Can hidden Ectomyelois ceratonia infestation be detected non-destructively? NIR spectroscopy has a good answer for pomegranates

In recent decades, near-infrared (NIR) spectroscopy has been accepted as a powerful non-destructive testing (NDT) technology for quality assessment of most materials in most industries such as chemistry, medicine, agrofood, etc. This optical technology is rapid, safe, versatile, environmentally friendly, and cost-effective. NIR spectroscopy requires little or no sample preparation. Therefore, it can be easily adapted for real-time and on/in-line inspection. This NDT technology has been extensively used in agrofood industry due to its advantages. It is very successfully being used for rapid internal chemical compounds prediction and quality, safety and health assessment of fruits, non-destructively. Recently, few works have investigated the feasibility of utilizing NIR spectroscopy for non-destructive detection of some internal insect larvae or infestation in some fruits.

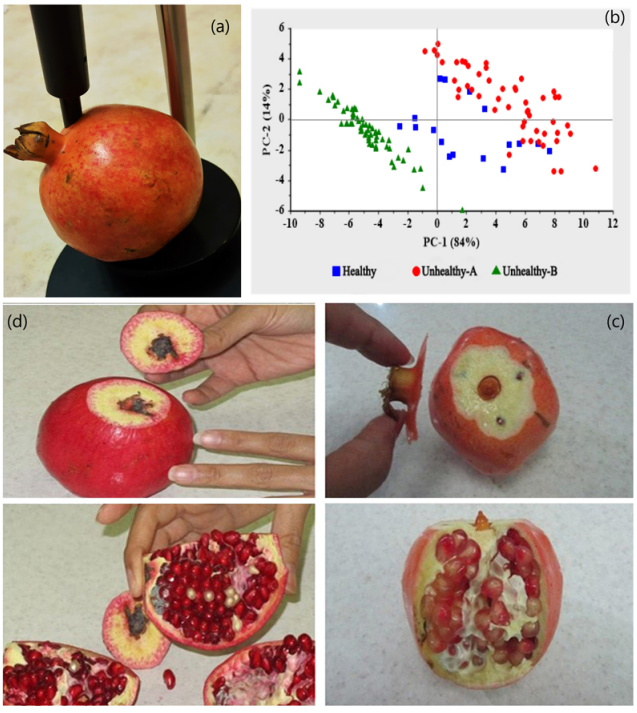

Fig. 1. Vis/NIR spectroscopy of pomegranate fruit at the position around and near the calyx (a), The scores plot of PC1 versus PC2 for clustering of the pomegranates into the three classes of “Healthy”, unhealthy without any external symptoms “Unhealthy-A”, and unhealthy with the external symptoms “Unhealthy-B” (b), “Healthy” pomegranate after cutting (c), “Unhealthy-A” pomegranate after cutting (d).

The carob moth, *Ectomyelois ceratonia* Zell. (Lepidoptera: Pyralidae), is a destructive insect and the most important pest of pomegranate (*Punica granatum*) fruit in the Middle East, especially in Iran. This pest attacks the fruits before and after harvest and causes 30–80 present yield losses. The insect normally lays eggs inside the crown, calyx, of pomegranates. After hatching, larvae penetrate into the fruit. The damage caused by larvae on the fruit is due to their feeding from internal parts of pomegranate mostly without external symptoms. This causes penetration of pathogenic fungi such as *Aspergillus* and *Penicillium* into the fruit. So, infested and unhealthy pomegranates are unmarketable and unfit not only for human consumption but also for the food processing industries. They are the key challenge for the exportation. Also, the pomegranates with hidden infestation may pass undetected in packing houses and processing lines and damage the surrounding healthy fruits during storage. So, development of a fast technique such as NIR spectroscopy for rapid and non-destructive detection of carob moth infested pomegranates is imperative. Hidden activity of the larvae with no external visual symptom as well as the complexity and variety of internal different parts of pomegranate fruit are key challenges facing this NDT technology for this end.

A research was conducted to investigate the feasibility of utilizing Vis/NIR spectroscopy at the range of 500–1000 nm combined with pattern recognition methods for detection of carob moth infestation in pomegranates during hidden activity of the larvae. Some fruits were artificially contaminated to the carob moth larvae of second age. Vis/NIR spectra of the blank samples and the contaminated pomegranates were analyzed one and two weeks after contaminating the samples as three groups of “Healthy”, unhealthy without any external symptoms “Unhealthy-A” and unhealthy with the external symptoms “Unhealthy-B”. Discriminant analysis (DA) based on principal component analysis (PCA) was used as a powerful supervised pattern recognition method to classify the samples (Fig. 1). The achieved results confirmed the capability of this technology for discrimination of healthy pomegranates from contaminated fruits to carob moth larvae with and without external symptoms of larvae infestation. The total percentage of correctly classified samples with the best developed model of PCA-DA was approximately 98%. This model could also predict unknown samples with total percentage of correctly classified samples of above 90%.

This research showed that Vis/NIR spectroscopy can be useful for fast, low-cost and non-destructive screening and health control of the pomegranates. So, this optical NDT technology can be used for developing smart/expert handheld/portable/on-line/in-line systems for non-destructive inspection of the pomegranates in terms of carob moth infestation during hidden activity of the larvae.

Bahareh Jamshidi
Agricultural Engineering Research Institute, Agricultural Research Education and Extension Organization (AREEO), Karaj, Iran

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