Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.5448

ISSN: 2320 – 7051

Int. J. Pure App. Biosci. **5 (6):** 372-378 (2017)

Review Article

International Journal of Pure & Applied Bioscience

OPEN ACCESS

Optical Sensing Technologies in Seed Science Research-A Review

Kartoori Saisanthosh[1*], N. K. Biradar Patil, Shuba, A. C. and T. Joseph Raju[2]

Department of Seed Science and Technology, UAS, Dharwad 2. UAS Raichur, Karnataka

*Corresponding Author E-mail: sai.kalebu572@gmail.com

Received: 15.08.2017 | Revised: 23.09.2017 | Accepted: 27.09.2017

ABSTRACT

Quality seeds are of great importance in agricultural production. As such, rapid and non-destructive detection methods must be developed by the researchers for assessment of seed quality and seed health. Among the currently available non-destructive methods, optical sensing is one of the most promising technologies which has been used in Seed Science Research. This primarily focuses on Machine Vision, Near-Infrared Spectroscopy and Hyper Spectral Imaging. Machine Vision is widely applied to identify and classify seeds by using their visible features, such as colour, shape, texture and size. Near-Infrared Spectroscopy has an advantage in quality discrimination and prediction of internal chemical compositions by using spectral information. Hyper Spectral Imaging integrates the advantages of Machine Vision and Near-Infrared Spectroscopy. Hence, the novel optical sensing technology is proved to be emerging technology which should be harnessed by seed researchers in the area of Seed Science Research.

Key words: *Machine Vision, Near-Infrared Spectroscopy, Hyper Spectral Imaging*

INTRODUCTION

Crops including grains, vegetables and fruits are common raw materials in the food, medical and chemical industries. As such, seed quality and safety evaluation is important to consumers and industry. The yield and quality of crops, which are primary concerns of producers and consumers, are dependent on seed quality from pre to post harvest. Moreover, the safety and quality of crop seeds or their products are directly or indirectly related to human health; nevertheless, evaluation of these parameters is a time consuming process. For example, the calculation of germination percentage requires manual counting and grading of germinating seedlings by experienced technicians. Therefore, rapid, simple, and accurate detection techniques must be developed for farmers to ensure seed safety and quality during seeding, growth, harvesting, storage and transport to consumers.

In agricultural production, seed quality comprises varietal quality and sowing quality, which represent different seed characteristics. Variety quality is related to the genetic characteristics of seeds and can be summarized as seed purity and authenticity, which are important factors that contribute to final crop production.

Cite this article: Saisanthosh, K., Patil, N.K.B., Shuba, A.C. and Raju, T.J., Optical Sensing Technologies in Seed Science Research-A Review, *Int. J. Pure App. Biosci.* **5(6):** 372-378 (2017). doi: http://dx.doi.org/10.18782/2320-7051.5448

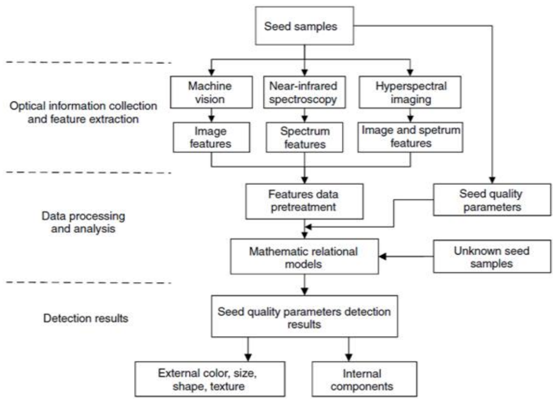
Sowing quality is associated with sprout and growth conditions of seeds after sowing; this parameter includes seed cleanliness, kernel fill, pest infection rate, moisture content, vigour and germination. Molecular identification, DNA analysis, isotope fingerprinting and mineral element analysis have been used to detect variety quality of seeds. Meanwhile, protein electrophoresis, gas chromatography, high-performance liquid chromatography and artificial technologies have been employed to evaluate sowing quality of seeds. Most of these chemical and physical techniques exhibit high accuracy and good reliability but also present certain limitations, such as high cost, health hazard, lengthy duration and high operator requirements. With increasing demand for rapid, non-destructive and reliable evaluation of seeds in the modern industry, high-performance techniques must be developed for evaluating seed quality and safety. A number of non-destructive testing technologies have been developed, including artificial taste (electronic tongue) and olfaction (electronic nose), acoustic and optical methods, computerized tomography scanning, magnetic resonance imaging and multisensory data fusion. This mainly focuses on three novel optical technologies, namely, machine vision, near-infrared spectroscopy and hyper spectral imaging. Data processing, analysis methods and their applications in safety detect ion and quality control of different seeds are also discussed.

