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Non-destructive detection of jelly seed disorder in Amrapali and Pusa Surya varieties of mango (*Mangifera indica*)

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ABSTRACT

Mango (*Mangifera indica* L.) varieties, viz Amrapali and Pusa Surya were subjected to X-ray imaging for detection of jelly seed disorder. Fruits of each variety were subjected to X-rays with different combinations of voltage, current and time in a trial and error manner to obtain X-ray image. It was found that X-ray source of 48 kV, 6.5 mA, with an exposure time of 320 mA gave the best contrast images of jelly seed internal disorder. X-ray images were stored and further processed with MATLAB. Fruits which were used for X-ray imaging were also compared destructively for jelly seed disorder incidence. After comparison, it was found that both destructive and non-destructive (X-ray) images, as well as processed images, were similar. Hence, it can be concluded that X-ray imaging can be an useful method for detecting jelly seed disorder in mango.

Key words: Image processing, Internal breakdown, Physiological disorder, X-rays

During the last few years, jelly seed disorder has caused as erious problem in certain areas, thereby hampering the export and consumption of mango (*Mangifera indica* L.). The jelly seed disorder is related with the ripening process, in which there is a mesocarp breakdown in the surrounding area of the seed and development of 'off flavour'. In the progressive stage, the affected tissues may become discoloured (Oosthuyse 1992**.** The seed is sometimes completely enclosed by affected tissue, or the fruit entirely affected. Fruits affected by jelly seed disorder can't be identified from out-side and buyers come to know about it only when fruits are cut open. The quality of fruits is usually confirmed by destructive methods, but such test samples can't be marketed. In the case of fruits like mangoes, which have great demand in the world market, it becomes really important to identify some modern techniques, which are capable of detecting imperceptible internal physiological disorders and other damages without destructing the fruits.

Of the numerous such non-destructive techniques, many studies on the use of X-ray inspection and quality evaluation have been reported in the field of agriculture. X-ray imaging has been used in the detection of internal disorder in several fruits such as core breakdown in pears (Lammertyn *et al.* 2003), stone weevil in mangoes (Spoorti *et al*. 2015), and internal breakdown in pomegranates (Lembe and Umezuruike 2014). X-ray inspection has a distinctive advantage over other detection techniques, as it is non-destructive imaging of internal features of the sample, which detects internal defects and can be easily handled. This technique has become progressively common in recent years in food industries of processed foods, packaged foods, canned foods, etc., due to increase in prominence in food safety. X-ray affect on food products has been proven safe with respect to microbiological safety and nutritional quality of irradiated food (Yuichi *et al*. 2003).

Eventhough X-ray imaging has great potential in resolving the difficulties associated with consumer acceptance and quality of mango, a very little work has been done for the detection of internal breakdown disorders in mango using this technique, and no research work has so far been cited on jelly seed disorder detection. Our work will illustrate the use of X-ray in the detection of jelly seed disorder susceptible mango genotypes such as Amrapali and Pusa Surya.

MATERIALS AND METHODS

This study was conducted in the Division of Food Science and Postharvest Technology, ICAR-Indian Agricultural Research Institute, New Delhi during 2014-2016. Jelly seed disorder susceptible mango genotypes, namely Amrapali and Pusa Surya were selected for the study. These varieties were selected on the basis of preliminary studies conducted on varietal evaluation for the incidence of jelly seed disorder in mango during 2014. Fruits of

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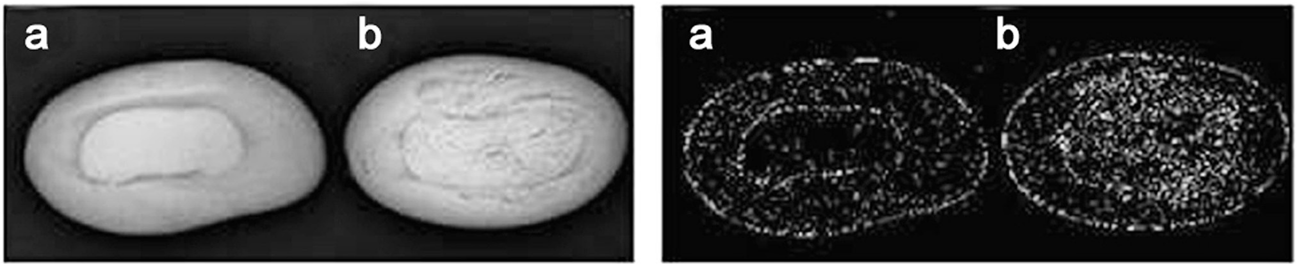

