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Monitoring geometric characteristics of rice during processing by image analysis system and micrometer measurement

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A b s t r a c t. Variations of the geometric characteristics of three Iranian rice varieties, namely Tarom Mahalli, Fajr and Neda, at different processing levels were determined using micrometer and image processing methods. The results obtained by both procedures showed that the geometric characteristics of all three varieties *ie* length, width, height and projected area, are decreased and the sphericity increased by removing the outer and the brownish layers. The relationships between the micrometer data and the image processing ones were obtained linearly as represented by regression equations. It was found that the micrometer data are underestimated for all the geometric factors and that the true size and sphericity *ie* ones obtained using image analysis, can be estimated with root mean square error (RMSE) of less than 6% from the dimensional features provided by micrometer procedure.

K e y w o r d s: rice, geometric characteristics, micrometer measurement, image processing

INTRODUCTION

Rice is the staple food for most of the Asians (Badawi, 2004) and more than half of the world's population relies on rice as the major daily source of calories and protein. Ancient records indicate that rice has been cultivated in Iran since the first century BC (FAO, 2007) and today Iran is one of the most important rice producers among the middle-east countries. Rice cultivation is the principal activity and source of income for millions of households around the globe. It is also a popular traditional activity in Iran, contributing a great amount to the national income.

After harvest rough rice (or paddy) enters whitening section, during which the hulls and the brownish outer bran layer are removed from paddy and brown rice, respectively. By removing the bran particles, the white rice (milled rice) is then produced. Knowledge of physical dimensions plays an important role for designing huller and husker equipments. Moreover, it is an essential issue in marketing and grading, developing new varieties, and drying operations. At the present time, specialised technicians are employed to assess the dimensional properties. However, in most cases these methods are cumbersome, tedious, time consuming and have low reproducibility. It is then of major technical and economical importance to implement new methods for reliable and fast assessment of grain varieties. Of these methods, image processing systems play a more and more important role in the food evaluation by maintaining accuracy and consistency (Du and Sun, 2004). Increasing applications of the image processing techniques are evident in grain-based industries for quality grading and classification based on kernel size, shape and appearance (Yadav and Jindal, 2007a). Sakai *et al*. (1996) studied the effects of three rice varieties and polishing methods on the shape of brown and white rice by means of image analysis system. Dalen (2004) determined the size distribution and the percentage of broken rice kernels by different kinds of flat bed scanner and image processing system. Yadav and Jindal (2001) used the machine vision system to monitor the milling process and developed models for estimating the head rice yield and whiteness of milled rice samples. Shahin and Symons (2003) determined the seed size and colour attributes for identifying the lentil type using image analysis system. Doehlert *et al*. (2004) analysed the oat kernel size uniformity using image analysis technique and sequentional sieving method. Mohoric *et al*. (2004) used the RARE imaging method to monitor the cooking of single rice kernel in real time and at high spatial

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resolution in three dimensions. Yadav and Jindal (2007b) also modelled the dimensional changes in milled rice kernel during cooking and soaking by image analysis. Correa *et al.* (2007) studied the physical and mechanical properties of three varieties of rice at different processing levels *ie* paddy, brown rice and white rice. Razavi and Farahmandfar (2008) investigated the effect of hulling and milling on the gravimetric, frictional and aerodynamic properties of three varieties of rice grains.

The attempt to evaluate the size and shape factors of three rice varieties at different processing levels by both micrometer procedure and digital image analysis system.

