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Computer vision of microwave treated red kidney beans (Rajma)

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IMAQ vision development module and LabVIEW based programming is potentially useful for analysis of untreated and treated red kidney beans. The IMAQ vision development tool and LabVIEW based programming used several algorithms to display the boundary values, edge detection, length and width of the red kidney beans present in the captured images by webcam. In addition, application of image processing has been used for the threshold conditions and number of edges present in the images. These edges and threshold conditions describe the information about the red kidney beans. A test result has shown the ROI histogram to detect the pixels intensity along with standard deviation and mean value of the images. Resultant coefficient of determination has shown the percentage variation in red, green and blue plane such as 35.78%, 37.33% and 46.38% respectively. It is necessary to count the insects' eggs on surface of red kidney beans to avoid the hatching of insects' eggs before and after treatment. In this paper we have used method for counting the insects' egg count on surface of red kidney beans in the captured images.

Keywords LabVIEW, IMAQ vision, Image processing, Grain size, Histogram, Color, Insect's egg identification, Red kidney beans

1 Introduction

Red kidney beans are the good source of protein and other nutrients as well as very good source of cholesterol-lowering fiber[1]. To measure grain type and quality visual inspection is one of the best method but evaluation process is very time consuming for that computer vision is a novel technology to obtain information or to control process from the actual images[2]. The image processing leads to the several techniques such as segmentation, threshold, measurement, classification, etc. of acquired images[2]. In this process image processing plays an important role to measure accurate, fast and objective quality characteristics of food products. A study reveals that color machine vision system used to extract the nine morphological features and six color features in the acquired images[3]. Literature cited the use of morphology models, color models, texture models and a combined model of all three for the classification of cereal grains[4-7]. According to the author, image processing algorithms also contributes towards the grid formation, local thresholding, threshold value interpolation, background removal, and morphological filtering for the determination of infestation sites of a fruit in X-ray image[8]. Many studies reveal that machine vision system is very useful for wheat and barley grain kernels classification by discriminate analysis (DA) and K-nearest neighbors (K-NN) algorithms[9]. Review article described the interest in shrinking, color, texture, porosity, sensing, optimization and process imaging (such as image acquisition, processing, feature extraction and pattern recognition) for real-time control in food drying[10].

Nowadays, image processing technologies are widely used for the several applications such as grading and sorting of agricultural and food products[11-12], shape classification and other classifications[4,13-14], inspection of ginseng roots quality[15], color vision analysis[16-18], quality control of bakery products[19], textural features and classification of grains and cereal gains[6,14,20], thermal processing of biomaterials[21], silkworm egg counting[22] and determination of surface area and volume of agricultural products (such as eggs, lemons, limes and peaches)[23], etc.

LabVIEW is widely used for scientific image processing and machine vision applications with the help of NI Vision assistant and other image processing tools[10,24-25]. The Vision toolkit accepts 32-bit color images for Red-Green-Blue (RGB) or Hue-Saturation-Luminance (HSL) models as 8-bit channels. First alpha component describes the opacity of image, other components display the RGB or HSL model with zero representation a clear pixel and 255 representing the fully opaque pixels[25]. LabVIEW

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IMAQ Vision is also useful for quality and safety inspection of food and agricultural products by pre-processing, segmentation, defect detection, feature extraction and classification algorithms[26-27]. LabVIEW IMAQ Vision builder showed the morphological, color and texture attributes along with moisture and quality of biomaterials[21]. LabVIEW and NI Vision Development module is used in the real time environment for cloud particle images, display area, contour and number of cloud particles[20].

This paper presents the research work on different image processing techniques in LabVIEW environment with IMAQ Vision to identify the threshold values, edge detection, grain size and number of insect's present on the surface of red kidney beans images.

