Title Detection of insect and fungal damage and incidence of sprouting in stored wheat using near-infrared hyperspectral and digital color imaging

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Abstract

Canada has a reputation of exporting high quality grain globally. Wheat grain quality is defined by several parameters, of which insect and fungal damage and sprouting are considered important degrading factors. There is an increasing demand among grain buyers and consumers towards zero-tolerance to contamination in grain and processed grain products. At present, Canadian wheat is inspected and graded manually by Canadian Grain Commission (CGC) inspectors at grain handling facilities or in the CGC laboratories. Visual inspection methods are time consuming, less efficient, subjective, and require experienced personnel. Therefore, an alternative, rapid, objective, accurate, and cost effective technique is needed for grain quality monitoring in real-time which can potentially assist or replace the manual inspection process.

Insect-damaged wheat samples by the species of rice weevil (*Sitophilus oryzae*), lesser grain borer (*Rhyzopertha dominica*), rusty grain beetle (*Cryptolestes ferrugineus*), and red flour beetle (*Tribolium castaneum*); fungal-damaged wheat samples by the species of storage fungi namely *Penicillium spp., Aspergillus glaucus* group, and *Aspergillus niger* ; and artificially sprouted and midge-damaged wheat kernels were obtained from the Cereal Research Centre (CRC), Agriculture and Agri-Food Canada, Winnipeg, Canada. Healthy and damaged wheat kernels were imaged using a long-wave near-infrared (LWNIR) and a short-wave near-infrared (SWNIR) hyperspectral imaging system and an area-scan color camera.

The hypersrptral data from both LWNIR and SWNIR were analyzed using multivariate image analysis (MVI) after applying pre-processing and calibration techniques. The wavelengths corresponding to the highest principal components (PC) factor loadings were considered to be significant. Up to six statistical features (maximum, minimum, mean, median, standard deviation, and variance) and histogram features from the significant wavelengths images were extracted and given as input to various classifiers. From the color images of individual kernels, 230 features (123 colour, 56 textural, and 51 morphological features) were extracted and the top 10 features from 123 color features and combined 230 features were

selected and given as input to various classifiers. These top features were also combined with the SWNIR features to develop classification models. Linear, quadratic, and Mahalanobis discriminant analysis classifiers were used to develop supervised classification algorithms. Back propagation neural network (BPNN) classifiers were also investigated for their performance.

Long-wave NIR hyperspectral imaging gave high accuracy in classifying healthy and damaged wheat kernels and detected 85.0-100.0% healthy and insect-damaged kernels, 95-100.0% healthy and fungal-infected kernels, and 85.0-100.0% healthy and sprouted kernels in two-way classification. The SWNIR hypersepcrtal imaging gave high damage detection rate but caused high false positive errors of up to 28.0% and misclassified healthy kernels as damaged. In some cases, the top features from color images also resulted in high false positive errors. Combined features from color and SWNIR images gave very high classification accuracy and detected 91.0-100.0% healthy and insect damaged, 99.0-100.0% healthy and fungal damaged, and 95.3- 99.3% healthy and sprouted (midge-damaged) wheat kernels. Classification results of statistical discriminant classifiers were better than the BPNN classifiers.