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Potential of NIR Computer Vision Technique for the Detection of Mango's Defects

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ABSTRACT

Currently, research on computer vision technique is most prevalent for quality assessment of agricultural produce. This technique assists in achieving the specified objectives prior to sale of agricultural products in the global market. Defect detection is an important task during sorting and grading of mangoes. But, the colour camera based computer vision system (CVS) has been found unable to detect the hidden defects just below the peel of mangoes. The near infra-red (NIR) camera, in contrast, can be used for identification of such defects. A semi-automatic NIR CVS was developed for inspection of hidden defects just underneath of the peel of mangoes. Image acquisition, image processing and image analysis are the main functions of developed NIR CVS. The NIR camera was used to capture standard image from the samples of *Chausa* fruits. Algorithm steps were developed for image processing and analysis of hidden defects. Water core, fungal infection and the defects on the surface of mangoes, which were hidden just below the peel, identified and quantified. The present study, thus, showed that the NIR CVS has potential for detection of hidden defects of mangoes. The semi-automatic CVS can be upgraded to fully automatic for commercial application.

Keywords: Defect, Detection, Mango, NIR imaging, etc.

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INTRODUCTION

Defects of mango fruit are always an obstacle in their marketing. Any type of defect whether it is external or internal or just below the peel of mango degraded the quality of fruit. The defect detection has always been a serious issue for mangoes in Asian countries. Since the quality of mango fruit is affected by the defects (any type), if it is not identified, caused huge losses of fruit's nutritional as well as economical values in national and international market. The reputation of the suppliers, in addition, is also affected in the global markets. Several non-destructive technologies, however, have now been developed for the detection of external defects. But, hidden defect detection of mangoes using computer vision technology is still a challenging issue. As computer vision provides real information about the nature and attributes of the produce, reduces costs, guarantees the maintenance of quality standards and provides useful information in real-time (Marhoon *et al.,* 2013, Hippargi 2018). It can also be applied for exploring agricultural produce in invisible regions of the electromagnetic spectrum, such as the ultraviolet or infrared regions. The application of computer vision system equipped with the NIR camera has now been getting momentum throughout the food industry. Because, in addition to no need of sample preparation and short measuring times, more than one quality parameters can be estimated at the same time by this technique. Intrinsic properties of fruits, so far, can be evaluated by NIR spectroscopy in the range of 1200-2200 nm (Jha *et al.,* 2014). Jha *et al.* (2012) have predicted sweetness of intact mango and the maturity of mango (Jha *et al.* 2014) nondestructively using NIR spectroscopy in this order. The best prediction model for maturity index ()mIof mango was achieved in the wavelength range of 1600-1800nm by them. Similarly, potential of near infrared spectroscopy (NIRS) in the wavelength range of 900–1700 nm for determination of sweetness (total soluble solids, TSS); sourness (acidity) and their ratio for 5 cultivars of apple was also studied by Jha and Ruchi (2010). In another study, the NIR CVS can was used for the rapid measurement of some physical properties of mango. The NIR based CVS, which is very close to human vision was found very efficient for the measurement various fruit's shape attributes important to design harvest and post harvest equipments (Patel *et al.,* 2020).

Further, the color values of mangoes were modeled by some researchers for the nondestructive evaluation of the mango fruit. Further, there are several applications of the IR imaging in the food industry. For instance, identification of foreign bodies in food products and evaluation of physiological properties of foodstuffs such as firmness, soluble-solid content, acidity, etc which appear to be highly correlated with IR signals reported by the researchers (Patel *et al.,* 2012). Raghavendra (2016) has studied internal defects mangoes using commercially available non-destructive techniques such as X-ray or X-ray CT, NIR imaging, MRI/NMR, etc. and reported that NIR imaging technique can be applied for internal defects tracking of mangoes.

