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High speed measurement of corn seed viability using hyperspectral imaging

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HIGHLIGHTS

- HSI technique was developed for investigation of microwave treated corn seeds.
- PLSDA model classified treated and untreated corn seeds with high accuracy.
- Image processing method was helpful for visualization and detection of untreated seeds form treated seeds.
- HSI demonstrated a potential tool for detection of corn viability effected by heat treatment.

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ABSTRACT

Corn is one of the most cultivated crops all over world as food for humans as well as animals. Optimized agronomic practices and improved technological interventions during planting, harvesting and post-harvest handling are critical to improving the quantity and quality of corn production. Seed germination and vigor are the primary determinants of high yield notwithstanding any other factors that may play during the growth period. Seed viability may be lost during storage due to unfavorable conditions e.g. moisture content and temperatures, or physical damage during mechanical processing e.g. shelling, or over heating during drying. It is therefore vital for seed companies and farmers to test and ascertain seed viability to avoid losses of any kind. This study aimed at investigating the possibility of using hyperspectral imaging (HSI) technique to discriminate viable and nonviable corn seeds. A group of corn samples were heat treated by using microwave process while a group of seeds were kept as control group (untreated). The hyperspectral images of corn seeds of both groups were captured between 400 and 2500 nm wave range. Partial least squares discriminant analysis (PLS-DA) was built for the classification of aged (heat treated) and normal (untreated) corn seeds. The model showed highest classification accuracy of 97.6% (calibration) and 95.6% (prediction) in the SWIR region of the HSI. Furthermore, the PLS-DA and binary images were capable to provide the visual information of treated and untreated corn seeds. The overall results suggest that HSI technique is accurate for classification of viable and non-viable seeds with non-destructive manner.

1. Introduction

The world population standing at approximately 7.2 billion people as par the statistics report by the United Nations Department of Economic and Social affairs [1], the food shortage continues to increase linearly, and with inadequate distribution to all parts of the world. This requires robust approaches to increasing agricultural production at all levels to meet the food demand both quantitatively and qualitatively. Optimized agronomic practices as well as improved technological interventions at all levels of production including among others field preparation, seed preparation, planting, irrigation, harvesting, and post-harvest handling are key to improving the nature and output of agriculture.

Today, corn (*Zea mays* L.) is currently one of the most and widely grown cash and food crops in several parts of the world [2], being used both for humans, feed for animals as well as other industrial uses such as in breweries, biofuel processing, and

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cosmetics [3–5]. The economic research policy report by USDA [6] indicated that more than 90% of the corn produced in the United States is used as animal feed while the rest is used for other peripheral purposes such as baking, popcorn and corn flakes for human consumption. In Uganda, about 50% of the corn produced is consumed in institutions such as schools, security agencies, and business companies, whereas about 20% is consumed by households as the main carbohydrate food [7]. Corn farm productivity is often determined by a number of factors ranging from inherent seed properties to external factors such as weather, pests and diseases, and loss of soil fertility due to soil exhaustion. Seed germination and vigor are the primary determinants of any crop productivity [8,9] notwithstanding any other factors that may play during the growth period. There are a lot of factors that cause loss of seed viability during storage, they are influenced by conditions present in the field during crop production (drought, high pest infestation, diseases, presence of other stress conditions), as well as conditions present during storage (presence of pathogens, variations in temperature, humidity etc.). The viability of corn seed is often being lost during storage due to variability in storage conditions, mainly to high moisture content (>14%) or temperature (>25 °C), or physical damage during mechanical post-harvest processing such as shelling, or over heating during artificial drying especially using microwave dryers [10–12]. As seed companies and large – scale corn farmers often deal with bulk quantities of seed during processing and storage, there is a vital need for a quick and efficient method to determine the germination condition and viability of the seed prior to sale or planting in order to reduce the cost of fertilizers, herbicides, pesticides and labor.

