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Development of simple, rapid and accurate method for identification of head rice and brokens using image processing

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Abstract
The quality analysis of rice is done regularly during storage period at Food Corporation of India (FCI) and other godowns. This quality evaluation is done manually by trained person. This process is tedious and reliable results dependent on the skill of the person. Machine vision is an emerging technology for rapid identification of grain quality. It provides alternative for an automated, non-destructive and cost-effective technique. Therefore, present study was undertaken to develop and validate a simple, rapid and accurate method for identification of head rice and brokens of three varieties i.e. Punjab Pusa Basmati 1509, PR121 and PR124 using digital image processing method. The images of randomly selected 40 grains each of head rice and brokens for each variety were captured through flatbed scanner followed by processing of images using open source Image J software. The values of various morphological parameters (viz. length, width, thickness, sphericity, geometric mean diameter and volume) of sample grain extracted were compared by the values calculated using digital vernier caliper. Statistical analysis showed that the results obtained by digital vernier caliper can be linearly correlated to the results obtained by image processing. For varieties Punjab Pusa Basmati 1509, PR121 and PR124, variation in manually calculated length and predicted length was 98.5%, 98.3% and 93.8% and the variation in manually calculated width and predicted width was 97.6%, 96.9% and 97.9%. All the results were found significant at 5% level of significance ($p<0.05$).

Research Highlights: The study showed that the identification of rice kernels using manual method took more than 30 minutes. Hence, taking above facts into consideration, an automated, non-destructive and cost-effective technique i.e. image processing method was developed for identification of rice kernels. This method took almost 5-7 mins for identification of rice kernel.

Keywords: Head rice, brokens, image processing and manual method

1. Introduction
Rice (*Oryza sativa* or *Oryzaglaberrima*) is a staple food for two–third of the world population. It is mainly produced and consumed in the Asian region. India has the largest area under rice in the world as well as ranks second in the production after China. It contains 72-75% of carbohydrates in form of starch. The quality of rice grain has distinct effect on milling operations and head rice yield. The quality of milled rice depends mainly on the grain size, shape, whiteness and cleanliness (Dalen 2003) [1]. All these factors are closely related to the process of milling, in which paddy is first subjected to dehusking i.e. removal of hulls and then whitening i.e. removal of brownish outer bran layer followed by polishing that is carried out to remove the bran particles and provides surface gloss to the edible white portion. Finally, the head rice and brokens are separated before packaging (Sakai *et al.,* 1996) [8].

Actual quality determination of head rice and brokens in laboratory is done manually or by using indented cylinder grader for larger sample. The necessary adjustments are made by a trained operator, based on visual inspection to produce milled rice with a minimum amount of broken kernels. The proper inspection and classification of good quality of rice grain is very important. In grain handling and milling system, types of grain and quality are assessed mainly by visual inspection. The dimensions of the rice kernels are measured using vernier caliper. This evaluation process is tedious and not fully reliable. However, even a trained human can perform quality examination only on a few known rice varieties (Guzman and Peralta 2008) [2].

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The determination of milled rice quality parameters can also be done by image processing techniques that will enable regular monitoring of milling operation in an objective manner, and thus allow the operator to quickly react within a few minutes to change in material properties. Machine vision is an emerging technology for rapid identification of grains. Machine vision method has been developed for determining morphological features of grain (Yadav and Jindal 2001 and Shahin and Symons 2001) [10, 9]. Machine vision system not only helps in determining the morphological parameters but can be used for detection of fissures or crakes in grains (Lan *et al*. 2002) [6] and visual characteristics of cooked rice (Yanagihara 2000) [11]. Hence, this method provides a rapid and accurate alternative for identifying the geometrical features of grains.

Many researchers have used flatbed scanners to address the problem of the cost and issues related with CCD cameras. This article presents a digital image processing method using flatbed scanner for identification of head rice and brokens. The flatbed scanner is also known as desktop scanner. The flatbed scanner system used for image processing had been grown rapidly in few years. It has been used for imaging of organ tissue (Kuchen-buch and Ingram 2002) [4], measurement of pharmaceutical pellets and chromatographic plates and gels (Lonnberg and Carlsson 2001) [7]. In this study, flatbed scanner system with image processing method was used to develop and validate a simple, rapid and accurate method for identification of head rice and brokens.

2. Materials and methods
Three varieties of freshly harvested paddy i.e. Pusa Basmati 1509, PR121 and PR 124 were procured from fields of Punjab Agricultural University, Ludhiana. The procured paddy was brought to 14% moisture content through open sun drying before milling. Various milling equipment like universal moisture meter, Satake laboratory dehusker or sheller, Satake laboratory rice polisher, indented cylinder grader were used to convert paddy into rice. A flatbed scanner model HP DeskJet Ink Advantage Scanner 2135 was used for image acquisition of rice varieties used for experiment. An open source image software ImageJ was used during digital image processing of rice. ImageJ is a versatile public domain Java based image processing program which can perform various image processing operations. ImageJ is being extensively used in the image processing of agricultural produce due to its ease of use, recordable macro language, and extensible plug-in architecture.