Advantages of Optical sensing technology in Seed science research

1. Simple and accurate detection method (Eg: Virus detection in seeds using OCT)
2. Time saving and quick method (Eg: Germination % using Differential spectra)
3. Non destructive method (Eg: Protein, CHO and fat estimation using reflectance spectroscopy)
4. Economically cheaper (Eg: Viability test using differential spectra)
5. Saves resources (Eg: GM & non GM seeds using NIR spectroscopy)
6. Reliable and reproducible results (Eg: > 95% accuracy of seed infestation detection)
7. Safer technology (Eg: No use of chemicals)

Block diagram of seed quality and safety

The general methodology of optical detection techniques for evaluating seed quality and safety. First, optical information is collected from prepared seed samples and different features are extracted using different techniques: image, spectrum and combined image- spectrum features are obtained through machine vision, near-infrared spectroscopy and hyperspectral imaging, respectively.



Second, relational mathematical models, including those for calibration and validation, are developed. Calibration models are implemented using the extracted feature data and known seed quality parameters, whereas validation models are used to verify the generalisability of calibration models by using unknown seed samples. Finally, the developed models are used to detect seed quality, particularly the quality of the exterior and internal components of the seeds.

Concepts of Optical sensing technology

1. Machine vision technology
2. Near Infrared Spectroscopy
3. Hyper spectral imaging

MACHINE VISION TECHNOLOGY

Machine vision, also known as computer vision or computer image processing, is an engineering technology that involves computers, optics, electronics, mathematics, information theory, artificial intelligence, pattern recognition, automation, visionics, mathematical morphology, digital image processing and other specialisims. Machine vision is a type of artificial intelligence that deals with simulating human vision. This technique is non-destructive, reliable and rapid and has been proven to be an effective and powerful technique for safety detection and quality evaluation of food and agricultural products, particularly crop seeds.

A typical machine vision system generally consists of five basic components: illumination system, sensor or camera, frame grabber or digitiser, monitor and computer. Most applications of machine vision deal with the visible spectrum (380 to 780 nm). A machine vision system should be capable of identifying and grading seeds based on image features, such as size, shape, colour and texture. Colour refers to the intensity of pixels, size reflects the number of pixels, shape describes the target boundary and texture denotes the dependency between pixels and their neighbouring pixels or variation in pixel intensities. The superiority, disadvantages and feasibility of different image features should be simultaneously considered to select the most suitable feature for specific applications[7,15]. Machine vision has already been used, with varying success, to assess seeds of a range of crop and non-crop species. ASUS–AMD Athalon 64 X2 6000 took less Time for recognize new image and Time for Image processing Than other computers hence ASUS–AMD Athalon 64 X2 6000 can be recommended to get higher classification output per unit time. Real-time sorting is enabled by the use of IEEE 1394 direct memory access image transfer, DirectX, and dual-core processors available in low cost PCs. The sorter appears to be nearly as accurate at separating wheat samples with low contrast differences as it is with samples having high contrast. With image processing, three features were extracted and showed to more accurately discriminate red and white wheat samples than a single feature, as is performed with commercial colour sorters[11]. Optical sensing method to diagnose the seed abnormalities using optical coherence tomography (OCT) from the results of cross-sectional sensed area of the abnormal seeds and reported that OCT with the proposed data and processing method can systemically pick up morphological modification induced by *Cucumber green mottle mosaic* (viral infection) in melon seeds indicating an additional subsurface layer under the surface which is not found in normal seeds. If the OCT images have an unclear additional layer, it makes it difficult to distinguish the infected seeds precisely[8].

Near Infrared Spectroscopy

Infrared spectroscopy deals with the infrared region of the electromagnetic spectrum, which has longer wavelength and lower frequency than visible light. The most commonly used spectroscopy ranges are near-infrared (NIR; 780 to 2500 nm) and mid-infrared (MIR; 2500 to 25000 nm). NIR spectroscopy is based on molecular overtone and combined vibrations, and typically penetrates deeper into a sample than MIR. Fourier transform infrared (FTIR) spectroscopy is a technique used to record infrared spectra and detect radiation in the MIR region. As an efficient FTIR technique, attenuated total reflectance spectroscopy is widely used in analysis of biological and liquid samples. Diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS) is a sampling technique developed for infrared analysis of powder materials and turbid liquids[5]. This mainly focuses on the NIR spectroscopy technique, which has penetrating capacity and can be used to detect internal seed qualities, such as protein, moisture content and damage detection. Reflectance/transmission spectra from grain can be used to predict test weight with accuracies that are suitable for rough screening, but not process control. However, Positive correlations were obtained between measured test weight by common procedure (weighting 250 ml of grains) and predicted test weight by Zeltex Accu Harvest which recorded R^2 of 0.877. that means 87.7% similar results obtained from predicted and measured values and positive correlations was obtained between measured test weight by common procedure[3].