MATERIALS AND METHODS

Three paddy varieties, namely Fajr, Neda and Tarom Mahalli, were obtained from Amol research centre for rice located in Amol city, Mazandaran province, Iran. They were all related to a single source and one crop year (2007). The grains were cleaned manually by removal all foreign matter such as dirt, stones and broken rice. The grains were dried to approximately 12% (w.b.) by air convection oven at 105±3°C (Razavi and Farahmandfar, 2008). About 5 kg of rough rice sample of each variety was separated and kept in polyethylene bags. Samples of rough rice were dehusked with a rice dehuller (Satake, THU-35, Satade Corp., Hiroshima, Japan), and the brown rice was obtained. The output of rice dehusker was milled for 30 s in a friction mill (McGell Miller#2 , Rapsco, Brookshir, TX). The resulting milled rice was cooled to room temperature and then separated manually into head rice and broken rice. The paddy, brown and head-milled rice samples were kept in polyethylene bags and then stored at 5°C in refrigerator until the experiments.

50 individual grains were randomly selected from the remainder of each rice variety at each processing level and the three dimensions were measured using a digital micrometer (model QLR digit- IP54, China) with an accuracy of 0.001 mm. The length (L), width (W) and height (H) of rice grain were defined as the longest dimension of the maximum projected area, shortest dimension of the minimum projected area, and the minimum diameter of the maximum projected area, respectively. The average diameter of each sample was obtained using the arithmetic mean and geometric mean of three axial dimensions. The arithmetic mean diameter (Da), geometric mean diameter (Dg) and the sphericity (ϕ) of samples at each level of moisture content were calculated by the relationships given by Mohsenin (1978). The projected area of rice grains was found by analogy with a prolate spheroid shape.

The images were prepared using a desktop scanner (Canonscan 8400F). Fifty rice kernels were placed on the glass plate of the scanner avoiding kernel to kernel contact. The kernels were then covered by a non-reflecting black cloth. The scanner resolution was set to 300 dpi and the images were stored in JPEG format for further analysis. The Clemex image processing software (Clemex Vision Professional, PE4, Canada) was used to determine the required measurements of each grain. The images were processed with a 5×5 filter to reduce noise. Different threshold levels were selected for each rice variety at each processing level. By removing the background of each image, the images only contained the grains. Further image analysis determined the area, sphericity and also major and minor axes representing the length and the width of grains, respectively. The determined parameters were in pixels and the program had the capability to convert the measurements to µm.

All the geometric properties of rice grains were determined with fifty replications at each level of processing. The kernels for both experiments were chosen from the same batch using a standard method for sampling. Means, standard deviations, regression equations, coefficient of determinations and RMSE values were obtained by Microsoft Excel software (2007). Results were subjected to analysis of variance and means were compared using Duncan test at 5% probability by MSTATC software, version 1.42. The R^2 and the RMSE statistics were used to evaluate the goodness of fit. The final RMSE values <10, 10-20, 20-30 and >30%, representing the excellent, good, fair and poor fit, respectively. To compare the image processing data and micrometer measurements, the slope and intercept values of linear regression equations were tested against 1 and 0 values using Student t-test (Analla, 1998).

RESULTS AND DISCUSSION

Data of size and shape factors analysis measured by micrometer and image processing system are presented in Table 1. Mean values of geometric characteristics measured by micrometer have decreased during the processing levels. It indicates that the processing levels *ie* removing the outer and the bran layers, have a significant effect on the size values for all three varieties. It is obvious that the paddy of Fajr and Tarom Mahalli varieties have the maximum and minimum length values, respectively. However, there is no significant difference between the lengths of the last processing level for these varieties. The width and the height of Neda and Fajr varieties showed the highest and the lowest values for all processing levels. The width of Neda and Tarom Mahalli varieties did not have any statistically significant differences. Seeds graded uniformly, according to size, provide uniform germination and usually give increased harvesting yield (Varnamkhasti *et al.*, 2008). Effective grading according to width occurs when the sieve is vibrating vertically. When the length of the particle is no more than twice the width, the grading would be accepted even on sieves which vibrate horizontally (Klenin *et al.*, 1986). Therefore, grading operation for three studied varieties can only be performed based on the vertical vibration. It is not in agreement with the results obtained for Sorkhe and Sazandegi cultivars which could be separated using vertical and also horizontal vibrating sieves (Varnamkhasti *et al.*, 2008).