2.1 Sample selection
A paddy sample weighing 200 g was milled out of which 20 g polished rice was randomly selected. This standard method is also adopted by FCI. Forty kernels each from head rice and brokens from selected varieties were manually selected by random selection method for the study.

2.2 Manual method
The length (a), width (b) and thickness (c) of randomly selected 40 grains each from head rice and brokens were measured manually in three mutually perpendicular directions with the help of digital vernier caliper (Model: CD-6" R) of least count 0.01mm.

2.3 Image processing method
The randomly selected forty rice kernels were placed on flatbed scanner model HP DeskJet 2135 at 300 dpi for image acquisition. It is the foremost step in image processing technology. After acquiring image, binarization of image was done. The binarization process converts the image into two values 0 and 1. The binary image thus formed above was twice eroded and dilated simultaneously (Fig 1). Dilation and erosion and are two fundamental operations in morphological image processing from which all other morphological operations are based. Dilation adds pixels to the boundaries of objects in an image, while erosion removes pixels on object boundaries. The number of pixels added or removed from the objects in an image depends on the size and shape of the structuring element used to process the image. In the morphological dilation and erosion operations, the state of any given pixel in the output image is determined by applying a rule to the corresponding pixel and its neighbors in the input image. A various morphological parameters of sample grain were selected. The values of various morphological parameters of sample grain were extracted and tabulated by image processing software. Finally, the grading of sample grain was done.
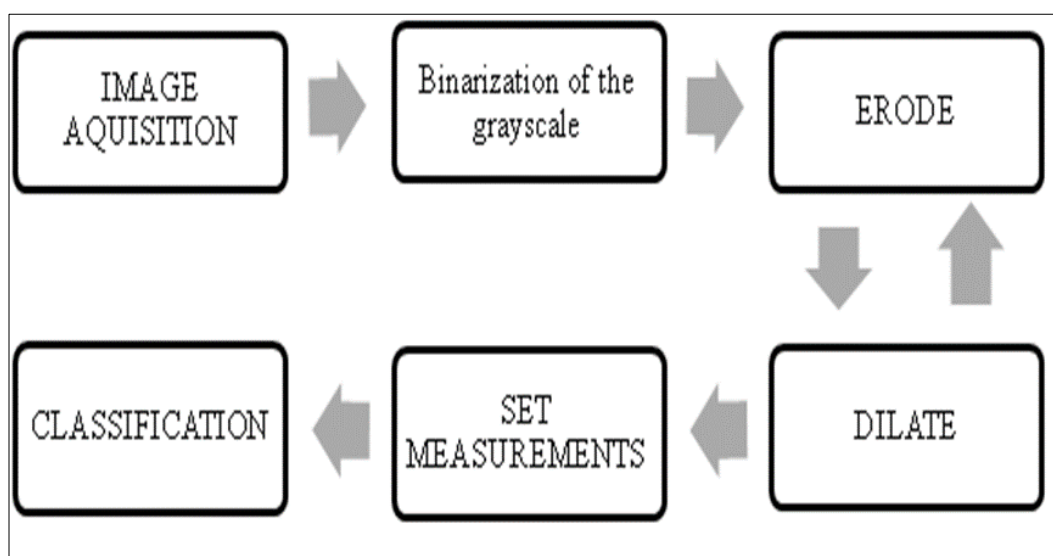

Fig 1: Flow chart of image processing

2.4 Morphological features
2.4.1 Volume
The three principle dimensions i.e. length, width and thickness were used to calculate the volume considering ellipsoidal shape of the rice grains (Kumar *et al.* 2013) [5].

$$\text{Volume (mm}^3) = \frac{4}{3} \times a \times b \times c$$

Where a, b and c are length, width and thickness respectively.

2.4.2 Sphericity and geometric mean diameter
According to Jouki and Khazaei (2012) [3], sphericity is the ratio of the surface area of the sphere having the same volume as that of the grain to the surface area of the grain, can be expressed as follows:

$$\text{Sphericity} = \frac{\sqrt[3]{(abc)}}{a}$$

The geometric mean diameter (GMD) was calculated by considering spherical shape of the rice grain which is expressed as follows

$$\text{GMD} = (abc)^{1/3}$$

2.4.3 Aspect ratio
The aspect ratio is the ratio of length and width (Jouki and Khazaei 2012) [3] that is expressed as follow,

$$\text{Aspect ratio} = \frac{\text{Length of rice kernel}}{\text{Width of the rice kernel}} = a/b$$

2.5 Statistical Analysis
Statistical was done to find significance of R^2 value by comparing F calculated (F_c) with F-chart (F_t) ($p<0.05$). If F_c is greater than F_t than value is significant whereas is F_c is smaller than F_t, it is non-significant.