2 Materials and Methods

2.1 Experimental setup and software

The sampling chamber is typically an air tight black box chamber with the length 30 cm, width 25 cm and height 30 cm. Sampling chamber is incorporated with white light, Logitech C920HD pro webcam (model: Carl Zeiss Tessar HD 1080p with a resolution of up to 1920 x 1080 pixels) and sampling holder. The sampling holder has been placed in the sampling chamber on 12 cm height from bottom and it consists of samples in borosil petri dish. Images are captured by the camera installed in the chamber which is further connected to the computer with the help of USB cable.

Images captured through the webcam are processed with the LabVIEW 18 based developed software. Application specific image processing components is included in LabVIEW software environment with NI-IMAQ and NI-Vision. The developed software controls the camera and performs the image analysis on the captured images. The captured images are 640 pixels X 380 pixels in size frame. After capturing the images from the camera, the images one by one processed for the analysis. Figure 1 shows the experimental setup of image capture and processing.

2.2 Sample preparation

2.45 GHz based domestic microwave oven was used to treat the infected Red kidney beans (Rajma beans) samples. Total 20 samples of infected red kidney beans with each 20 gm weight are used for microwave heat treatment at 90 W to 900 W with time span 30 sec to 90 sec. The treated samples further placed into the desiccators to cool down and then used those samples for the image capture and analysis.

2.3 Proposed system algorithm

The proposed image analysis of the red kidney beans is based on seven sub-processes in the proposed system;

- ROI Histogram
- RGB Color measurement
- HSL Saturation
- Threshold
- Edge detection
- Grain size
- Egg count

2.4 Region of interest (ROI) histogram

First select the region of interest (ROI) from a captured image to perform the analysis and then build the mask. The beans, insect's eggs and insects present into the ROI act as objects. This mask is used to compute the histogram of ROI.

2.5 RGB (Red, Green, Blue) color detection

For the reference, select a captured image that contains the color information. That image can consist of multiple colors information so using the entire regions in the image to learn the color information using the IMAQ Color Learn VI. The output color spectrum contains a compact description of the color information is learned. Further the algorithm calculates the color of a particular selected beans image region.

Image decomposition technique (RGB color extraction) with the help of LabVIEW used to detect RGB color in RGB color plane. For extraction of RGB values from the image apply the color extraction

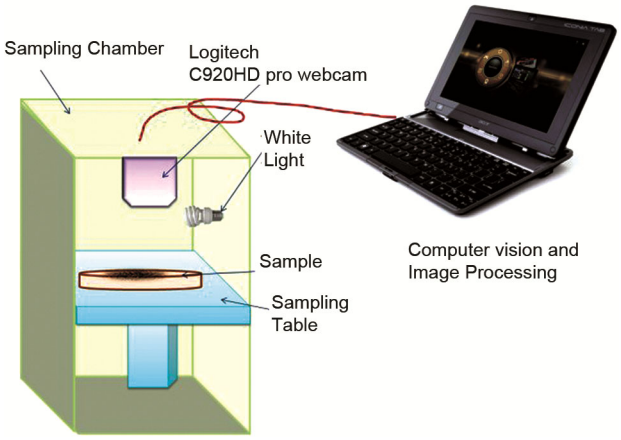

Fig. 1 — Experimental setup and image processing.

algorithm, first process image into x and y plane coordinate and extract the color pixel values in 32 bit integer value form and then convert these values into RGB color value by extraction method.

2.6 Saturation

HSL (Hue, Saturation, Lightness) determined by the color plane extraction algorithm for saturation plane of images. The algorithm consists of color plane extraction method, in which HSL plane is selected and extracted the saturation plane from RGB images.

2.7 Threshold

The capture d image is analyzed by the threshold algorithm. The IMAQ threshold tool consists of different types of threshold algorithms, in which local, manual and automatic threshold algorithms are used and compared for the further analysis. After the comparison, local threshold produces the best results for the selected image. For the local threshold algorithm, first image should be gray or convert RGB image into the gray image then fed the parameters such as method: background correction, object type: dark objects and window size (32 x 32) of the image. The output image displays in the form of binary image with the maximum threshold.