Fig 1 A, X-ray image of a) good mango fruit, b) jelly seed affected fruit. B, MATLAB processed image of a) good mango fruit, b) jelly seed affected fruit.

selected varieties were harvested at the mature stage from mango orchards of Division of Fruits and Horticultural Technology, ICAR-IARI, New Delhi. After harvesting, the fruits were de-sapped in the field and then brought to the laboratory, washed with tap water, air-dried under the fan and stored in a ripening room maintained at 22 °C. The ripened fruits were subjected to both non-destructive and destructive evaluation.

The fully ripened fruits of the selected mango varieties were subjected to X-rays (Fig 1A). For this, different combinations of voltage, current and time in the range of 30 to 60 kV, 4mA to 8mA, 100 to 400mA, respectively were used in a trial and error manner to develop a good X-ray image. For each exposure, 8 to 14 fruits (depending on the fruit size), each numbered by the marker, were placed in one frame for X-ray imaging. When X-rays were exposed on mango fruits, the rays passed through dense and non-dense areas of fruit pulp and finally reached the X-ray sensitive film or sensor. Depending on the energy received by the sensor or film from X-rays, each pixel transmitted a discrete value indicating the quantity of energy received. If the X-rays crossed a non-dense area, the pixel received a high quantity of energy, which was then converted into a strong signal, whereas, if the X-rays crossed a dense area, the pixel received a low level of energy, which was converted into a weak signal. The information received from sensitive elements, was stored in a computer for further processing. After exposure of fruits to X-rays, fruits were brought to the lab and based on the X-ray images, jelly seed disorder affected and non-affected fruits were cut transversely by the side of the stone. The cut fruits were examined with naked eye for the occurrence and/or non-occurrence of jelly seed disorder and verified by comparing with that of X-ray images. The percentage of fruits showing incidence of jelly seed disorder was calculated by dividing the disorder affected fruits by total number of fruits examined. After that, digital photographs of the cut mango fruits were taken with the help of a digital camera.

The developed images were stored and further processed with image processing tool box MATLAB (The Math Works, Inc.). Different algorithms were used for edge detection in the initial stages. Among them, Edge detection algorithm 'Prewitt' operator was found more suitable for detection of edges in the image. Edges were calculated by using difference between corresponding pixel intensities of an image. The comparison was done between X-ray image of a good mango fruit and jelly seed affected fruit and also between MATLAB processed image of the same fruits (Fig 1B). The data obtained from the experiments were analysed using OP Stat and the results were compared from ANOVA by calculating the LSD at 0.05 (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

It was found that using X-ray source of 48 kV, 6.5mA, with an exposure time of 320mA gave the best contrast images of jelly seed in exposed mangoes. The X-ray sources