3. Results and discussions
3.1 Calibration of image size
The 40 grains sample was selected randomly each from the head rice and brokens. The results through image processing were calibrated with help of known dimensions of a paper (One square inch). The unit of results got through image processing is in pixels. It was converted into millimeters for easy calculations. The following calculations helped in calibration,

▪ Manual reading:
Length = 25.4 mm
Breadth = 25.4 mm
Area of one square inch paper   =   645.16 mm²

▪ Image processing:
Area of one square inch paper   =   94503 pixel
Therefore,

$$1 \text{ pixel} = \frac{645.16}{94503} = 0.006826 \text{ mm}^2$$

$$1 \text{ pixel length} = \sqrt{0.006826} = 0.0826 \text{ mm}$$

$$1 \text{pixel length} = 0.0826 \text{ mm}$$

3.2 Image processing method
A binary image was prepared to identify the rice kernels in the Flatbed scanner (FBS) image as shown in Fig 2, by arranging the 40 grains of head rice and brokens in a single layer on the glass plate of the flatbed scanner resulting in an image with rice kernels without touching each other. A contrasting background was essential during image acquisition for image classification. Therefore, black sheet was used as background for scanning rice samples. Further, this black sheet was painted with black color to get the clear outlining of the rice grain image during image processing. In image analysis software, several techniques are available to separate foreign material minute object which are not required in analysis. These routines are based on a shrinkage operation on the feature in the binary image, by peeling off, one by one, a layer of pixels from the perimeter of the features. The aim of this erosion is to separate objects that are not required without losing the integrity of the single features. The erosion is followed by dilation in which the eroded features grow to their original shape. In this study, the ImageJ software was used for analysis. Values of various morphological parameters of sample grain were extracted. These parameters were tabulated by image processing software. The extracted parameters are also exported to the Microsoft Excel. Finally, the grading of sample grain was done.
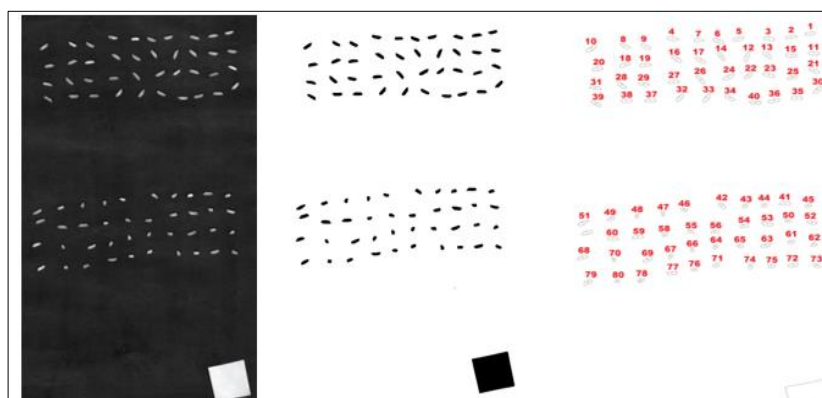

Fig 2: Image acquisition, binarization and outlining and labeling of 40 kernels

3.3 Length, width and thickness of rice kernels
The average length, width and thickness of rice kernel for three varieties i.e. Punjab Pusa Basmati 1509, PR 121 and PR 124 were shown in Table 1. A relationship was drawn between calculated width and thickness to drive value for predicted thickness using the predicted width for further calculations. The relationship between the manually measured length and the predicted value of length of rice grain of different varieties are linear with R^2 (shown in Table 2). The variation in predict length and the calculated length is 98.5%,

98.3% and 93.8% for Punjab Pusa Basmati 1509, PR 121 and PR 124 respectively, which is significant at $p<0.05$ The Punjab Pusa Basmati 1509 has the highest value of R^2 among the three varieties. The relationship between the manually measured width and the predicted value of width of rice grain of different varieties are linear with R^2(shown in Table 2).

