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Estimating Volume and Mass of Tomato Fruits by Image Processing Technique

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Abstract: A technique based on image processing was developed to determine volume and mass of tomato fruits. The images of different grades of tomato were attained using a digital camera. A MATLAB based algorithm was developed to enumerate and process these digital images. The geometric characteristics such as axial dimensions, mass, volume, density, sphericity, aspect ratio and ellipsoid ratio were recorded. The size of tomato varied from 30.00-77.62 mm. The bulk density was maximum (0.26 g/cc) for tomato of size 57-66 mm. The aspect ratio was higher than unity for tomatoes of all grades indicating the variation in length with respect to width. The differences between two methods were normally distributed and predictable to lie between M - 1.96SD and M + 1.96SD, known as 95% limits of agreement. The paired samples t-test results showed that parameters observed with image processing method was not significantly different from the measured using vernier caliper. A linear relationship between mass of tomato and the projected area, volume and axial dimensions was also developed for calculation of mass using image processing. This information can be used to design and develop sizing systems.

Keywords: Tomato, Image processing, Volume, Mass, Grading

The knowledge of engineering properties of horticultural products is very important in developing new consumer products, evaluating and retaining the quality of products and designing of machines, processes and controls. The physical properties of food materials (raw, unprocessed and processed) include particle size and shape, density, surface area and porosity. Among all the important quality parameters, fruit size and shape are one which is mostly preferred by consumers i.e. consumer prefers fruits of uniform size and equal weight. So, the determination of fruit size and shape is very important in meeting the standards of quality parameters which results in monitoring the increasing market growth. The determination of physical properties such as size, unit mass, volume, sphericity and density using advanced technologies were reported by many researchers. In recent researches, it has been estimated that there is a huge loss of crop before consumption because of poor handling, storage, transportation and marketing practices. One of the major reasons for this loss is the time-consuming manual grading. Grading of the agricultural produce is considered very important as it improves handling, packaging, transportation and other post-harvest operations. The process of grading of fruit starts with the sorting of fruits by size, shape and colour by humans assessed by sight and feel. The increasing cost of labour and also demand for consistency in quality of products lead to mechanization of the sorting process (Tabatabaeefar and Rajabipour 2005, Lorestani and Tabatabaeefar 2006, Shahi-Gharahlaretal 2009, Adebowale et al 2011, Seyedabadiet al 2011, Ercisli et al 2012, Shahbazi and Rahmati 2013).

The application of image processing-based methods in agricultural activities has been developed for years (Lak 2011). Nowadays, commercial fruits such as strawberries, orange, peaches, tomato and apples have been graded by the use of image processing and machine-vision technology (Spreer 2009). The main components of machine-vision technology consist of a color CCD camera with an image capturing device and a lighting source to evaluate fruit based on different engineering properties such as size, shape, color and defection. Due to the availability of infrastructures, the automated sorting/ grading in various food industries had suffered substantial growth in the developed and developing countries. The application of computer in field of agriculture and food industries has resulted in better sorting, grading of fresh crops, recognition of defects such as cracks, dark spots and bruises on fresh fruits and seeds. So, automation is one of the most important aspects of agricultural mechanization. It allows improvement in efficiency, increase in capacity and protection to human workers from tedious and hazardous activities. The digital image processing has become very important and more probable to many areas including agricultural industry (Yimyam et al 2005, Chalidabhongse 2006, Bulanon 2012). The use of machine vision knowledge for quality examination, classification, sorting, and grading agricultural products is becoming more fascinating (Teoh 2010). This technology has been extensively used in the agricultural and food industry for evaluation and inspection as they offer suitable, quick and economic assessment. The automated examination of produce using this technology not only results in labor savings, but also advances inspection objectivity (Valente 2009, Spreer 2009). The development in hardware and software for digital image processing and their use in analysis of food crops have inspired several studies for the development of the system which can assess the quality of different foods. So as the manual and mechanical system which is currently being used for sorting/grading is labour intensive and also the new technology of image processing has not been fully explored in India for up gradation of the sorting/grading equipment, there is a need to develop such system which can meet the demand of the products in market without compromising the quality parameters. The present study has been planned to develop a system based on image processing technology to perform functions of sorting/grading based on volume and mass with greater precision at a faster rate without any drudgery.

