Non-destructive and fast determination of N, P and K in compound fertiliser by near infrared spectroscopy

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Introduction

Fertilisers are an important elemental source for growth and development of crops, whether intended for yield increasing or quality improving, they are indispensable. The amount of compound fertiliser produced in China is more than ten million tons and it is increasing at the rate of 5–7% per year. Chemical analysis methods are widely used for quality testing but these methods are complex and time-consuming. We expect to find an alternative method that is fast, non-destructive and has low running costs.

Near infrared (NIR) spectroscopy has been widely used for fast and non-destructive analysis in agriculture, food, pharmaceuticals, textiles, cosmetic and polymer production.[1–4] Of all the techniques available for fast assessment, NIR is the most suitable method for analysis.

In this study, we explored the feasibility of using NIR spectroscopy for the analysis of N, P and K in compound fertiliser samples.

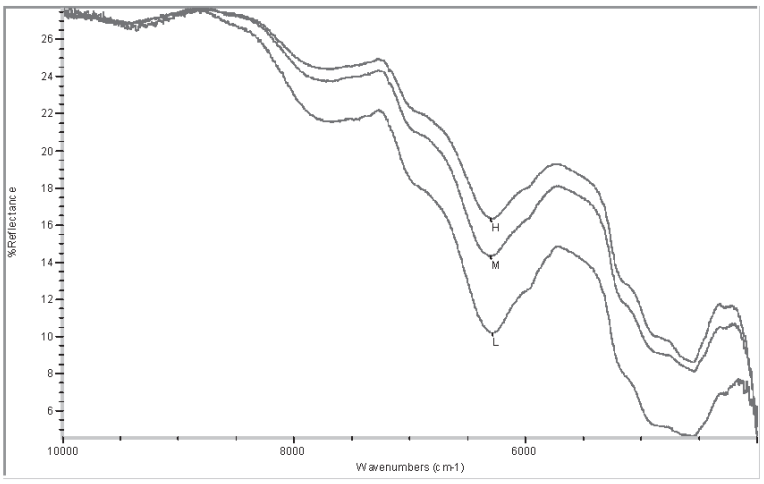

Figure 1. Original spectra of Lanfei (H, M and L).

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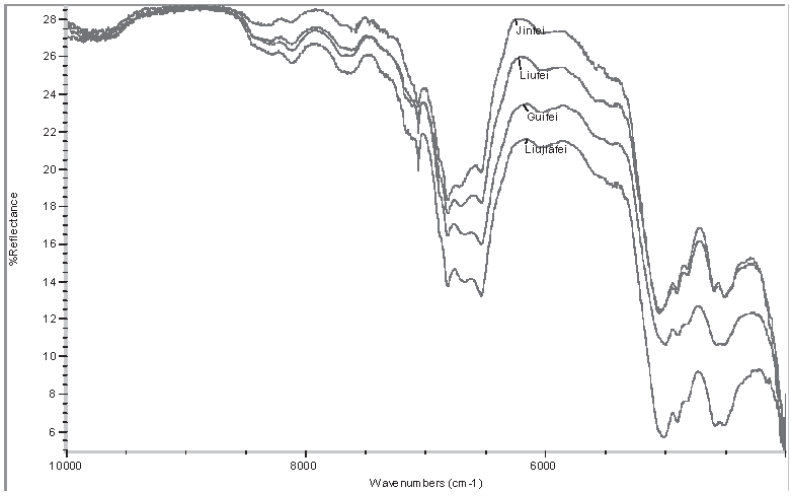

Figure 2. Original spectra of four fertilisers.

Materials and methods

Sample collection and chemical analysis

Seventy compound fertiliser samples were collected in 2000 from Batian Compound Fertiliser Ltd in Shenzhen, China. The five varieties were Lanfei, Jinfei, Liufei, Guifei and Liujiafei, which included 30 from Lanfei and 40 of the other four kinds of fertilisers. The contents of N, P and K were determined chemically and these results were used to develop NIR spectroscopic methods.

NIR spectral acquisition

The NIR spectrometer used in this experiment was a commercially available 360N (Nicolet Co., USA). The spectral data of N, P and K were generated in the wavenumber range from 10000 cm^{-1}–4000 cm^{-1}. The original spectra are shown in Figures 1 and 2.

Table 1. The range of N, P, K contents in compound fertiliser.

	Calibration			Prediction		
	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
Lanfei range	14.90–16.92	4.43–5.60	8.16–11.63	15.18–16.38	4.55–5.00	8.26–11.36
Average	15.72	4.82	10.08	15.65	—	10.10
Others range	13.27–17.43	—	6.48–10.46	13.82–16.90	—	6.52–10.42
Average	15.29	—	8.30	15.46	—	8.53

Table 2. The main parameters of N, P and K in compound fertiliser.

