Non-destructive internal defects detection in apple fruits using novel x-ray dark field imaging and machine learning

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Objective: To propose a non-destructive and automatic method for apple internal defects detection based on novel x-ray dark field imaging and machine learning
Methods: In order to obtain healthy and defect fruits, ‘Braeburn’ apples were randomly divided and stored in optimal and browning-inducing conditions for 3.5 months. Intact apples were scanned using a grating-based interferometer to get conventional x-ray transmission images as well as novel dark field radiographs. The dark field image modality generates contrast images related to differences in x-ray scattering in the scanned fruit, while the transmission image render contrast due to differences in attenuation of the x-rays. For the data pre-processing, image type conversion and background removal were conducted to reduce computational cost and focus on the object in the image respectively. Then histogram-based and texture features were extracted globally through statistical methods. Those features were combined into latent variables by using the partial least square method. Optimal latent variables were selected through 10-fold cross validation based on the F1 score. Three different machine learning algorithms (linear discriminative analysis, linear support vector machine and logistic regression) were used to develop classifiers. 80% and 20% of the data were used to train and test these classifiers. Different metrics (accuracy, F1 score, recall and precision) were applied to evaluate classifier performance. As a benchmark, the same workflow was executed on the corresponding x-ray transmission images.
Results: From qualitive visual inspection, dark field images of defect fruits seemed to give higher contrast between healthy and defect regions compared with corresponding transmission images. For dark field image dataset, all three classifiers achieved 100% accuracy on the test data when optimal latent variables were used. Moreover, the linear support vector machine needed least number of latent variables. For the transmission image dataset, the highest accuracy was only 65% achieved by using linear discriminative analysis.
Conclusion:
The results indicate that the proposed method can non-destructively detect apple internal defects based on novel x-ray dark field imaging and machine learning.