T a b l e 1. Mean and standard deviation of geometric characteristics of Tarom Mahalli, Fajr and Neda rice varieties at different processing levels by manual procedure

Variety	Levels of processing	Length (L)	Width (W)	Hight (H)	L/W	Da	Dg	Sphericity	Projected area
Tarom Mahalli	Rough rice	9.91 ± 0.50 Ca	2.31 ± 0.13 Aa	1.85 ± 0.12 Ba	4.30±0.27 Ba	4.69±0.20 Ba	3.48±0.14 Ba	0.35±0.01 Ab	18.00±2.44 Ba
	Brown rice	7.55 ± 0.25 Cb	2.11 ± 0.16 Ab	1.72 ± 0.05 Bb	3.60±0.33 Bb	3.79±0.10 Bb	3.01±0.09 Bb	0.40±0.01 Aa	12.49±1.73 Bb
	Milled rice	7.35 ± 0.29 Ac	2.02 ± 0.12 Ac	1.68 ± 0.06 Bc	3.66±0.29 Bb	3.68±0.11 Ac	2.92±0.09 Ac	0.40±0.01 Ba	11.62±1.47 Ac
Fajr	Rough rice	10.87 ± 0.59Aa	2.13 ± 0.14 Ba	1.80 ± 0.08 Ca	5.14±0.49 Aa	4.93±0.19 Aa	3.46±0.11 Aa	0.32±0.02 Bb	18.13±2.78 Ba
	Brown rice	7.72 ± 0.33 Bb	1.77 ± 0.11 Bb	1.63 ± 0.10 Cb	4.39±0.35 Ab	3.71±0.11 Cb	2.81±0.09 Cb	0.36±0.02 Ca	10.70±1.43 Cb
	Milled rice	7.48 ± 0.27 Ac	1.68 ± 0.13 Bc	1.60 ± 0.06 Cb	4.49±0.44 Ab	3.59±0.10 Bc	2.72±0.09 Bc	0.36±0.02 Ca	9.83±1.43 Bc
Neda	Rough rice	10.28 ± 0.50 Ba	2.35 ±0.17 Aa	2.00 ±0.05 Aa	4.39±0.33 Ba	4.88±0.19 Aa	3.64±0.13 Aa	0.35±0.01 Ac	18.99±2.92 Aa
	Brown rice	7.93 ± 0.30 Ab	2.12 ± 0.10 Ab	1.79 ± 0.10 Ab	3.74±0.25 Bb	3.95±0.11 Ab	3.11±0.09 Ab	0.39±0.01 Bb	13.21±1.43 Ab
	Milled rice	7.31 ± 0.31 Ac	2.01 ± 0.14 Ac	1.76 ± 0.05 Ac	3.65±0.32 Bb	3.69±0.11 Ac	2.96±0.09 Ac	0.40±0.02 Aa	11.54±1.65 Ac

For each test, the mean followed by the same capital letter is in line and the same lower case letter in the columns, they do not differ statistically at 5% probability through the Duncan test.

T a b l e 2. Mean and standard deviation of geometrical characteristics of Tarom Mahalli, Fajr and Neda rice varieties at different processing levels by image processing system