Identification and proper labeling of genetically modified organisms is required and increasingly demanded by law and consumers worldwide. The feasibility of near infrared reflectance technologies for discriminating Roundup Ready and conventional (not genetically modified) soybean (*Glycine max* L.) seeds is studied. A low resolution pushbroom imaging unit, a commercial diode array instrument with single seed adapter, and a non-commercial instrument (light tube) which takes the whole seed reflectance spectra were tested. Principal Component Analysis with Artificial Neural Networks (PCA-ANN) and Locally Weighted Principal Component Regression (LWR-PCR) were used for creating the discrimination models. Light tube recorded highest classification accuracies around 94.2% were achieved by using LWR-PCR when validation was performed with seeds belonging to samples and images included in the training set. The principle behind this spectral absorbance is that the genome sequence of CP4 EPSPS in GM plants produces aromatic amino acids through shikimic acid pathway which provide resistance to herbicide but this shikimic acid pathway genes are tightly linked with lignin biosynthetic pathway. Hence, more lignin deposition below spongy parenchyma cells of testa of seed will not allow light to enter seeds. Hence, less absorbance in GM seeds. And one more probable reason is spectral differences caused by smaller structural changes in protein and crude fibre content. NIR spectrometers are not precise enough to detect compounds at the DNA concentration level (parts per trillion)[1].

Strong NIR absorption bands near 1400 nm - 1440 nm and 1900 nm - 1950 nm have often been applied to the quantitative analysis of water concentration in seeds. Absorption bands at 1454 nm are related with O-H stretch overtone bond, and at 1940 nm related with O-H bonds, which are mainly related with moisture concentration[13].

The result for the correlation coefficient between the degree of infestation (DI) and the reflectance shows wavelengths having a high correlation. The wavelengths from 400 to 830 nm have a high correlation higher than 0.5. Also, the wavelengths from 946 to 1340 nm have a higher correlation more than 0.5 and these wavelengths were chosen as starting points in analyzing the data. Overall, NIR spectroscopy was proved to be useful to detect insect infestation. More results will be published soon using a combination of different stages and all the stages with many levels of infestation[2].

FT-NIR spectra To perform the NIR calibration model for prediction oil, protein, erucic acid and crude fibre content of spectra were collected in available whole NIR range spectral domain 10 000–4000/cm. spectral patterns of all the samples were found to be similar across the whole wavelength range along the X-axis, however along the Y-axis changes among different samples were observed. The NIR spectrum does not only depend on the chemical composition of samples but also on the physical characteristics of the samples, which are usually observed as the background and noise in the spectrum[12]. NIR spectroscopy can discriminate viable and non-viable seeds of *J. polycarpos* successfully, although the success of discriminating among the non-viable seed lot fractions (empty, insect-attacked and shrivelled seeds) was limited. cutting and examining the internal content of the non-viable seed lot fractions confirmed that some of the insect-attacked seeds were totally devoid of its contents while some were partially consumed; whereas the shrivelled seeds differed in the content of the black undifferentiated mass of tissues from a quarter to half the size of the seed. When two-class models were fitted to the spectral data to discriminate between viable and non-viable seeds, the modelled (R^2Y) and predicted (Q^2cv) class membership of the calibration set were improved substantially (more than 90%) for both PLS-DA and OPLS-DA models compared to the four-class models.

Hyper spectral imaging

Hyperspectral imaging, also known as imaging spectroscopy or imaging spectrometry, originated from remote sensing and has been introduced into the field of seed technology, as well as safety analysis and assessment. Hyperspectral images, also known as hyperspectral image cubes, hypercubes or spectral cubes, are 3D in nature and include two spatial dimensions and one spectral dimension. A hyperspectral imaging system includes light sources, wavelength dispersion devices and area detectors. As the center of a hyperspectral imaging system, wavelength dispersion devices are used to disperse broadband light into different wavelengths. The area detector collects light from the wavelength dispersion device, which carries useful information, and then measures the intensity of the light by converting radiation energy into electrical signals. The three common sensing modes used for hyperspectral imaging are reflectance, transmittance and interactive. Reflectance mode is applied to detect external quality feature, whereas transmittance mode is used to determine internal component concentration and internal defects of relative transparent materials. Moreover, the interactive mode is employed to detect additional information about the sample; this mode presents less surface effects compared with reflectance mode. Machine vision and near-infrared spectroscopy can only provide spatial or spectral information, whereas hyperspectral imaging, which integrates machine vision and near- infrared spectroscopy advantages, can simultaneously obtain spatial and spectral information by using only one system. In this regard, hyperspectral imaging has been widely used by researchers to evaluate exterior quality and predict the internal composition of seeds and agriculture products.