Furthermore, research in public domain reported that NIR Videocon camera can be used to capture NIR images of infested wheat samples and for the detection of insects. In the

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spectral region between 450 nm and 900 nm, bruises on apple fruit can be detected by using hyper spectral imaging technique. Similarly, the potential of NIR imaging for detecting and locating insects in cereal grain has also been reported by several researchers. They reported that how line segment detection can be achieved with a minimum computation if two masks embodying a vectorial design strategy. Several researchers have detected internal defects such as browning by using light transmission. However, no defect just below the peel of mango has been detected by NIRS technique.

The main objectives of this research were to study the potential of NIR imaging for detection of defects of mangoes below the peel and to develop a NIR based computer vision system. In addition, to develop an algorithm to identify and segregate hidden defects for *Chausa* mango fruit and to identify the spectral region and band-pass filter/ resolution which was appropriate for detection of defects.

MATERIAL AND METHODS

For the defect detection of mangoes, a semi-automatic CVS (Fig. 1) fabricated in Division of Post Harvest Technology in Indian Agricultural Research Institute, New Delhi (India) was used (Patel *et al.,* 2019b). The NIR computer vision system was used for the detection of mangoes defects. This system mainly consists of an illumination chamber, image acquisition system (lighting arrangements and NIR camera), frame grabber, image processing and analysis software and computer hardware. The detailed description about computer vision system, its accessories and developed algorithms, and other steps involved in the processing and analysis of images has been explored below.

Description of the illumination chamber

Illumination chamber is an iron sheet made confined chamber to guard the objects from the sunlight outside. This chamber has diffuser i.e. cylindrical lighting system, to give light scattered over the surface of the objects so that highlights and light reflections can be avoided. The light intensity in the diffuser was controlled with the help of nine fluorescent bulbs (50watts, 220 Volts) fitted at 45° cylindrically (Fig. 1). Thus arranged visible lighting regime was used for the uniform illumination of the objects during NIR imaging.

In addition to visible lighting arrangement, the illumination chamber has also been equipped with four 15W fluorescent UV tube (100 nm - 400 nm) to illuminate the mango fruit with UV light and for capturing of the reflected UV image using UV camera. Although, before capturing of the fruit's images using the NIR camera in visible light, it assured that UV lighting system was off and vice-versa (Patel *et al.* 2019b). The research dealt with NIR camera using deferent band-pass filters and visible illumination by cylindrical lighting only. The image profiles acquired at different wavelength bands such as 730 nm, 766nm, 780nm, 800nm, 830 nm, 852nm, 855nm, 880 nm, 905 nm, 940 nm, 1000 nm 1050 nm, 1064 nm, 1100nm, 1150 nm, 1200 nm, 1250nm, 1300nm, 1350nm, 1400nm, 1450 nm, 1500 nm, 1550 nm, 1600 nm and 1650 nm are presented in Fig. 2 to check which wavelength bands are more suitable for defect detection.

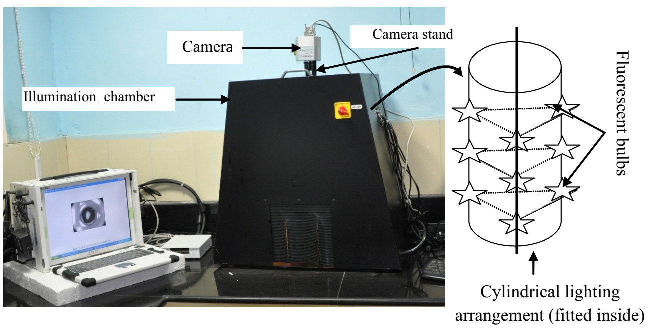


Fig. 1: Computer vision/imaging system Patel *et al*. (2019)

Camera setup and computer software/hardware

The NIR camera (Model: NIR-300GE; Made: Vosskohler GmbH, Germany) with resolution (320x 256 pixels) placed at the top of the illumination chamber manually at about 200 mm from the top of the fruit. However, the distance between the NIR camera and bottom/floor of the illumination chamber was 59 cm. NIR images of the manually placed real mango fruit on the sample holding platform were captured by sending a video signal from the camera to the industrial computer equipped with a frame grabber. All images were stored in computer hardware memory in BMP format.