Variety	Levels of processing	Length (L)	Width (W)	L/W	Sphericity	Projected area
Tarom Mahalli	Rough rice	11.07 ± 0.54 Ca	2.79 ± 0.20 Aa	3.98 ± 0.26 Ca	0.46 ± 0.04 Ac	22.63 ± 2.20 Ba
	Brown rice	7.96 ± 0.44 Bb	2.34 ± 0.12 Ab	3.41 ± 0.23 Cb	0.59 ± 0.03 Ab	14.68 ± 1.25 Bb
	Milled rice	7.38 ± 0.52 Bc	2.27 ± 0.12 Ab	3.26 ± 0.30 Bc	0.61 ± 0.04 Aa	13.04 ± 1.10 Cc
Fajr	Rough rice	11.97 ± 0.71 Aa	2.68 ± 0.24 Ba	4.51 ± 0.53 Aa	0.39 ± 0.04 Bc	21.67 ± 1.77 Ca
	Brown rice	8.45 ± 0.52 Ab	2.12 ± 0.11 Bc	3.99 ± 0.31 Ab	0.51 ± 0.04 Cb	13.90 ± 1.07 Cc
	Milled rice	7.96 ± 0.44 Ac	2.34 ± 0.12 Ab	3.41 ±0.23 Ac	0.59 ± 0.03 Ba	14.68 ± 1.24 Ab
Neda	Rough rice	11.50 ± 0.95 Ba	2.81 ± 0.67 Aa	4.17 ± 0.46 Ba	0.46 ± 0.05 Ac	23.47 ± 3.82 Aa
	Brown rice	8.65 ± 0.48 Ab	2.42 ± 0.14 Ab	3.58 ± 0.30 Bb	0.57 ± 0.03 Bb	16.52 ± 1.17 Ab
	Milled rice	7.43 ± 0.44 Bc	2.29 ± 0.12 Ac	3.26 ± 0.27 Bc	0.61 ± 0.03 Aa	13.77 ± 1.07 Bc

Explanations as in Table 1.

The geometric and arithmetic mean diameters decreased during the processing as axial dimensions. Although similar trends of variation were observed for both mean diameters, the arithmetic mean diameter values were higher than the geometric mean diameter ones for all cases.

The results indicate that removing the hull has made the sphericity values increase. This result is obviously validated by the obtained images (Fig. 1). The sphericity values of rice grains at all processing levels fall within the 0.32-1 range suggested by Mohsenin (1986) for most agricultural products. It is also in agreement with the results reported for the rough rice of Sorkhe and Sazandegi varieties (Varnamkhasti *et al*., 2008).

The projected area of all three varieties showed significant decrease by de-hulling and milling operations. There was about 35.44, 45.78 and 39.23% decrease for the projected area values of Tarom Mahalli, Fajr and Neda varieties, respectively.

The results of size and shape factors analysis by image analysis system are summarized in Table 2. Similar trends are observed for dimensions variations during processing and between varieties. However, the values obtained for length, width and sphericity by micrometer were lower than those obtained by image analysis. It seems that the subjective nature of micrometer measurement has made some deviations from the real values for dimensions and also projected area calculated based on these dimensions. The sphericity values extracted using Clemex image processing software were higher than the results obtained by means of a micrometer.

Histograms of length, width and area distributions presented as stacked bar graphs provide much more information about grain size uniformity and the relation of digital image analysis data to ones obtained by micrometer (Figs 1 and 2). The size uniformity of all varieties was improved by removing the hull and brownish layer in both methods. However, the size distribution around the mean value remains fairly unchanged in micrometer method.

Figures 3-6 represent the relationship between the image processing data and the usual micrometer measurement. The figures show that the values obtained by micrometer were underestimated compared to image processing data for all factors. However, the results obtained using Student`s t-test indicate that there is no difference between the slope and the intercept values of fitted equations against 1 and 0 values (the slope and the intercept values of 1:1 line).

Regarding the coefficients of determination and RMSE, linear regression equations are adequately appropriate for fitting image processing data against the micrometer method. These results validated the hypothesis that the true size and the sphericity of rice grains can be estimated with root mean square error (RMSE) of less than 6% from the dimensional features provided by micrometer procedure.