MATERIAL AND METHODS

The tomato of variety *Punjab Chhuhara* was considered for the present study. A total of 25 fruits each of different grades of tomato were selected at random from the storage piles. The mass of each fruit was measured by an electronic weighing scale with an accuracy of ±0.1g. The axial dimensions (length, width and thickness) of tomato were measured using a digital vernier caliper with an accuracy of 0.01mm. The other parameters like shape, density, sphericity and true volume were determined using standard methods (Mohsenin 1986). Based on the shapes of tomato i.e. considering them to be ellipsoid, volume of fruits was calculated using three axial dimensions of fruits and geometric mean diameter. The following equations were used in calculations.

$$\text{Volume of ellipsoid} = \frac{4\pi}{3} \times L \times W \times T \ (\text{mm}^3)$$

Where L, W T are length, width, thickness in mm

$$\text{Change in volume(\%)} = \frac{\text{True volume - Calculated volume}}{\text{True volume}} \times 100$$

The same parameters were determined using image processing technique also. The setup of image processing consisted of a digital camera (AF-S DX NIKKOR 18-55mm f/3.5-5.6G VR II) connected to computer having image processing software. The camera was mounted on the image acquisition box for keeping the standardized distance. The height of optical lens of camera was tested for three different heights based on the size of tomato of different grades and height with the best results was selected. For tomato, the different heights of optical lenses tested were 145mm, 160mm and 175mm. Among them, height of 160mm was selected for capturing images of tomato. Images were captured in natural illumination. The camera was mounted on the tripod stand for keeping the distance of the fruit from the camera uniform. The analysis of the images of tomato for different grades was done using Image processing software (MATLAB R2013a, version 8.1). The flowchart showing image analysis algorithm used for processing of different images of tomato is given in Figure 1. The fruit images were calibrated for axial dimensions and other geometric properties by using images of a square sheet of black colour of size 5cm x 5cm under similar conditions. The data related to geometrical features attained by image processing of tomato was compared with the measured physical parameters and a correlation was studied between measured parameter (size, volume etc.) and those analyzed from image. The analysis was based on plots between different physical parameters like axial dimensions and volume determined by both the methods. The mass of tomato was also predicted on the basis of volume.

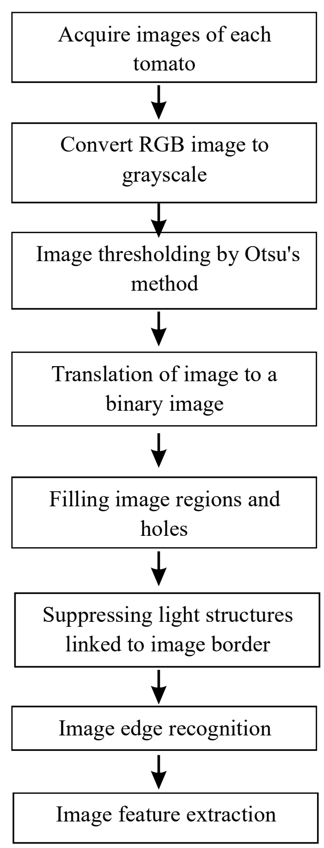

Fig. 1. Flow diagram for image processing and analysis

Statistical analysis: The statistical analysis was performed using Descriptive Statistics at 95% confidence level for mean in Microsoft Excel 2007. The paired t-test and the Bland-Altman plots (the mean difference confidence interval approach) were used to compare the engineering characteristics determined by image processing technique and the standard method. The paired t-test was used to test the significance of difference between the two measurements. A correlation was developed between parameters measured by both the methods. The Bland-Altman approach was used to plot the agreement between the values measured by both the methods.

RESULTS AND DISCUSSION

Tomato fruits of variety *Punjab Chhuhara* were separated into six grades viz. Grade A (30-34 mm), Grade B (35-39 mm), Grade C (40-46 mm), Grade D (47-56 mm), Grade E (57-66 mm) and Grade F (67-81 mm). A total of 150 fruits were evaluated for each parameter. The length of the tomato fruit was considered as the major criteria for grading categories. The length of tomato fruits varied(mm) between 30.00-33.99, 35.04-39.23, 40.19-46.00 48.17-55.90, 57.34-65.85 and 67.11-79.48 for grades A, B, C, D, E and F respectively. The true volume of different grades of tomato was determined using water displacement method (Table 1). The true volume of smallest grade of tomato was 4666. mm^3 whereas it was 38760 mm^3 for largest grade.