2.8 Edge detection

The selected image converts the RGB image into the gray scale and then select the ROI to find the edges of the images. To find all the edges of the selected image, the gray image is treated by the NI Vision development tools such as ROI selection and edge detection. The edge detection algorithm selects the overlay the edges locations on the images and displays the total number of edges present into the selected ROI. The edge detection algorithm consists of kernel size=3, width=3, minimum edge strength=10, interpolation type= bilinear fixed and data processing method= average. On the basis of algorithm, the output result displays in the form of number of edges detected line profile and gradient information of the selected image.

2.9 Grain size

For the red kidney bean size measurement 300 dpi RGB image is used on the NI vision assistance for measurement algorithm. The measure algorithm is used to calculate the length and width of the red kidney beans by selecting the region of interest in the images. Output results of the length and width of the samples are shown in the form of pixels, so to convert the pixels value into millimeter (mm) shown in Eq. (1)

$$I = (P \times 25.4)/dpi \quad \ldots (1)$$

Where I = length/width value in millimeter (mm); P= Pixels and dpi= 300 dpi constant value of image

2.10 Insect's egg count

Algorithm for counting the insect's eggs on the surface of red kidney beans shown in Fig. 2. To count the eggs present into the red kidney bean surface, NI vision assistant is used. For smoothing of the gray image, low pass filter is used along with the mask and then applying the edge detection's Prewitt algorithm[28-29] shown in Eq. (2 to 5):

Consider the arrangement of pixels $[i,j]$ in the image:

$$\begin{matrix} a_0 & a_1 & a_2 \\ a_7 & [i,j] & a_3 \\ a_6 & a_5 & a_4 \end{matrix} \quad \ldots (2)$$

Partial derivative of the Eq. 2

$$X_x = (a_2 + ca_3 + a_4) - (a_0 + ca_7 + a_6) \quad \ldots (3)$$

$$X_y = (a_6 + ca_5 + a_4) - (a_0 + ca_1 + a_2) \quad \ldots (4)$$

Now c=1, then the Prewitt operator

$$X_x = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \text{ and } X_y = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \quad \ldots (5)$$

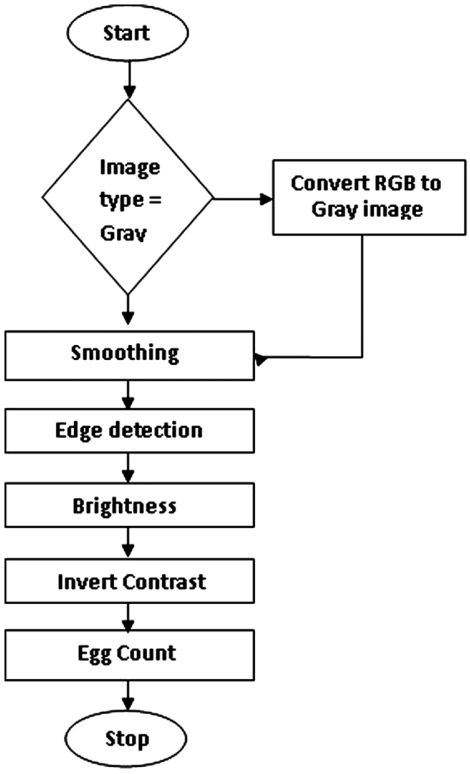

Fig. 2 — Algorithm for insect's egg count.

Where c = constant implies pixels closer to the center mask; X_x and X_y are approximations at $[i,j]$

After the implementation of Prewitt algorithm, brightness, contrast and gamma values are adjusted. The adjusted image is further inverted by the contrast and implemented the local threshold algorithm on it. Now the threshold image is in binary image so the further particle analysis is implemented on the image for particle count. The particle count is manual in this process for counting the eggs present on the surface of red kidney beans.