Furthermore, the NIR camera was connected through Gigabit Ethernet port on the PC via Cat5e Ethernet cable. Industrial computer (PC type) was used in this research with an LED screen for desk mounting; desk types a keyboard and mouse; TFT color Display of 15" XGA (1024 x 768); Pentium®4 1,7GHz; 4GB of RAM; 4 serial ports RS-232; 4 USB ports; Hard Disk of 500 GB; 3 slot for PCI. IMAQ Vision that is a library of LabVIEW (National Instrument product, Austin, TX) software (version 10.0) was used for the image processing and analysis in this research work.

Image processing for defect detection

Image processing and analysis were performed by thresholding, filtering and other preprocessing techniques included in LabVIEW software. Fruits of *Chausa* cultivar were selected on the basis of peel colour more suitable for image processing. For this purpose, 60 ripe fruits were procured randomly in the spring from their corresponding orchard and brought to the laboratory. Six images at different posture of each fruits were taken using NIR camera and thus obtained 360 images were processed and developed defect detection algorithm. A reference image was taken and processed using NIMAQ vision software to develop above said algorithm (Fig. 3). Fig. 3 showed the flow chart of an algorithm developed for the quantization or calculation of percent area of black spot underneath of the peel in terms of defected area using NIR camera. This flow chart represents various image processing steps used in algorithm during processing of images using IMAQ vision system and the bruise detection and classification method is based on thresholding the gray levels of mango image pixels. Each image is preprocessed in terms of brightness improvement, contrast enhancement and setting up the specified value of gamma to get more information and easiness in thresholding.