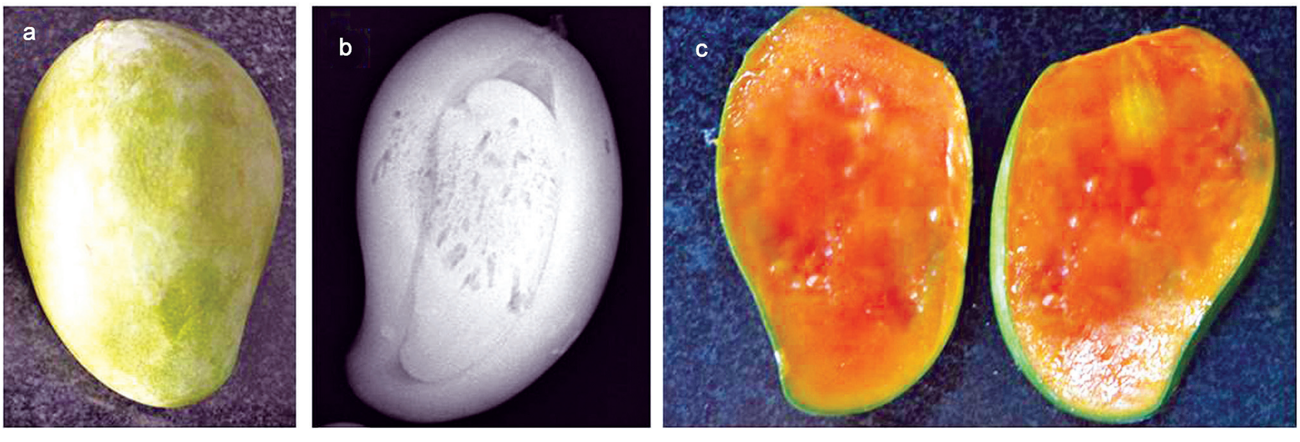

Fig 2 Jelly seed disorder (left to right) in Amrapali mango variety (a), X-ray image (b) and destructively cut opened image of same X-rayed fruit (c).

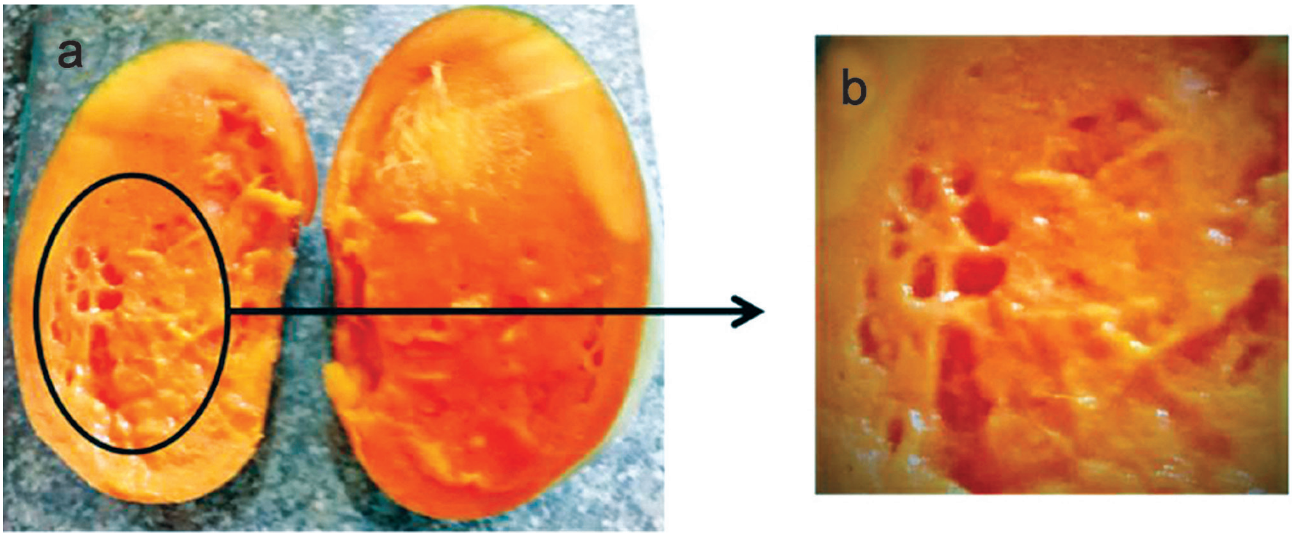

Fig 3 Advanced stage of jelly seed disorder (left to right) in Amrapali mango variety (a), and close-up view of jelly seed disorder showing air pockets (b).