3 Results and Discussion

From the above image processing algorithms, the output ROI histogram detects the pixels intensity of the captured and processed images with the help of LabVIEW based software. Histogram and RGB color values of the processed images presented in Fig. 3 to Fig. 6.

Table 1 explains the R^2 or coefficient of determination is the percentage variation in red, green and blue plane. In the processed images red color variation 35.78%, green color variation 37.33% and blue color variation 46.38%.

Table 1 — R^2 variation in RGB plane

RGB plane	Color extraction equation	R^2
Red	y = -0.9156x + 170.69	0.3576
Green	y = -1.8831x + 207.76	0.3733
Blue	y = -1.4818x + 192.73	0.4638

Figures 4-6 shows the saturation plane of each image as well as threshold values, edge detection and insect's egg position on the images. The local threshold method explains the threshold value of each pixel of the processed images.

The threshold plane replaces each pixel with the black pixel or white pixel according to the image intensity. So, the threshold image shows the partition between the foreground and background of each image. Thresholding typically reduces the number of

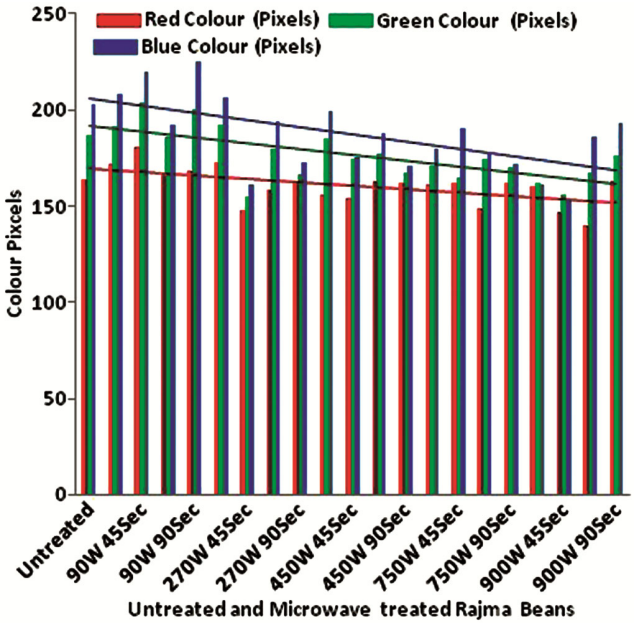

Fig. 3 — RGB color extraction plot.