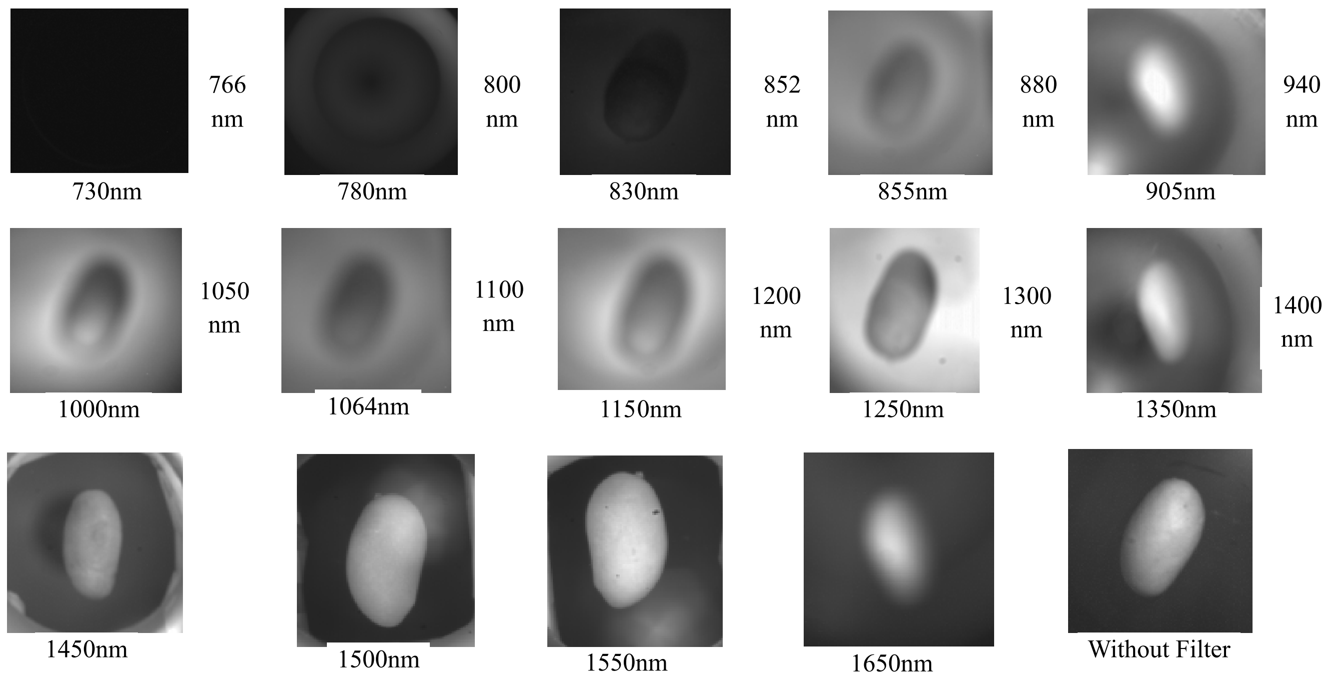


Fig 2: Various images of mangoes acquired by using NIR image acquisition system at different band-pass filters/ wavelengths (nm).

After image improvement, subtract color operator was used and an intensity plane of image was subtracted, and the image was then subtracted with the value of hue, saturation, luma, red, green and blue as 180, 240, 60, 64, 0 and 128, respectively and finally these images were thresholded by some specified value of RGB color model [R (0, 65), G (0, 112) and B (0, 9)]. The lookup table was used to equalize/redistributes pixel intensities in order to provide a linear cumulated histogram. Particle filter was used to extract defect area by using centre of mass X parameter ranged between 2 and 38. After filtering the defected particles, we count the no of pixels whose gray level is lowered than the threshold using particle analysis step of IMAQ vision software. With the help of this algorithm step, we can also count the number of pixels comprising the entire fruits surface after thresholding. Consequently, the ratio of low gray level value pixels to the total number of pixels can be calculated. A high ratio means that there is a big fraction of low gray level pixels which can be suspected to be of bruised surface. The ratio can also be compared against another specified threshold value. If the ratio is less than the threshold, we can level the mango fruits as good, otherwise are bruised.

RESULTS AND DISCUSSION

Figure 2 shows various image profiles captured by the NIR camera using wavelength bands between 730 nm and 1650 nm. The clarity of the image was found to be satisfactory only for 1450nm, 1500nm, and 1550nm wavelength band-pass filters. Although, the band-pass filter of wavelength 1550 nm was found more efficient to detect the defects (just underneath of peel) of the mangoes. These images, thus, captured NIR camera using band-pass filter 1550 nm were used for further processing and analysis to extract the required information and/ or for the detection of bruise or defect underneath of the