The actual optical sensitivity of system ranges from 380 to 1,030 nm but only the range of 500–900 nm was used to avoid low signal-to-noise ratio. The average reflectance spectra of each variety of seeds in the spectral range of 500–900 nm. It can be seen that the trends of the spectral curves were quite similar except the one of cultivar I (Heinuo) since this variety looked almost black while others appeared approximately yellow. PCA was applied on all spectral data (500–900 nm) acquired from all samples to reduce the high dimensionality and to check qualitative discrimination in the spectra among the maize seeds[14].

Data processing and analysis methods

1) Image data processing in machine vision

Image processing is an important step in machine vision. After image acquisition, image pre-processing, image segmentation and feature extraction are performed to recognise and extract useful features from image data. Image pre-processing is performed to enhance the quality of the acquired image, which is often degraded by distortion and noise in the optical and electronic systems of the input device. Image pre-processing is also conducted through noise reduction and geometrical, grey-level and defocusing correction. Image segmentation is performed to partition the pre-processed image into multiple parts or objects, which are meaningful and easy to analyse. The segmented image is then directly subjected to further processing to achieve conclusions, making this method an important but challenging task in image processing. In the literature, various robust and efficient segmentation algorithms and methods have been proposed, which include thresholding, histogram based, clustering, edge detection, region growing, watershed transformation, compression based, partial differential equation based and split-and-merge methods.

2) Spectral data pre-processing in near-infrared spectroscopy

Spectral pre-processing mainly aims to reduce or remove effects in raw data without relevant information, thereby improving the linear relationship between the spectral signals and analyse concentrations. This pre-processing step mainly employs scatter correction and derivation. Scatter correction includes multiplicative scatter correction (MSC) or ex tended MSC, standard normal variate (SNV), detrending, baseline correction (BLC) and normalisation. MSC is used to compensate for additive and/or multiplicative effects in spectral data. Detrending is applied to remove nonlinear trends in spectroscopic data. This is usually performed by centering and scaling each individual spectrum to remove scatter effects and is used in combination with detrending to reduce multicollinearity, baseline shift and curvature in spectroscopic data.

3) Image and spectral processing in hyperspectral imaging

Hyperspectral images, which consist of 2D spatial information and 1D spectral information. Therefore, methods used in machine vision for image processing and analysis, as well as those in near-infrared spectroscopy for spectral pre-processing, are also used in hyperspectral image processing and analysis. However, with a large amount of data, optimal wavelengths are selected to remove redundant information and simplify calculations.

MULTIVARIATE DATA ANALYSIS

Multivariate analysis is performed to determine the mathematical relationship between the treated data and the reference chemical and physical properties of seeds for solving practical application problems. This mainly focuses on the classification and prediction problem. Numerous techniques and mathematical algorithms are available for applications with different requirements. The widely used techniques for classification include *K*-nearest neighbour, linear discriminant analysis, quadratic discriminant analysis, partial least squares-discriminant analysis (PLS-DA), soft independent modeling of class analogy, artificial neural network (ANN) and support vector machines (SVM).

Software for data processing and analysis

Machine vision- Publicly available image processing and analysis software include Matlab, SciLab, NumPy, ImageJ and MaZda

Near infrared spectroscopy- commercial software for spectral data preprocessing and multivariate analysis include

- Un scrambler (CAMO AS, Oslo, Norway),
- PLS Toolbox (Eigenvector, Research, Inc., USA),
- LS-SVM toolbox (Suykens, Leuven,Belgium),
- WinISI (Infrasoft International, Port Matilda, PA, USA),
- ParLeS (ParLeS, Sydney, Australia),
- SAS and JMP (SAS Institute, Inc., Cary, NC),

Hyper spectral imaging- sophisticated image or spectral processing can be achieved using advanced programming software, such as Matlab

- TQ Analyst and OMNIC (Thermo Fisher Scientific Inc., USA),
- OPUS (Bruker Optics, Ettlingen, Germany)