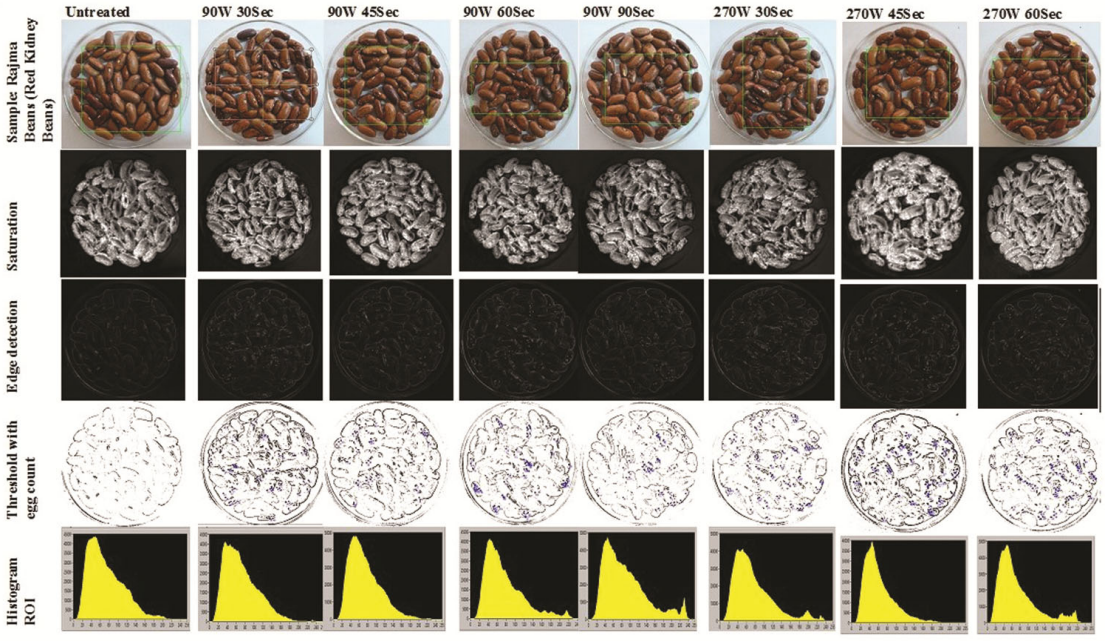

Fig. 4 — Image analysis of red kidney beans (untreated and treated from 90W 30 Sec to 270W 60 Sec).

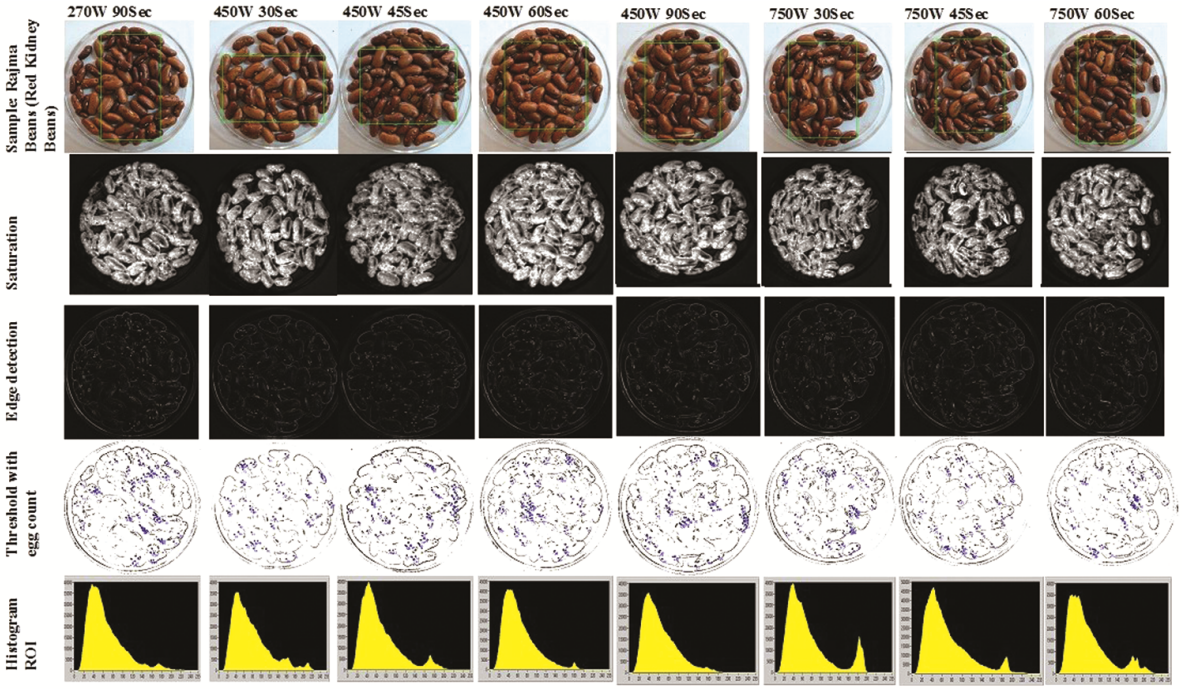

Fig. 5 — Image analysis of red kidney beans (untreated and treated from 270W 90 Sec to 750W 60 Sec).