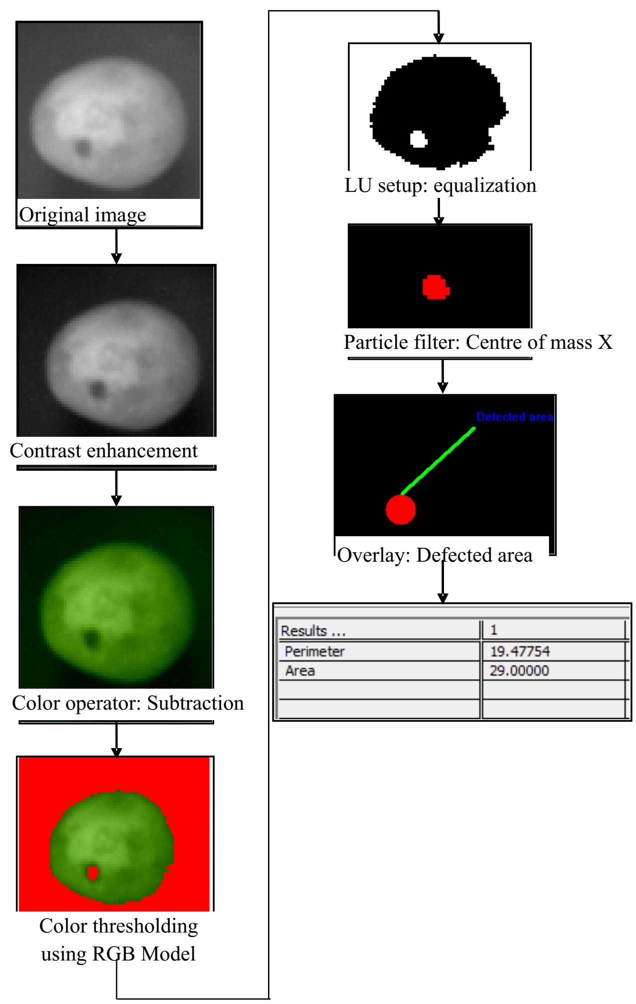


Fig 3: Flow diagram of algorithm steps for defect detection underneath the

peel of mango and/ or defected tissues. The images of fruits captured by the NIR camera using filters other than 1450nm, 1500nm and 1550nm wavelength found to be blurred in nature and inefficient to detect the defects on the surface area of mangoes. The images captured by the NIR camera without using filter were found to be clear and visible but inefficient to detect the hidden defects and water core. In contrast, the NIR camera with wavelength band pass filter of 1550 nm was found to be very efficient to detect hidden defects, fungal infection and water core. Thus, the spectral region between 1450 nm and 1600 nm is most appropriate for defects detection (Fig. 2).

The current study, however, contrasted to the findings given by Lu (2003). Lu (2003) has reported that the spectral region between 1000 nm and 1340 nm is most appropriate for bruise detection of Red Delicious and Golden Delicious apples. The dissimilarity in current finding might be due to the commodity difference. Similarly, Tao and Wen (2003) also reported that the near-infrared (NIR) range from about 750 nm to 1200 nm is sensitive to detect defects on fruits but separation of true defects from stem-end, stem, and/or calyx using only near-infrared is very difficult. To solve this problem, they suggest for using a near-infrared (NIR) and a mid-infrared (MIR: 5000 nm to 8000 nm) camera simultaneous for imaging of the fruit. However, Malchow (2007) has confirmed that imaging beyond 1000 nm by using NIR-responding camera improved the capability to see the transparent coatings. They reported that the inspections of fruit and vegetable with NIR cameras can detect and reject bruised fruit.

Bruising normally happens to the tissue beneath the fruit skin. After the fruit tissue is damaged, its cells are initially filled with water and turn brownish. As, time elapses, the damaged cells start to loss moisture and eventually become desiccated and blackish. This type of black spot, if any, underneath the peel of mango, using NIR image acquisition with wavelength 1550 nm band-pass filter can be detected. The strongest response, in this research, at the band pass filter that enhanced the best intensity contrast between bruised (below the peel) and unbruised mangoes observed for 1550 nm. However, the result of present study differed with the results reported by Tao and Wen (2003) for apple. According to them the strongest response was achieved for band-pass filter of wavelength ranged from 750 nm to 1200 nm. This dissimilarity in findings might be due to the difference in products. Further, the cause of appearance of bruised tissues the darker than unbruised in NIR images was might be due to absorption of infrared light by the water released from the bruised cells. Similar findings have also been reported by researchers using reflected UV imaging (Patel *et al.*, 2019a).

Sometimes, the skin of mango fruit is not broken because of injuries on the surface during the harvesting and handling. However, cells can be damaged in fruit flesh, and due to this damage, nutrients with water in cells can flow/ release and fill the spaces between cells. In such cases, the infrared light energy penetrates into the flesh through the skin during the illumination of fruits. So when their images are captured using a NIR camera, since there are no tiny gaps to spread infrared light, water in the spaces between the cells absorbs the infrared light.