were kept unchanged for the two mango varieties taken and were able to produce distinct X-ray images showing good and jelly seed affected fruits. The fruit varieties which are prone to jelly seed disorder in X-ray image displayed dark grey areas around the stone, indicating blemishes in the pulp surrounding the stone. While good fruits showed light grey uniform areas in full mango image (Fig 1A for comparison between good and affected mango X-ray images). Fig 2 shows X-ray images with jelly seed incidence as dark grey areas and their comparison with that of the same cut fruits showing incidence area in Amrapali and Pusa Surya variety, respectively. At the advanced stage of this disorder (Fig 3), the affected pulp showed desiccated or dry area, leading to the development of air pockets and cracking like areas. This may be due to the disintegration of cells from the affected portion of the pulp leading to the loss of moisture as the time progresses. The X-ray images which were obtained were similar to the findings of spongy tissue in Alphonso mango (Amol *et al.* 2015). There was a close agreement between detection based on X-ray imaging and internal examination of cut fruits (Table 1), indicating the reliability of the technique. The incidence of jelly seed disorder in Amrapali (45.50 %) was higher than Pusa Surya (36.95 %) variety of mango.

Table 1 Comparison of jelly seed affected mangoes by X-ray imaging and internal examination of cut fruits

Variety	Fruits examined	Fruits detected as jelly seed affected by X-ray imaging	Fruits showing jelly seed incidence in cut samples	Incidence of jelly seed disorder (%)
Amrapali	90	41	41	45.50
Pusa Surya	46	17	17	36.95
LSD ($P \leq 0.05$)				4.2

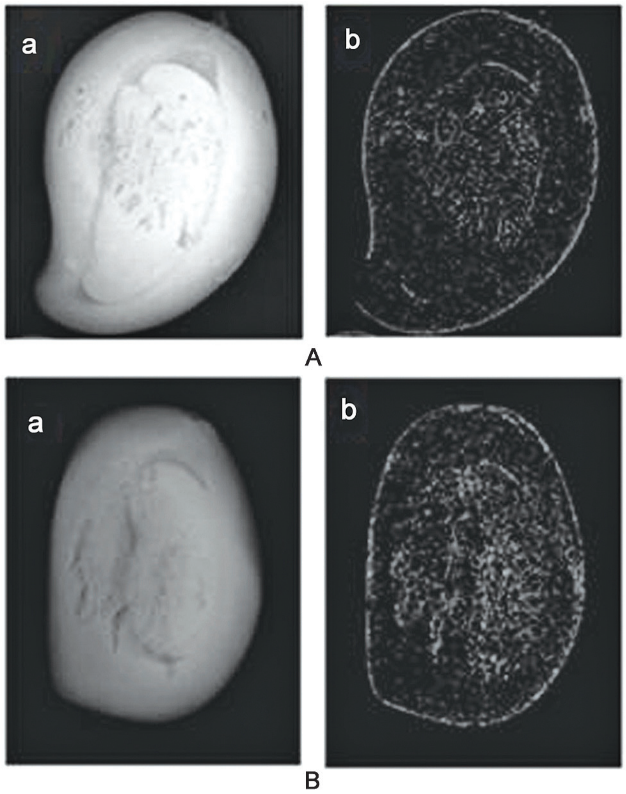

Fig 4 A X-ray image of jelly seed affected Amrapali mango (a) and MATLAB processed image of the same X-rayed image (b). B, X-ray image of jelly seed affected Pusa Surya mango (a) and MATLAB processed. image of the same X-rayed image (b)

Fig 4 shows the MATLAB processed images of Amrapali and Pusa Surya varieties. As seen in the Fig 2, similar kind of results were obtained even in Fig 4. There was a clear difference in the images of fruits, which were good and fruits which were affected by jelly seed disorder. The good fruits showed an uniform doting pattern in the

MATLAB processed images. Jelly seed affected fruits showed clustering of dots in the portion of jelly seed affected pulp, while the pulp with in the affected fruit which is free from jelly seed incidence, shows very less number of dots of uniform distribution or having no dots. The efficacy of the algorithm was also proven in the work done by Spoorti *et al.* (2015) on stone weevil in mango.

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