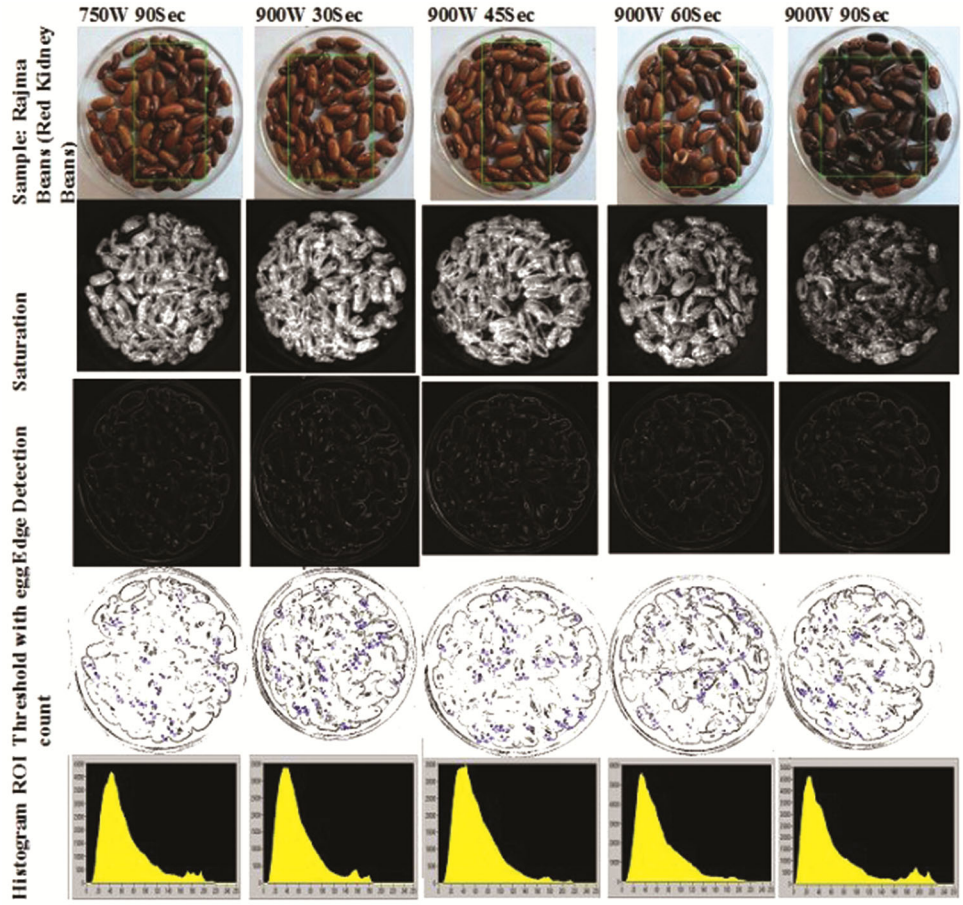

Fig. 6 — Image analysis of red kidney beans (untreated and treated from 750W 90Sec to 900W 90Sec).

Table 2 — Length and width of the red kidney beans.

Length (Pixels)	Length (mm)	Width (Pixels)	Width (mm)
469.36554	39	232.69078	19
453.92181	38	187.82971	15
436.58905	36	253.6474	21
432.92609	36	236.86494	20
430.25806	36	164.76044	13
431.79279	36	146.16429	12
399.0614	33	178.46568	15
325.40591	27	166.38811	14
429.80228	36	193.10359	16
429.46011	36	156.52477	13
378.25916	32	198.23723	16
485.07526	41	207.88939	17
257.57718	21	124.63145	10
471.55276	39	224.10934	18
469.83508	39	206.82602	17
455.80698	38	215.6409	18
329.07446	27	155.42522	13
296.07599	25	154.15901	13
475.27887	40	176.25549	14
425.10233	35	236.86494	20
453.3277	38	225.96017	19
429.06061	36	259.37811	21
405.8793	34	200.57169	16
499.40964	42	196.49936	16
506.9566	42	253.6474	21