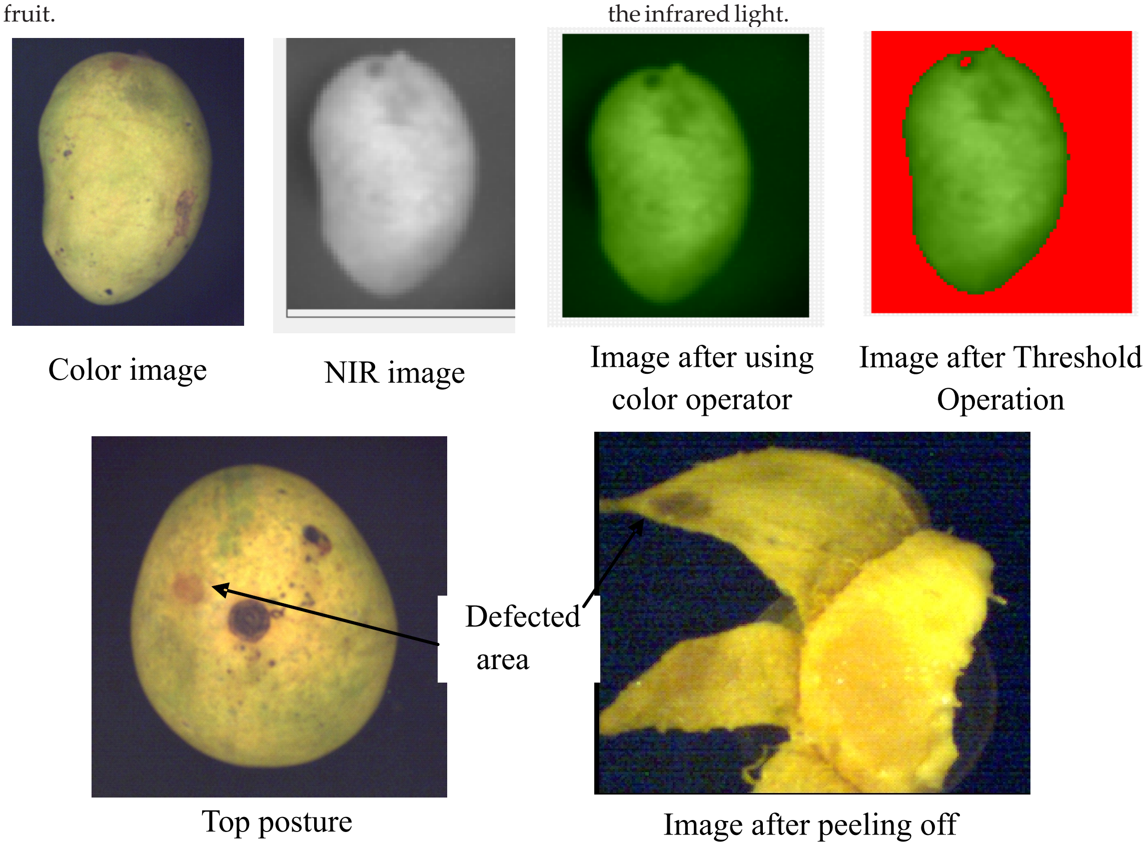
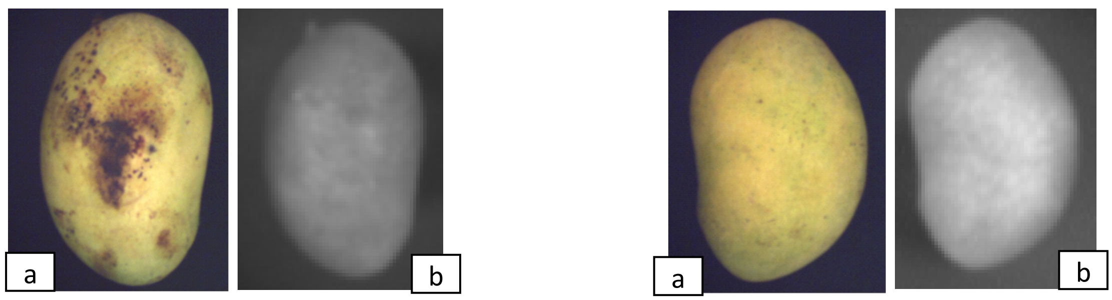


Fig 4: Appearance of defected area on fruit's surface in color image, NIR image, and after thresholding and peeling.

