SHORTWAVE INFRARED REFLECTANCE SPECTROSCOPY FOR ESTIMATING GRAIN PROTEIN CONTENT OF WHEAT AND RICE CROPS

*Yan Yan, Xiao Zhang, Dong Li, Hengbiao Zheng, Xia Yao, Yan Zhu, Tao Cheng**

National Engineering and Technology Center for Information Agriculture (NETCIA), MARA Key Laboratory of Crop System Analysis and Decision Making, MOE Engineering Research Center of Smart Agriculture, Jiangsu Key Laboratory for Information Agriculture, Institute of Smart Agriculture, Nanjing Agricultural University, One Weigang, Nanjing, Jiangsu 210095, China

Corresponding author: Tao Cheng (tcheng@njau.edu.cn)

Abstract: Grain protein content (GPC) of cereal crops is an important agronomic indicator for optimized cultivation, classified harvesting, and quality grading. Previous studies on the spectroscopic estimation of GPC were often conducted at the canopy level with vegetation indexes (VIs) derived from the visible and near infrared (VNIR) bands, which are apart from the absorption features of protein predominately located in the shortwave infrared (SWIR) region. From spectroscopy perspective, the causal relationships between sensitive spectral bands and protein absorption features are poorly understood. The physical links were examined in this study with the grain spectral properties of wheat and rice in the SWIR region. Specially, we extracted wavelet features sensitive to GPC with a signal processing tool continuous wavelet method (CWA), which has been widely applied to the spectroscopic estimation of biochemical parameters but not yet of crop grain quality. This study reports the first attempt to the spectroscopic estimation of GPC with wavelet features (denoted as $WF_{\lambda,scale}$) in comparison with the traditional normalized difference indices (denoted as $ND_{\lambda1,\lambda2}$). We conducted two experiments of paddy rice in 2017 and 2018 and winter wheat in 2018 and 2019 with different nitrogen (N) rates and crop varieties. The reflectance spectra of dried grain powder and GPC data were split into calibration (2017 rice and 2018 wheat) and validation (2018 rice and 2019 wheat) sets for performance evaluation.

Our results showed that the protein absorption features in SWIR could be enhanced using wavelet features and hence the GPC was accurately estimated. The wavelet-based method obtained high estimation accuracy on both calibration ($WF_{1610,5}$: R^2=0.93) and validation ($WF_{1610,5}$: R^2=0.93, RMSE=0.59%). Although the VI-based method had good performance on calibration data ($ND_{1780,1745}$: R^2=0.91, $ND_{1910,1980}$: R^2=0.93%), they had poor performance on validation data ($ND_{1780,1745}$: R^2=0.35, RMSE=1.83%; $ND_{1910,1980}$: R^2=0.00, RMSE=2.71%). The worse performance of spectral indices was due to the poorer model transferability across years. Therefore, the enhancement of protein absorption features in the SWIR region by the CWA is promising for the estimation of GPC. This study provides new insight into the spectral properties of grain reflectance spectra in response to GPC variation and lay the foundation for the spectroscopic estimation at canopy level in the future.

Key words: Grain protein content; Continuous wavelet analysis; Absorption feature; Shortwave infrared.