The variation in predict width and the calculated width is 97.9%, 97.6% and 96.9% for PR 124, Punjab Pusa Basmati 1509and PR 121 respectively, which is significant at $p<0.05$. The PR 124 has the highest value of R^2 among the three varieties. (Fig 3a-f)
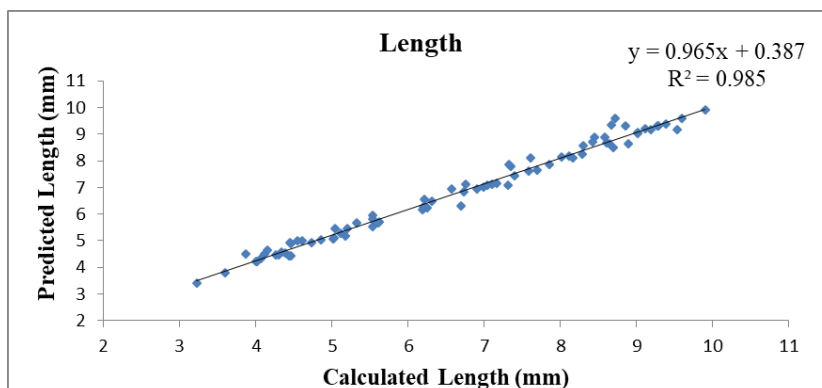
Fig 3a: Relationship between the calculated and predicted length of rice kernels for variety Punjab Pusa Basmati 1509
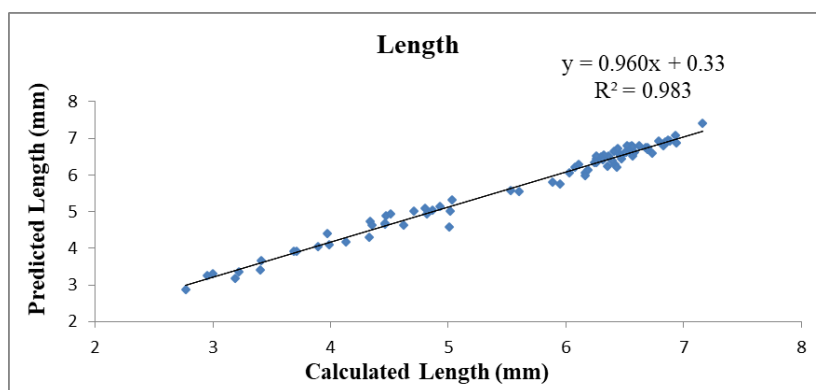
Fig 3b: Relationship between the calculated and predicted length of rice kernels for variety PR 121
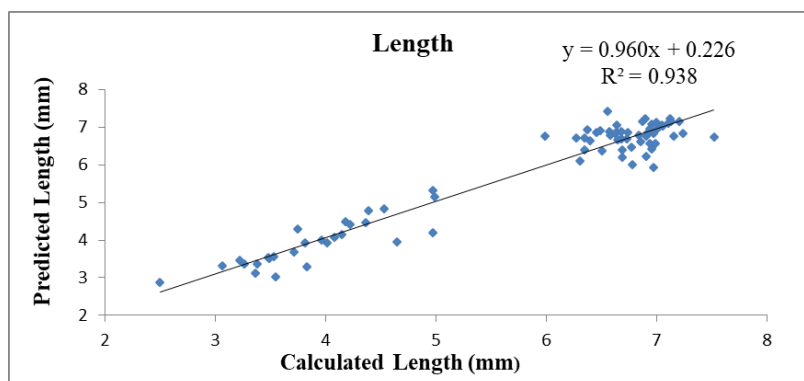
Fig 3c: Relationship between the calculated and predicted length of rice kernels for variety PR 124
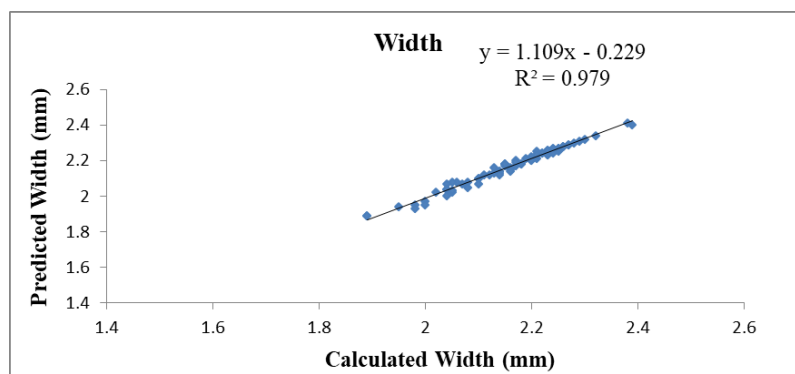

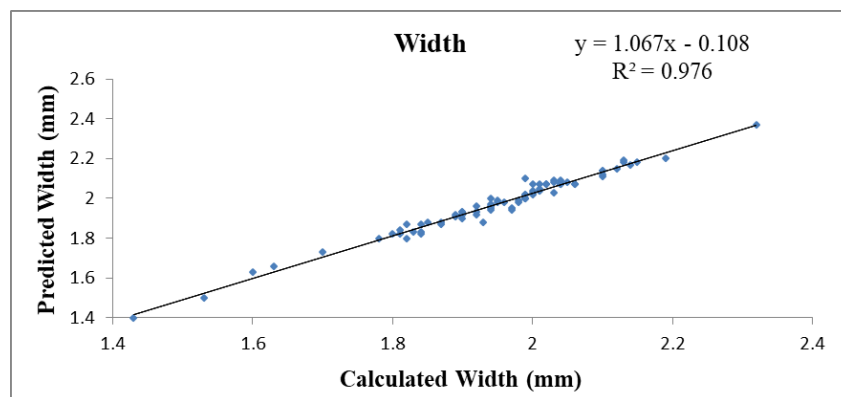**Fig 3d:** Relationship between the calculated and predicted width of rice kernels for variety PR 124