It is difficult or even impossible to screen and discriminate viable and nonviable seeds using naked eye or similar rudimentary methods. In the recent past, a number of viability test and classification methods have been invented. They range from simple handy gadgets to sophisticated analytical methods. The modern seed screening techniques are based on vibrational spectroscopy, which uses interaction of radiation energy with the sample to study the inherent chemical traits therein. The sample material absorbs or reflects the radiations entirely or in part depending on the molecular vibrations in a material. Vibrational spectroscopic techniques such as NIR, IR, Raman, VIS NIR, SWIR, and NMR have proved useful, and have so far been considered the most reliable for quality analysis of various agricultural products [13,14]. Agelet et al. [4] and Wang et al. [15] used near infrared spectroscopy to successfully discriminate artificially aged (nonviable) corns and wheat respectively from viable ones. Their tests however were done on single seed basis and laboratory scale which is not suitable for large scale operations. Given the bulkiness of the seed batches normally at hand, single seed analysis and discrimination or using conventional methods may be complex, labor intensive, and time consuming. The type of operations in seed companies require visual based analysis techniques such as hyperspectral imaging (HSI) which may be suitable for system automation as it captures chemical maps from the sample in a fast, reliable and real time manner. To-date, no researches have been published regarding the use of hyperspectral imaging for corn seed viability test and classification. The main aim of this research was to investigate the possibility of using hyperspectral imaging for fast and reliable corn viability test and discrimination.

2. Materials and methods

2.1. Seed selection and ageing treatment

In this study, three varieties of corn, i.e. yellow, white, and purple were used in experimentation. For each category of corns, 300 kernels were selected which were then divided into two equal groups of 150 kernels each. The first group of 150 kernels was heat treated to induce seed ageing, whereas the other 150 was left untreated and used as control. The artificial ageing treatment was done using a laboratory scale microwave oven with 1000 W input power and 40 s seed exposure time. The treatment was done at the most optimum condition whereby the treated and untreated samples could not be differentiated by eye. Both treated and untreated seeds for each corn category were scanned and analyzed using hyperspectral imaging and multivariate statistical analysis for discriminating between treated and untreated corn seeds.

2.2. Germination test

After HSI spectra collection of both corn groups (treated and untreated corn), a germination test was conducted which was followed by the International Seed Testing Association (ISTA) [21] to check the effect of heat treatment in corn. In this experiment both treated and untreated seeds were placed between germination papers and stored in incubator at 25 °C temperature. After seven days, the viability of both treated and untreated corn were inspected. Form the germination test we noticed that the untreated corn seeds were well germinated (indicting the seeds are viable) while the treated seeds were not germinated (indicating the seeds are non-viable). Therefore, the excessive heat treatment change the seeds form viable to non-viable, which indicates that the treated seeds have no potential to produce vigorous seedling under favorable conditions.

2.3. Hyperspectral data collection

For Visible/NIR and SWIR (shortwave infrared), the data of corn seeds were collected using a line-scan HSI system. The Visible/NIR, HSI system was composed of the light source, EMCCD camera (Luca RDL-604M, Andor Technology, South Windsor, CT, USA), and line scan imaging spectrograph (Headwall Photonics, Fitchburg, MA, USA), with the spectral range of 400–1000 nm. The SWIR HSI system was also composed of an imaging spectrograph (Headwall Photonics, Fitchburg, MA, USA, Xeva-2.5-320, Xenics, Belgium) with a spectral range 1000–2500 nm, an MCT (Mercury Cadmium Telluride) camera of 320×256 pixels, tungsten halogen light source (100 W), translation stage. Both HSI systems were computer controlled and operated in MS windows operating system environment.

2.4. Image acquisition and correction

The hyperspectral images of corn kernels on a seed-plate were captured as the translation stage moved from right to left at the camera focal point in the field of view (FOV). The sample corns were arranged in a 6×6 grid with lines of treated and untreated kernels diagonal to the vertical-axis (Fig. 1) to avoid any variances that could accrue from effects of non-uniform light source. The light source was used to illuminate the samples during reflectance measurement.

For VIS/NIR, the EMCCD camera was set at 5 ms exposure time and 0.2 mm step size to run 600 line scans on each sample plate, whereas for SWIR, the camera was set at 7 ms exposure time and 0.3 mm step size to run 400 line scans. The 3D hypercube images of the scanned samples comprised 502×600 pixels each with 128 bands in the 400–1000 nm wavelength range for VIS/NIR, and 320×400 pixels with 208 bands for SWIR HSI system. The acquired raw hyperspectral images were transformed into hyperspectral reflectance images by removing any possible noise generated by systematic irregularities as well as inconsistence of operation conditions of the surroundings such as temperature,