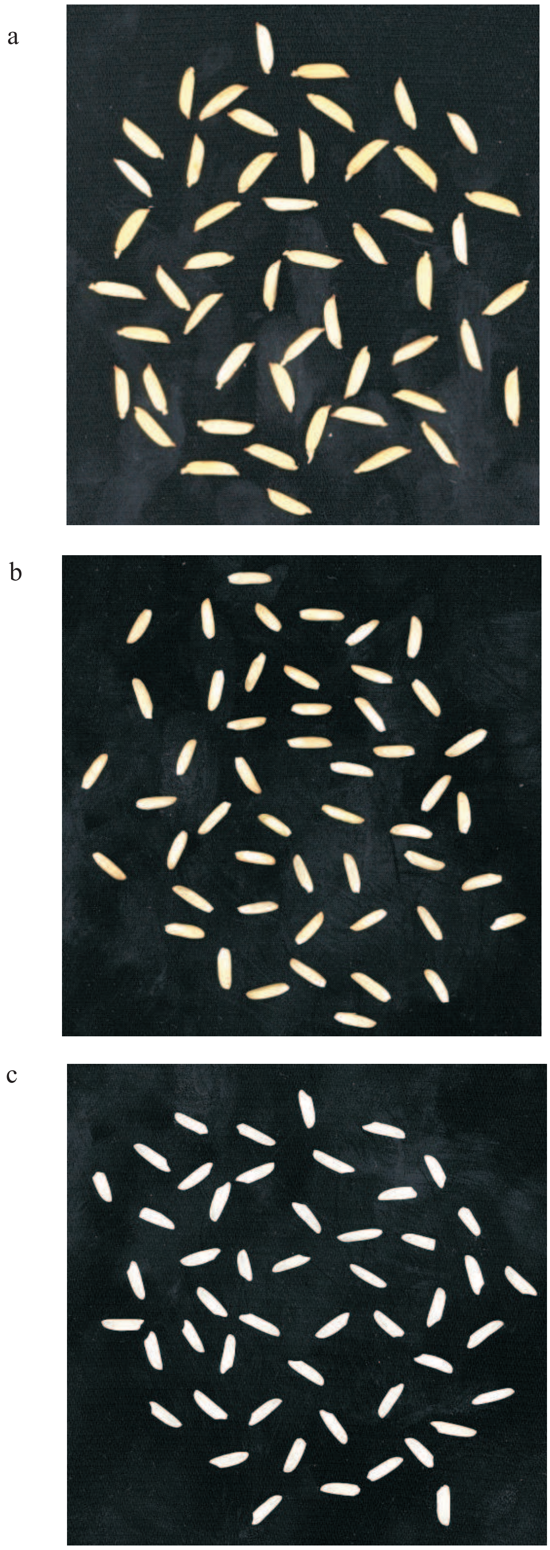
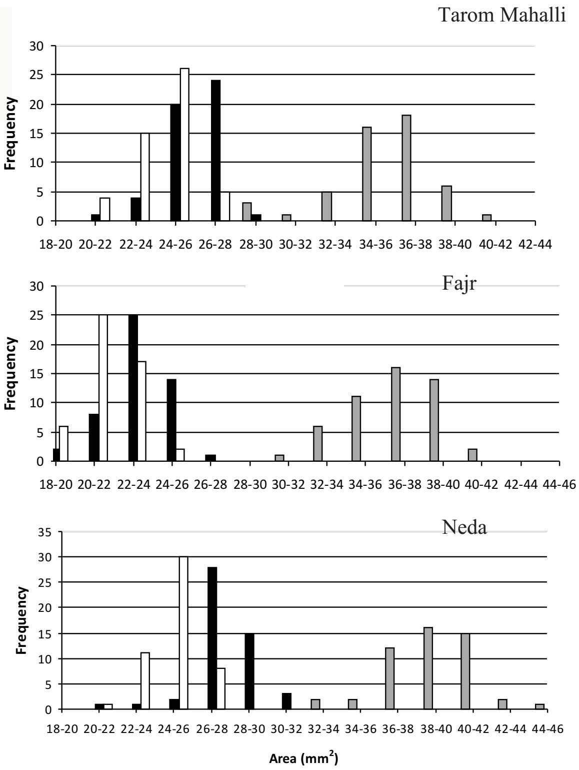