Linear relationship was observed between calculated volume and true volume for ellipsoid shape of tomatoes (Fig 2). In addition to this, the value of R^2 for all the samples of tomatoes of respective grades was greater than 0.9. This was in agreement with by Kumar et al (2013) for selected dry beans. Therefore, both the methods of volume measurement i.e. either by using equivalent diameter or by the three different axial dimensions can be used successfully. The percent change in volume was 89.74, 5.41, - 30.61, - 135.43, - 57.89 and - 68.1 for respective grades. The negative values indicated that calculated volume was higher as compared to that of true volume.

Engineering parameters of tomato by image processing: The physical properties of tomato fruits were also extracted from images with the help of MATLAB software. The parameters like major axis diameter, minor axis diameter, equivalent diameter were extracted from the images. The fruit images were calibrated by taking images of a black colour square sheet of size 5cm x 5cms from the standard height i.e. 160 mm selected for tomato mm.

For tomato, 1mm = 17 pixels

The volume calculated from the images of tomato (longitudinal and lateral view) of different grades also showed correlation with the measured true volume (Fig. 3). The value of R^2 for respective grades was observed to be 0.814, 0.915,

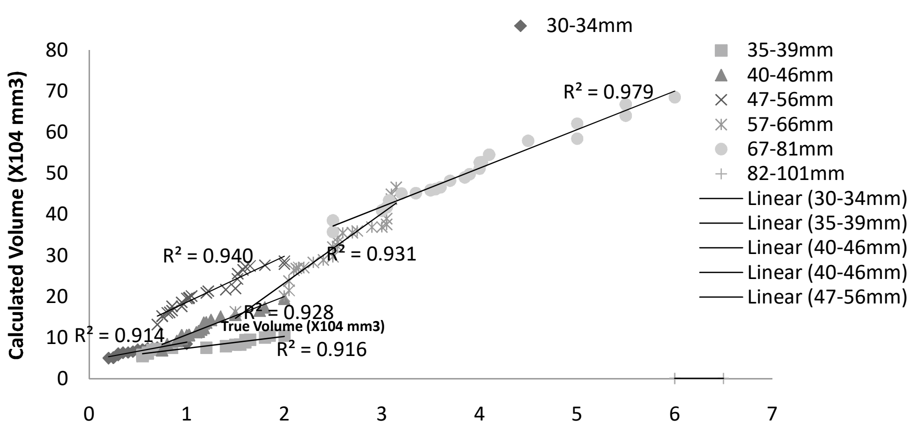

Fig. 2. Relationship between true volume and calculated volume for ellipsoid shape of tomato

Table 1. Volume of different tomato

Characteristics	Grade A (30-34 mm)	Grade B (35-39 mm)	Grade C (40-46 mm)	Grade D (47-56 mm)	Grade E (57-66 mm)	Grade F (67-81 mm)
Volume of ellipsoid tomato (mm^3)						
Mean	65010.15	78455.96	123993.80	210424.60	324000.10	500562.50
Standard deviation	12174.01	16944.40	30896.90	46718.50	83630.18	88059.16
True volume (mm^3)						
Mean	4666.67	11777.78	11779.00	12207.00	25170.00	38760.00
Standard deviation	2135.30	5341.41	3030.17	4042.89	4324.54	9283.02

0.910, 0.971, 0.893 and 0.963 for longitudinal view and 0.907, 0.920, 0.897, 0.969, 0.961 and 0.932 for lateral view. The relationship between the volumes of overall tomato measured with both the methods was also developed and is shown in Figure 4. The value of R^2 was 0.923.

Bland-Altman plot of mean values and differences of volumes for tomato obtained by image processing method and water displacement method were also plotted to check the agreement between both the methods (Fig. 5). The volumes determined by both the methods for tomato were normally distributed and was M = 14438.01 mm^3 (95% confidence interval). The 95% limits of agreement for comparison of volumes for tomato measured with both the methods were e -4848.25 mm^3 and 33724.27 mm^3 (Fig. 5).

The same pattern was observed by Khojastehnazhand et al (2009) for oranges, Rashidi et al (2007) for kiwifruit volume and Soltani et al (2010) for banana volumes. The paired samples t-test results showed that volume obtained with image processing method was not significantly different from the parameters measured with water displacement method for tomato (Table 2). Hence the images of tomato captured with digital camera can be efficiently used for the study of geometrical properties.