The appearances of black spots underneath the peel of mango in the color (RGB) image, in the NIR image (when acquired at 1550 nm wavelength), and in the image when thresholded and peeled off are given in Fig. 4. For the quantization or calculation of the percent area of black spots underneath the peel of mango fruit in terms of defective area, an algorithm is developed (Fig. 3) and discussed in the material and methods section. With the help of the developed algorithm, we can also count the number of pixels comprising the entire fruit surface after thresholding. Consequently, the ratio of low gray-level value pixels to the total number of pixels can also be calculated. A high ratio means that there is a big fraction of low gray-level pixels that can be suspected to be of the bruised surface. The ratio can also be compared against another specified threshold value. If the ratio is less than the threshold, we can level the mango fruits as good, otherwise are bruised. As the bruises on the fruit's surface appear darker than the non-defective parts of the surface.

In this present study after processing and analyzing the all acquired NIR images (360) of the mango fruit (60), about 8% of fruits were found to have such type of defects. The range of defective area just underneath the peel of fruits was found to be 0.02% to 4.8%, which was missed by human vision as well as by the color (RGB) and monochrome camera. The clarity of detection of external defects of the color (RGB) camera and monochrome, however, was much better than the NIR camera at a wavelength of band-pass filter 1550nm. Although, the main object of this study was not to detect external defects using a NIR camera. The defective fruits can be separated from the fresh fruits/ fruits without defects on the basis of the difference in pixel intensity (Fig. 5).



Fruit with defects (Low pixel intensity) Fruit without defects (High pixel intensity)

Fig 5: Appearance of fruit's image with and without defects when acquired by (a) color (RGB) and (b) NIR camera image.

Further, about 4% of acquired images were found to be missed by this algorithm and remained unprocessed/or improperly processed due to uneven contrast over the surface.

Thus, the NIR image acquisition system with a band-pass filter of 1550 nm wavelength can be used for the detection and characterization of defects just underneath the peel of mango on the basis of appearance. The appearance of bruised and unbruised cells just underneath the peel of mango was bright and dark, respectively while the appearance of the water core and fungal organism just below the peel of mango was darker. A similar result of NIR imaging has also been reported by Uthaisombut (1996) for cherry fruit. However, Unay and Gosselin (2007) used different visible and NIR interferometric filters to recognize the stem ends and calyxes in sound and defective Jonagold apples. According to them, NIR filters can overcome the problem posed by this cultivar's variegated red and yellow surface which makes it more difficult to detect skin damage by using standard color images.

Similarly, Aleixos *et al.* (2002) have presented a multispectral camera system capable of acquiring visible and NIR images from the same scene and used specific algorithms that were implemented on two processors and worked in parallel. They found that the system was capable of correctly classifying lemons and mandarins at a rate of up to 10 fruits per second, depending on the area of the external defects and the size and color of the fruit. Xing *et al.* (2006) also identified several visible and NIR wavelengths that could be used to discriminate the stem end and calyx from sound peel and bruises in apples. The NIR imaging techniques, therefore, could be one potential area that can be applied to internal defect tracking in mangoes (Raghavendra 2016).

CONCLUSION

As, there is no research has yet been reported that the application of colour camera based computer vision is efficient for the detection of hidden defects. It means that the colour camera based grading system is prone to errors which result in huge losses not only in terms of economical and qualitative but also in terms of reputation of fruit producers. The NIR camera based semi-automatic CVS, thus developed in this research, has found been capable for detection of such defects. Therefore, it can be concluded that the NIR camera has much potential and future prospects for the defect (hidden) detection of mangoes which are generally missed by color camera. However, it is a different matter that more research is still needed for its commercial level of application.

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