Fig 3e: Relationship between the calculated and predicted width of rice kernels for variety Punjab Pusa Basmati 1509
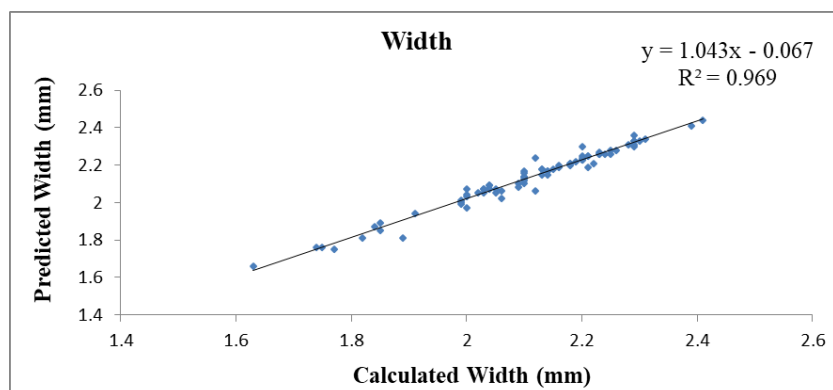

Fig 3f: Relationship between the calculated and predicted width of rice kernels for variety PR 121

3.4 Sphericity of the rice kernels

The average sphericity of rice kernel for three selected varieties i.e. Punjab Pusa Basmati 1509, PR 121 and PR 124 was found out to be 0.37, 0.45 and 0.44 for head rice whereas 0.5, 0.56 and 0.57 for brokens respectively by manual method. The results shows that the sphericity of different varieties when compared with their predicted (i.e. the value calculated by predicted values) and calculated value gave a linear value of R^2 that is presented in the Fig 4(a-c). The variation in predict width and the calculated width is 95.8%, 94.5% and 91.9% for Punjab Pusa Basmati 1509, PR 121 and PR 124 respectively, which is significant at $p<0.05$. The Punjab Pusa Basmati 1509 has the highest value of R^2 among the three varieties.
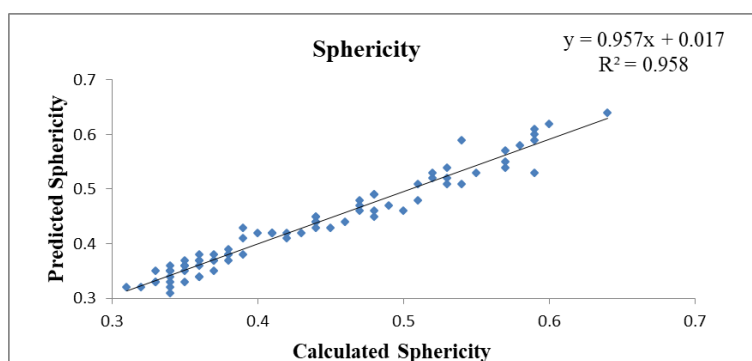

Fig 4a: Relationship between the calculated and predicted sphericity of rice kernels for variety Punjab Pusa Basmati 1509
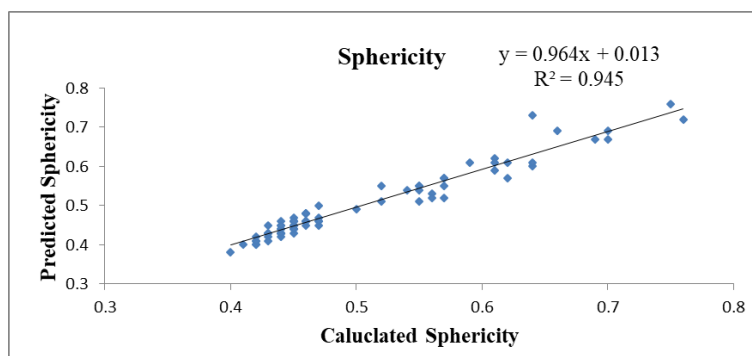

Fig 4b: Relationship between the calculated and predicted sphericity of rice kernels for variety PR121
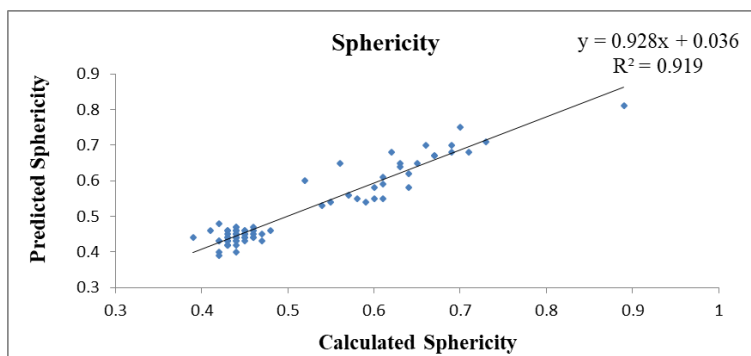
Fig 4c: Relationship between the calculated and predicted sphericity of rice kernels for variety PR124