	Lanfei				others			
	n	Range (cm^{-1})	*R*	*SE*(%)	*n*	Range (cm^{-1})	*R*	*SE* (%)
N	22	5989–5565	0.9925	0.22	3	9750–5250	0.9913	0.50
P	22	10040–5800	0.9731	0.10	—	—	—	—
K	22	8320–7350	0.9973	0.33	3	9950–7780	0.9896	1.20

Data analysis

Partial least square regression (PLSR) analysis was conducted using the Omnic 5.1 data analysis software (Nicolet Co.).

Results and discussion

The analysis characteristics of the samples and original spectra are given in Table 1. The best results were observed using the second derivative and PLSR analysis for N, P and K, which not only had good relationship but also a low standard error of prediction. The main parameters of N, P and K in compound fertiliser using NIR are presented in Table 2.

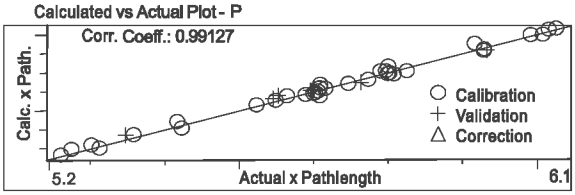

Figure 3. NIR calibration equation for nitrogen in four fertilisers.

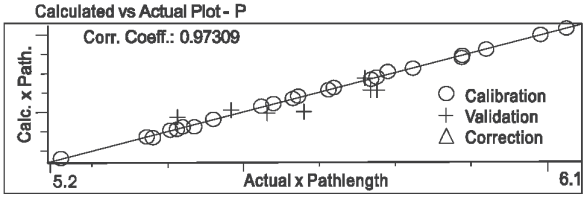

Figure 4. NIR calibration equation for phosphorus in Lanfei.

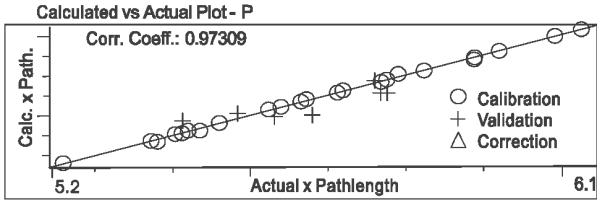

Figure 5. NIR calibration equation for potassium in Lanfei.

Table 3. Prediction results using NIR in Lanfei.

	N (%)			P (%)			K (%)		
No	Lab	NIR	residual	Lab	NIR	residual	Lab	NIR	residual
1	15.68	15.72	0.04	4.73	4.71	0.02	8.26	8.31	0.05
2	15.88	15.84	0.04	4.81	4.79	0.02	8.53	8.56	0.03
3	16.39	16.61	0.22	4.70	4.60	0.10	8.87	8.91	0.04
4	15.18	15.09	0.09	4.82	4.72	0.10	10.76	10.74	0.02
5	15.72	15.69	0.03	4.92	4.90	0.02	11.36	11.31	0.05
6	15.52	15.45	0.07	4.83	4.93	0.10	10.93	10.89	0.04
7	15.37	15.30	0.07	5.00	4.90	0.10	11.13	11.13	0.00
8	15.47	15.46	0.01	4.55	4.68	0.13	11.00	10.97	0.03

Table 4. Prediction results using NIR in the other four kinds fertiliser.

	N (%)			K (%)		
No	Lab	NIR	residual	Lab	NIR	residual
1	16.90	16.62	0.28	8.45	8.47	0.02
2	16.07	16.17	0.10	8.62	8.46	0.16
3	15.40	15.48	0.08	8.71	8.65	0.06
4	15.43	15.44	0.01	6.52	6.67	0.15
5	13.82	13.95	0.13	7.46	7.43	0.03
6	15.10	15.24	0.14	7.85	7.74	0.11
7	15.83	15.61	0.22	8.21	8.21	0.00
8	15.13	15.09	0.03	9.62	9.70	0.08
9	15.08	15.03	0.05	9.48	9.50	0.02
10	15.90	16.14	0.24	10.42	10.38	0.04

Figures 3 to 5 show the NIR regression equations developed for N, P and K in compound fertiliser samples respectively.

Validation statistics from PLSR analysis, comparing the results of chemical analysis with those predicted from NIR analysis, are shown in Tables 3 and 4.

Conclusions

This study has shown that NIR techniques can be used to rapidly and accurately determine the N, P and K nutrient components in compound fertiliser samples. Compared with the national standard

methods, the results obtained in these components were multi-correlative coefficients of 0.9913–0.9925; 0.9731; 0.9896–0.9973 correspondingly and the standard errors for the test samples are 0.01–0.28; 0.02–0.13; 0.00–0.16 respectively. The NIR techniques have been successfully used in the Batian fertiliser plant for quality control.

References

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