Fig. 1. Typical images of different processing levels of Tarom Mahalli rice variety obtained using a flat bed scanner: a – paddy or rough rice, b – brown rice, c – white rice.

a



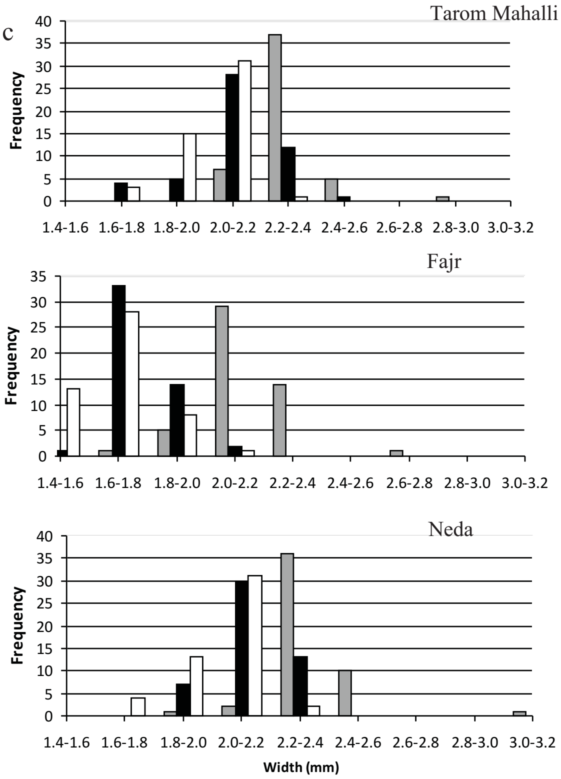
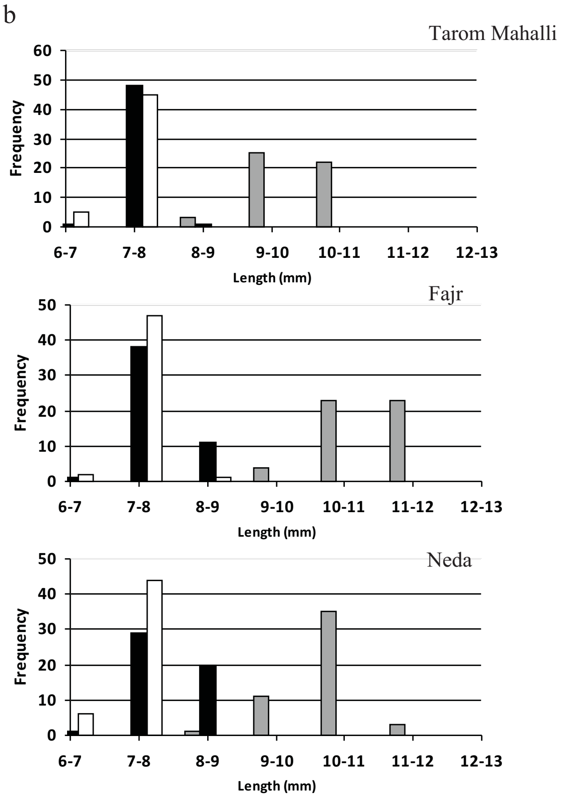


Fig. 2. Histograms showing distributions of rice grain: a – area, b – length, c – width from Tarom Mahalli, Fajr, and Neda varieties at different levels of processing (■ paddy, ■ brown rice, □ white rice) by conventional manual procedure.

b



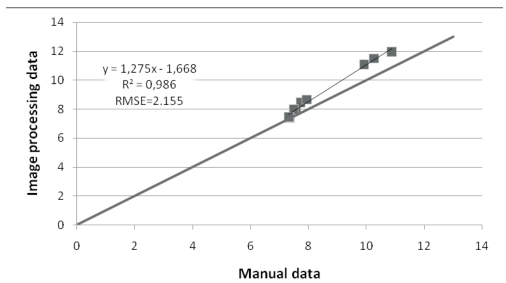


Fig. 3. The relationship between the length values of three rice varieties obtained by image processing method and manual procedure at different processing levels.