3.5 Geometric mean diameter of the rice kernels

The average value of geometric mean diameter of rice kernel for three selected varieties i.e. Punjab Pusa Basmati 1509, PR 121 and PR 124 was found out to be 2.93mm, 2.87mm and 3.00mm for head rice whereas 2.49mm, 2.55mm and 2.61mm for brokens respectively by manual method. The plot between predicted (i.e. calculated by the predicted values) and calculated geometric mean diameter gave rise to linear value of R^2 which is presented in the Fig 5(a-c). The variation in predict width and the calculated width is 92.1%, 88.3% and 87.7% for Punjab Pusa Basmati 1509, PR 124 and PR 121 respectively, which is significant at $p<0.05$. The Punjab Pusa Basmati 1509 has the highest value of the R^2 among the three chosen varieties.
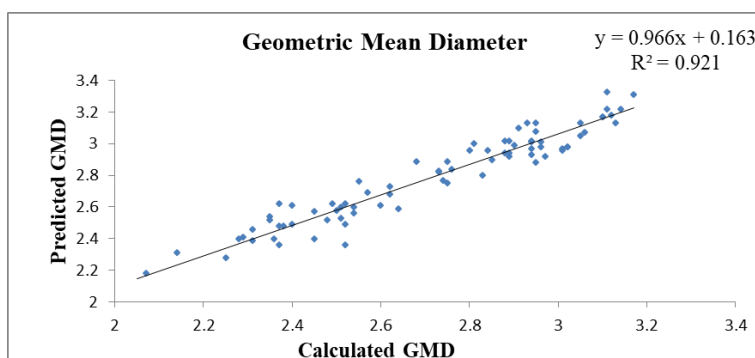

Fig 5a: Relationship between the calculated and predicted geometric mean diameter of rice kernels for variety Punjab Pusa Basmati 1509
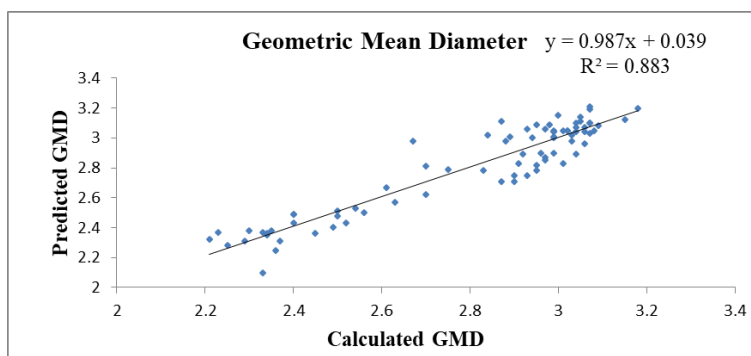

Fig 5b: Relationship between the calculated and predicted geometric mean diameter of rice kernels for variety PR124
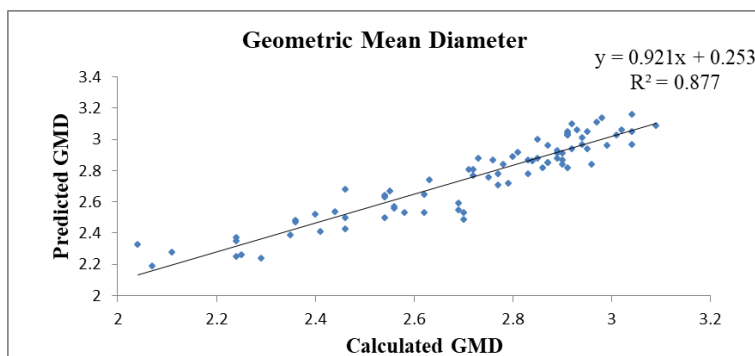

Fig 5c: Relationship between the calculated and predicted geometric mean diameter of rice kernels for variety PR121

3.6 Aspect ratio of the rice kernels

The average value of aspect ratio of rice kernel for three selected varieties i.e. Punjab Pusa Basmati 1509, PR 121 and PR 124 was found out to be 4.17, 3.08 and 3.13 for head rice whereas 2.64, 2.27 and 2.25 for brokens respectively by manual method. The plot between predicted (i.e. calculated by the predicted values) and calculated aspect ratio gave rise to linear value of R^2 which is presented in the Fig 6(a-c).The variation in predict width and the calculated width is 98.4%, 98.3%and 93.8% for PR 121, Punjab Pusa Basmati 1509 and PR 124 respectively, which is significant at $p<0.05$. The PR 121 has the highest value of the R^2 among them.
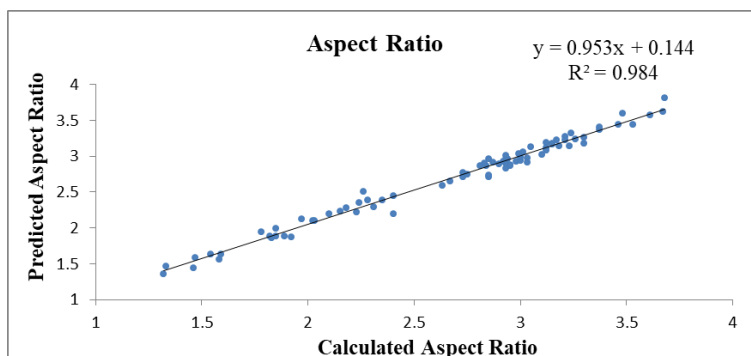

