) as predictors. The advantage with respect to MLR is that the X-variables (principal components) are uncorrelated, and that the noise is filtered. Also, usually a small number of principal components are preferable and sufficient for the models.

Prediction model consists of the relationship between the observed response variable y (Y-variables: nutritive values KCBK and KCBO) and the independent variable x (X-variables: NIR spectra data). The primary information that can be gathered from the interaction of the near-infrared radiation with the biological object is its physical, optical and chemical properties. Feed samples have shown to have identifiable C-H, N-H, C-H-O and O-H absorption bands in the near-infrared region whereas each have a specific vibrational frequency [8].

Prediction result for KCBK and KCBO parameters were shown in Table 1 and Table 2 respectively. It is obvious that even without spectra correction, NIRS methods seems feasible to predict KCBK and KCBO with coarse performance (RPD = 1.64 for KCBK and RPD = 1.60 for KCBO). Their prediction performances were significantly improved when spectra data were corrected by DT and SNV method. As shown in both Table.

Table 1. KCBK prediction performance of NIR spectra data

Spectrum	Statistical Parameter			
	R^2	r	RMSE	RPD
Raw	0.61	0.78	2.03	1.64
DT	0.72	0.85	1.71	1.95
SNV	0.86	0.93	1.20	2.78

Table 2. KCBO prediction performance of NIR spectra data

Spectrum	Statistical Parameter			
	R^2	R	RMSE	RPD
Raw	0.59	0.77	2.51	1.60
DT	0.69	0.83	2.18	1.84
SNV	0.81	0.90	1.71	2.35

Based on prediction results, SNV provide the most accurate and robust prediction results by achieving maximum correlation coefficient $r = 0.93$ and $RPD = 2.78$ for KCBK and maximum $r = 0.90$ and $RPD = 2.35$ for KCBO prediction. Scatter plot drawn for the best results is shown in Fig. 2.

In general, judging from prediction performance evaluation, NIRS can be used and improved by correcting spectra data. Regression approach probably can be enhanced using another method such as partial least square regression (PLSR) or support vector regression (SVR).

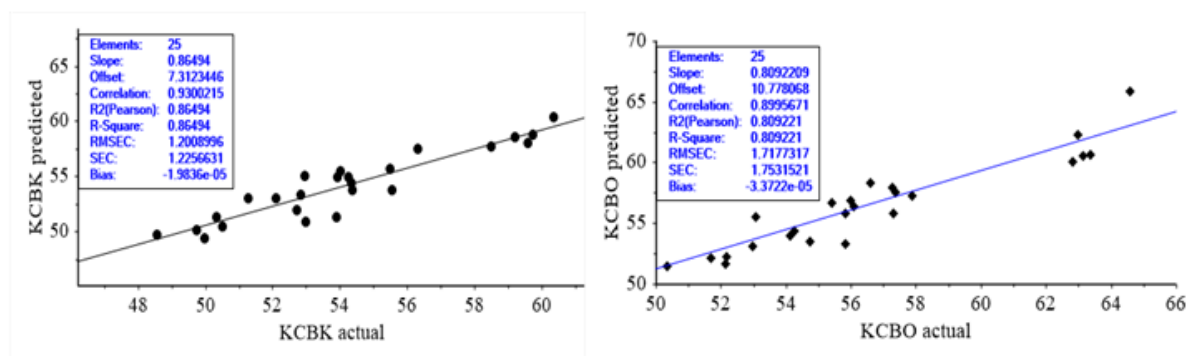


Figure 2. Scatter plot between actual and predicted feed nutritive values using SNV spectra data.

Based on regression and loading curve derived from SNV-PCR data, important and relevant wavelength for KCBK and KCBO prediction were observed around 1403 -1484 nm, 1908 - 2006 nm, and 2310 nm as shown in Figure. 3.

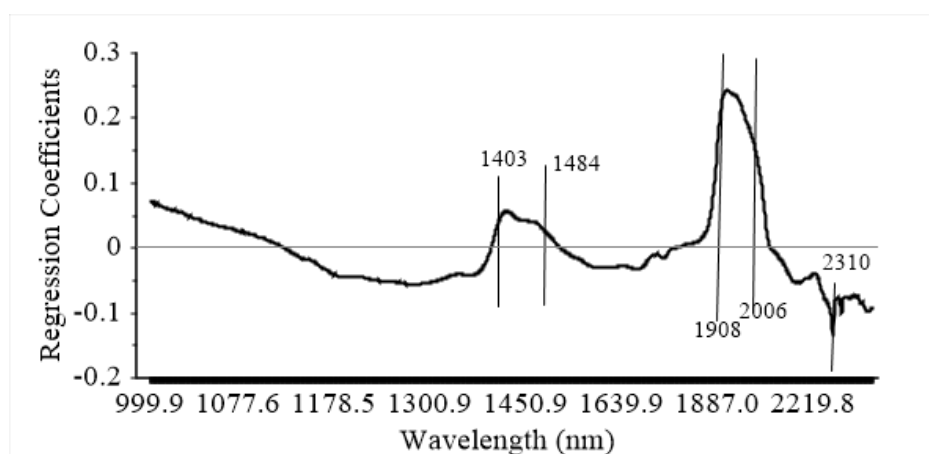


Figure. 3. Important wavelength in NIR region for KCBK and KCBO prediction.

4. Conclusion

Based on obtained results, it may conclude that NIRS can be used as an alternative fast and simultaneous method used to predict feed nutritive values (KCBK and KCBO). SNV spectra data provide the most accurate and robust prediction result with correlation coefficient $r = 0.93$ and RPD = 2.78 for KCBK and maximum $r = 0.90$ and RPD = 2.35 for KCBO prediction.

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