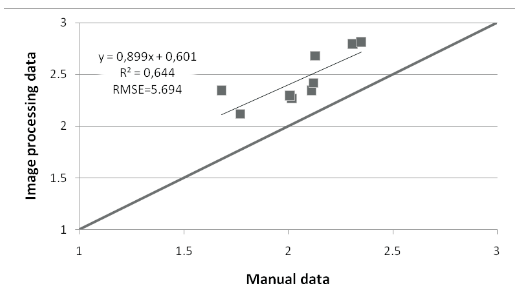
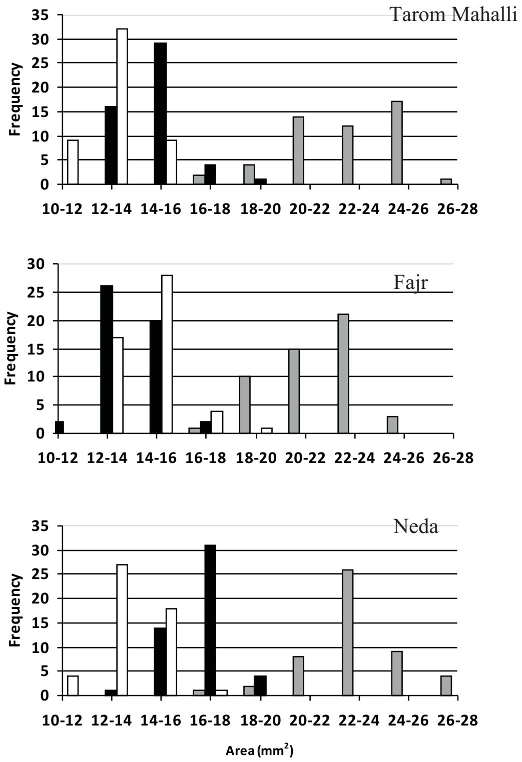
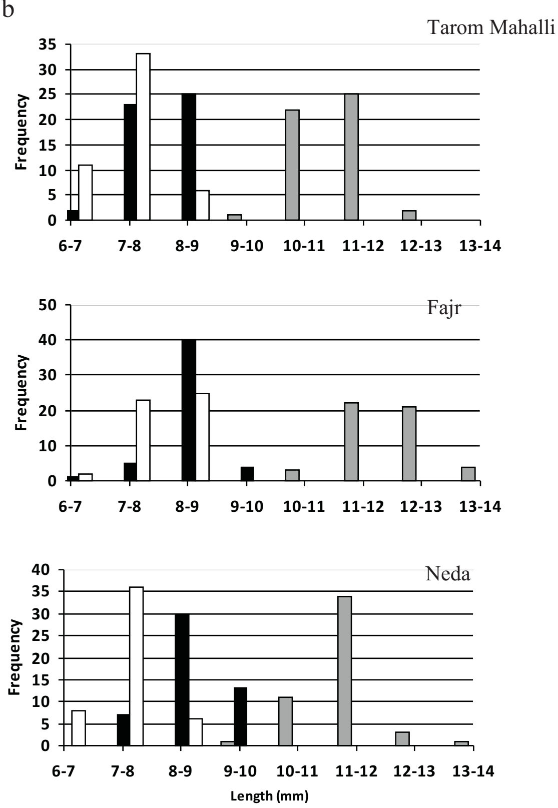


Fig. 4. The relationship between the width values of three rice varieties obtained by image processing method and manual procedure at different processing levels.