Fig 6a: Relationship between the calculated and predicted aspect ratio of rice kernels for variety PR121
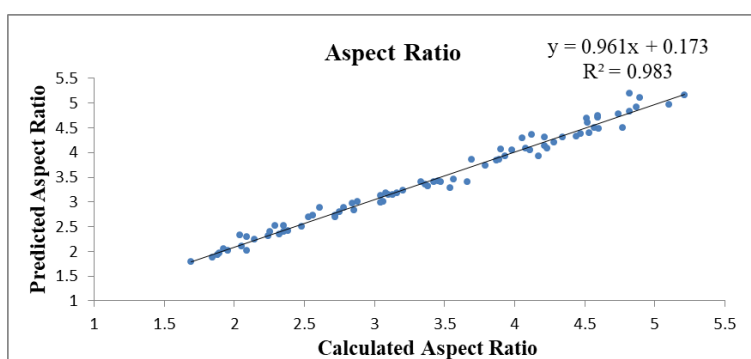

Fig 6b: Relationship between the calculated and predicted aspect ratio of rice kernels for variety Punjab Pusa Basmati 1509
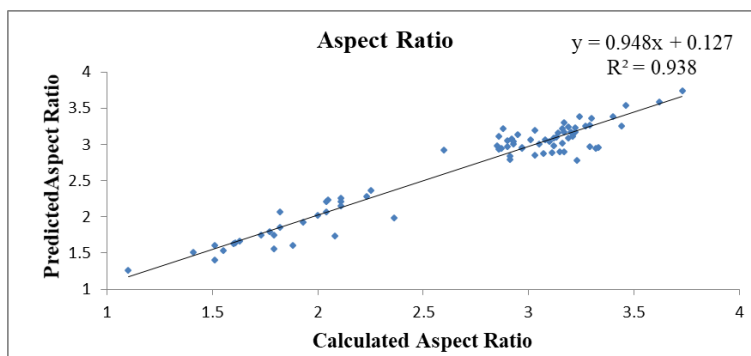

Fig 6c: Relationship between the calculated and predicted aspect ratio of rice kernels for variety PR124

3.7 Volume

The information for the shape is very important to work out their volumes when used in the combination with their true densities indicating the quality and soundness for human consumption. A plot between the calculated volume and predicted volume (i.e. volume calculated by predicted values) considering the elliptical shape of the grain is presented in Fig 7(a-c). Their relationship gave linear value of R^2 (shown in Table 2) for different varieties. The variation in predict width and the calculated width is 91.9%, 87.0%and 86.6% for Punjab Pusa Basmati 1509, PR 121 and PR 124 respectively, which is significant at $p<0.05$. The Punjab Pusa Basmati 1509 has the highest value of R^2 among all selected varieties.
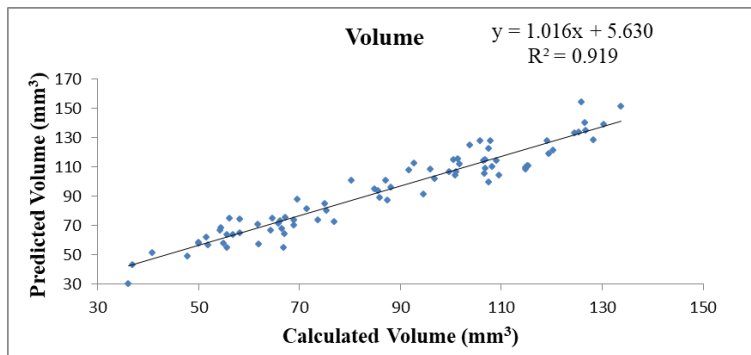
Fig 7a: Relationship between the predicted and calculated volume of rice kernels for variety Punjab Pusa Basmati 1509
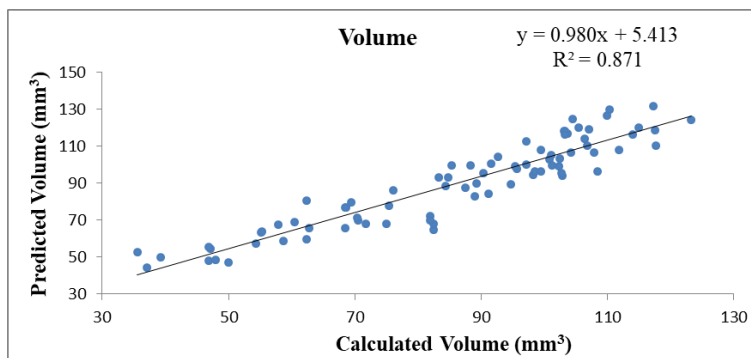