Table 3 — Red kidney beans edge detection, statistical analysis and number of insect's eggs detection

Red kidney beans	Edge detection	Standard deviation	Mean value	No. of eggs detected
Untreated	45	38.49	72.51	0
90W 30Sec	163	36.78	70.91	64
90W 45Sec	76	36.14	73.39	44
90W 60Sec	126	72.68	75.61	64
90W 90Sec	63	50.81	88.3	55
270W 30Sec	125	43.89	75.29	76
270W 45Sec	130	33.17	61.39	65
270W 60Sec	124	47.72	73.39	79
270W 90Sec	133	36.3	63.84	78
450W 30Sec	118	42.25	74.45	62
450W 45Sec	104	39.28	66.94	68
450W 60Sec	115	33.46	63.17	77
450W 90Sec	129	32.12	61.75	61
750W 30Sec	135	47.35	71.69	70
750W 45Sec	144	42.66	69.13	61
750W 60Sec	118	45.29	72.36	53
750W 90Sec	100	40.85	65.85	45
900W 30Sec	132	34.54	58.01	60
900W 45Sec	136	34.94	61.34	54
900W 60Sec	136	37.72	62.42	70
900W 90Sec	119	50.91	60.51	55

false edge fragments and convert the below threshold values to zero.

Further edge detection of the processed images shows the number of edges present along with the line profile and gradient information of the selected image. The edge detection in the processed images significantly describes the local change in the first derivative of the image intensity. Line profile of the images describes the two edges with opposite polarity that are close together and the gradient information measures by the vector and magnitude of the gradient. The edge contents having non zero values for the gradient and displays the significant changes in the gray values in processed images by using the Prewitt operator algorithm. The Prewitt operator observed the pixels closer to the center of masks.

Figures (4-6) shows the insect's egg count position in each processed image. After the threshold and edge detection, particle analysis plays a critical role to count the insect's eggs on the surface of the red kidney beans in processed images. The threshold images used to count the insect's eggs and displays maximum number of eggs present.

The ROI histogram identifying line profile for edge detection and also calculates the mean value and standard deviation of each captured images, which is shown in Table 1.

Grain size measurement algorithm was used to detect the length and width of the red kidney beans present on the RGB image. The measured length and width are in the form of pixels values, which are further converted into the millimeter size value for the easy understanding. The red kidney beans length and width shown in the Table 2. The measurement algorithm shows the approximate values of the red kidney beans size.

Table 3 explains the information about the number of edges detected and insect's egg count on surface on the red kidney beans processed images. Table 3 also exhibits information about the number of edges detected in each processed image. It also indicates the average intensity value and how widely intensities value varies through the mean value and standard deviation in each image.

4 Conclusion

The main contribution of this work is to overcome the problem of detecting the insect's eggs on surface of red kidney beans on captured images. In this paper several algorithms are implemented to discuss the boundary conditions, positions and structure of red

kidney beans and detection of insect's eggs on red kidney beans surface.

In this paper we have used the ROI histogram and RGB color determination algorithm by using Red (R), Green (G) and Blue (B) planes and their values to extract the color values and their standard deviation of the captured images. The RGB color detection shows the color pattern of the images along with the standard deviation and mean value of the captured images. Overall, 20 different images are used on the basis of their treatment. The results obtained from these images shown in the Table 1 to Table 3 respectively. Results explain the number of edges and number of eggs detected on the red kidney beans images. Further Figs(4-6) shows all the image processing steps to carry out threshold value, color histogram and color saturation of the processed images. The results also observed the insect's egg count in the threshold condition. Also, the resultant R, G and B color variations shows the R^2 values 35.78%, 37.33% and 46.38%.

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