a



b



c

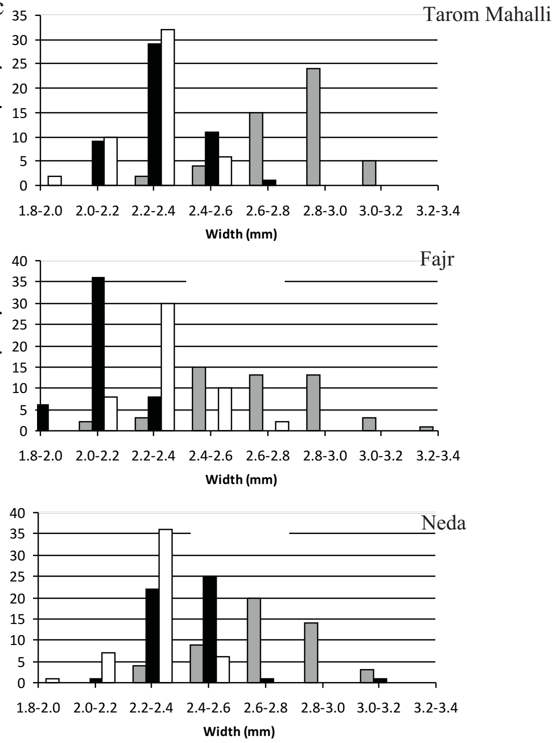


Fig. 5. Distributions of rice grain: a – area, b – length, c – width for three rice varieties at different levels of processing (■ paddy, ■ brown rice, □ white rice) by image processing method.

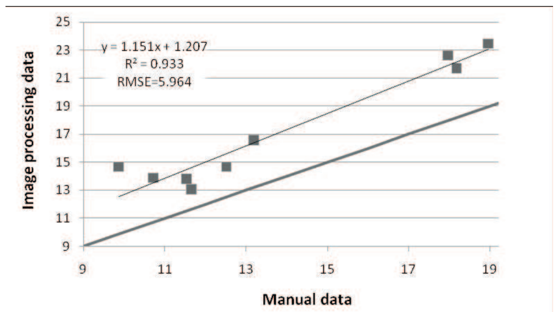


Fig. 6. Relationship between the projected area values of three rice varieties obtained by image processing method and manual procedure at different processing levels.

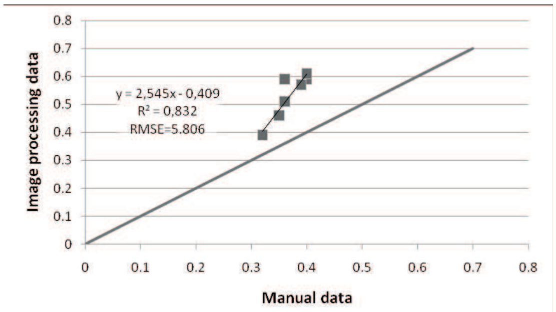


Fig. 7. The relationship between sphericity values of three rice varieties obtained by image processing method and manual procedure at different processing levels.

Rice is classified into three categories *eg* long, medium and short by the ratio of length to width (L/W) (Sakai *et al*., 1996). The results obtained by both methods used (Tables 1 and 2) indicate that these three varieties belonged to the long category *ie* the grain length and width ratio was higher than 3.0 in all cases.

The complete image processing method, from scanning the grains to receiving a result, took about 3 min, of which about 2 min were for image processing. However, the manual procedure took at least 1 h for size determination of 100 or more rice grains.

CONCLUSIONS

1. Removing the husk and bran had significant effects on dimensional attributes.

2. Sphericity showed significant increase during the de-husking and milling operations.

3. The results obtained by micrometer procedure were underestimated for all geometric characteristics.

4. The results obtained by micrometer can linearly be converted to the more accurate and reliable results obtained by image processing system.

5. The image processing method is a rapid procedure for investigating the geometric characteristics of rice varieties.

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