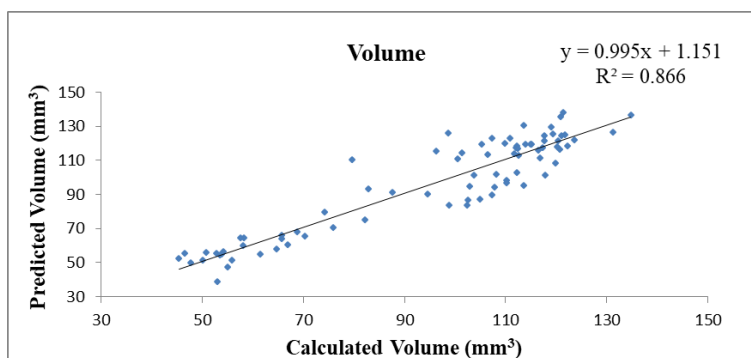**Fig 7b:** Relationship between the predicted and calculated volume of rice kernels for variety PR 121

Fig 7c: Relationship between the predicted and calculated volume of rice kernels for variety PR 124

Table 1: Average value of geometric characteristics of Punjab Pusa Basmati 1509, PR124 and PR121 by manual method and image processing method.

Sample		Length (mm)		Width (mm)		Thickness (mm)		GMD (mm)		Sphericity		Aspect Ratio	
		MM	IPM	MM	IPM	MM	IPM	MM	IPM	MM	IPM	MM	IPM
Punjab Pusa Basmati 1509	Head Rice	8.10±2.48	8.20±2.51	1.95±0.42	1.97±0.47	1.61±0.18	1.65± 0.39	2.93±0.56	2.98±0.62	0.37±0.08	0.37±0.08	4.17±1.11	4.17±1.16
	Brokens	5.12±3.30	5.33±3.38	1.96±0.53	1.98±0.58	1.57±0.24	1.66± 0.48	2.49±0.44	2.58±0.64	0.50±0.15	0.50±0.15	2.64±1.57	2.72±1.64
PR124	Head Rice	6.82±0.83	6.83±0.82	2.19±0.30	2.20±0.31	1.82±0.54	1.82± 0.26	3.00±0.33	3.01±0.30	0.44±0.05	0.44±0.05	3.13±0.60	3.12±0.62
	Brokens	4.81±2.43	4.79±2.11	2.14±0.25	2.14±0.27	1.77±0.32	1.77± 0.23	2.61±0.57	2.61±0.60	0.57±0.32	0.57±0.24	2.25±1.15	2.24±1.15
PR 121	Head Rice	6.47±1.44	6.55±1.23	2.11±0.37	2.14±0.39	1.74±0.32	1.75± 0.32	2.87±0.46	2.90±0.49	0.45±0.08	0.44±0.07	3.08±0.68	3.08±0.74
	Brokens	4.74±1.97	4.88±2.00	2.11±0.48	2.13±0.47	1.70±0.48	1.74± 0.38	2.55±0.51	2.61±0.42	0.56±0.20	0.55±0.21	2.27±0.95	2.31±0.97

MM= Manual method, IPM= Image processing method, GMD= Geometric mean diameter

Table 2: Relationship between the calculated and predicted length of rice kernels

Variety	Parameter	Prediction Equation	Value of R^2
Punjab Pusa Basmati 1509	Length	$y = 0.965x + 0.387$	0.985
PR 121		$y = 0.960x + 0.33$	0.983
PR 124		$y = 0.960x + 0.226$	0.938
Punjab Pusa Basmati 1509	Width	$y = 1.067x - 0.108$	0.976
PR 121		$y = 1.043x - 0.067$	0.969
PR 124		$y = 1.109x - 0.229$	0.979
Punjab Pusa Basmati 1509	Sphericity	$y = 0.957x + 0.017$	0.958
PR 121		$y = 0.964x + 0.013$	0.945
PR 124		$y = 0.928x + 0.036$	0.919
Punjab Pusa Basmati 1509	Geometric mean diameter	$y = 0.966x + 0.163$	0.921

PR 121		y = 0.921x + 0.253	0.877
PR 124		y = 0.987x + 0.039	0.883
Punjab Pusa Basmati 1509	Aspect Ratio	y = 0.961x + 0.173	0.983
PR 121		y = 0.953x + 0.144	0.984
PR 124		y = 0.948x + 0.127	0.938
Punjab Pusa Basmati 1509	Volume	y = 1.016x + 5.630	0.919
PR 121		y = 0.980x + 5.413	0.871
PR 124		y = 0.995x + 1.151	0.866

4. Conclusion

The results obtained by digital vernier caliper can linearly be correlated to the results obtained by image processing. The image processing method using flatbed scanner is more accurate, rapid and has better precision than more time-consuming manual method for identification of head rice and brokens. Manual method is cumbersome and time consuming. Manual method takes more than 30 minutes whereas image processing can identify head rice and brokens in 5-7 minutes which also include material preparation in the flatbed scanner.

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