CONCLUSION

Machine vision, near-infrared spectroscopy and hyperspectral imaging are efficient and reliable noncontact optical sensing technologies for assessment of quality and safety of various seeds. Machine vision is widely applied to identify and classify seeds by using their visible features, such as colour, shape, texture and size. Near-infrared spectroscopy has advantages in quality discrimination and prediction of internal chemical compositions by using spectral information. Hyperspectral imaging integrates the advantages of machine vision and near-infrared spectroscopy and has been extensively used for classification and prediction applications by using spatial and spectral information of seed samples. Previous studies indicated that optical sensing technologies can be used effectively as a reliable and accurate tool for variety identification and classification, quality grading, damage detection and composition prediction. With the urgent need of the industry for advanced testing methods and rapid development of technology and instrument, optical sensing technologies exhibit great potential to be a dominant method in quality and safety assessment of seeds.

REFERENCES

1. Agelet, Near infrared reflectance spectroscopy applied to discrimination of conventional and roundup ready soybean seeds, PhD thesis, Lowa State University Ames, Iowa (2011).
2. Agha, M, K., Lee, W, S., Wang, C., Mankin, R, W., Bliznyuk, N. and Bucklin, R. A., Determination of degree of infestation of triticale seed using NIR

spectroscopy. *http://www.ars.usda.gov/sp2UserFiles/person/3559/publications/Aghariceweevildetection/13., ASABE Meeting Presentation paper*: 1-5 (2013).

3. Bonfil, D. J., I. Mufradi, S. Asido and D. S. Long., On-combine near infrared spectroscopy applied to prediction of grain test weight. *Columbia Plateau Conservation Research Center USDA-Agricultural Research Service Pendleton*, OR 97810, USA (2009).
4. Daneshvar, A., Tigabu, M., Karimidoost, A. and Oden, P. C., Single seed Near Infrared Spectroscopy discriminates viable and non-viable seeds of Juniperus polycarpos. *Silva Fennica* **49(5):** 1-12 (2015).
5. Gunasekaran, S. and Irudayaraj, J., Optical methods: visible, NIR, and FTIR spectroscopy, In *Nondestructive Food Evaluation: Techniques to Analyze Properties and Quality*, (ed. S. Gunasekaran), 1-37, Marcel Dekker, New York (2001).
6. Huang, M., Wang, Q. G., Zhu, Q. B., Qin, J. W. and Huang, G., Review of seed quality and safety tests using optical sensing technologies. *Seed Sci. & Technol*., **43:** 337-366 (2016).
7. Jackman, P. and Sun, D.W., Recent advances in image processing using image texture features for food quality assessment. *Trends in Food Science and Technology*, **29:** 35-43 (2013).
8. Lee, C., Lee, S. Y., Kim, J. Y., Jung, H. Y. and Kim, J., Optical sensing method for screening disease in melon seeds by using optical coherence tomography. *Sensors.* **11:** 9467-9477 (2011).
9. Manjushree, H., Shakuntala, N, M., Vasudevan, S, N., Ibrahim, M, D., Prabhuraj, A. and Sangeeta, M., Characterization of paddy genotypes through image analyzer and electrophoretic technique of total soluble seed proteins. *The Ecoscan.* **9(1&2):** 393-396 (2015).
10. Nansen, C., Zhao, G., Dakin, N., Zhao, C. and Turner, S, R., Using hyper spectral imaging to determine germination of native australian plant seeds. *J. of Photochemistry and Photobiology.* **145:** 19–24 (2015).
11. Pearson, T., Dan, B. and Scott, H., Color image based sorter for separating red and white wheat. *Sens & Instrumen. Food Qual*. **2:** 280–288 (2008).
12. Singh, J., P.C. Sharma, S. K. Sharma and A. Kumar, Standardization of the fourier transform near-infrared reflectance spectroscopy for estimation of some oil quality parameters in mustard (*Brassica* spp.). *Plant Soil Environ.* **59(10):** 478-483 (2013).
13. Sundaram, Chari, V. K., Konda N, G. and Jeyam, S., Sensing of moisture content of in-shell peanuts by NIR reflectance spectroscopy, *J. Sensor Technology*, **2:** 1-7 (2012).
14. Zhang, X., Fei, L., Yong, H. and Xiaoli. L., Application of hyperspectral imaging and chemometric calibrations for variety discrimination of maize seeds. *Sensors*, **12:** 17234-17246 (2012).
15. Zheng, C., Sun, D. and Zheng, L., Recent developments and applications of image features for food quality evaluation and inspection - a review. *Trends in Food Science and Technology*, **17:** 642-655 (2006).