Prediction of mass based on volume: The connection between mass of the fruits and the volume estimated by both water displacement and image processing method was also studied (Fig. 6). The R^2 for water displacement method was 0.971 whereas was 0.984 for volume determined by image processing method. The volume and mass are highly

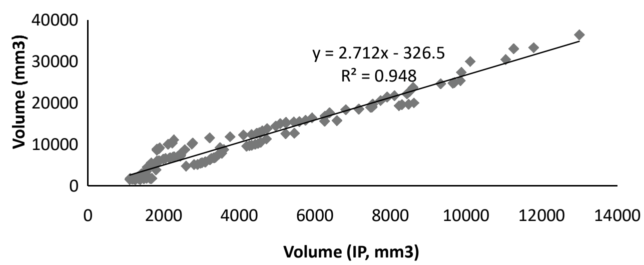

Fig. 4. Relationship between the volume of tomato measured with water displacement method and calculated from image

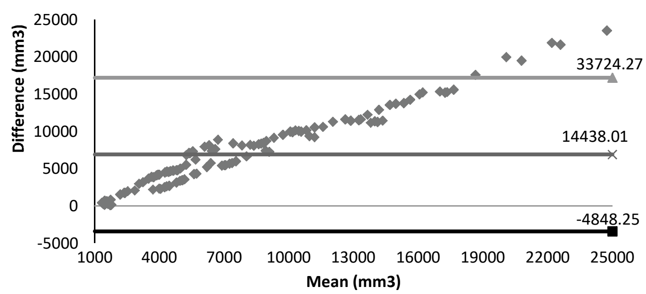

Fig. 5. Bland-Altman plot for the assessment of volume of tomato computed with image processing (IP) method and measured by water displacement method

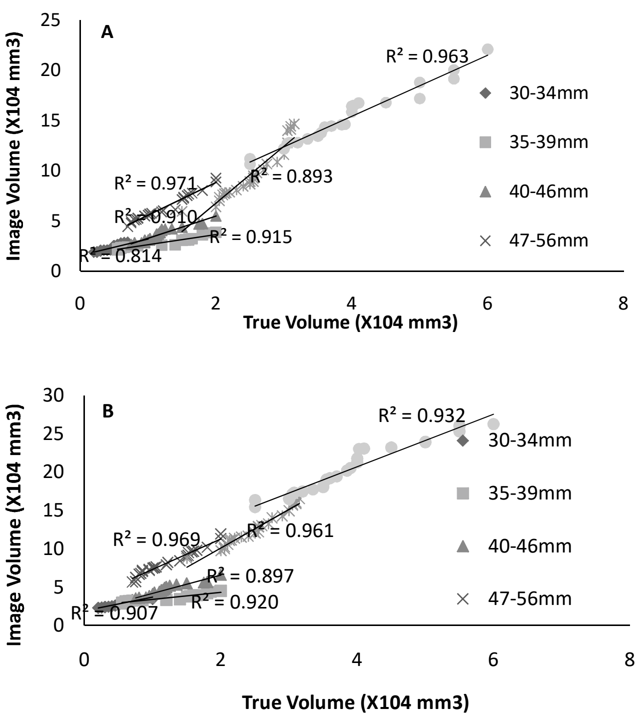

Fig. 3. Relationship between true volume and volume worked from images of different grades of tomato (a) Longitudinal view (b) Lateral view

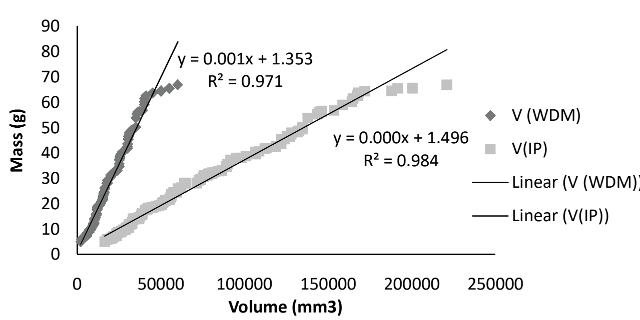

Fig. 6. Relationship between mass and volume of tomato

Table 2. Paired sample t-test analyses on a comparison of volume measurement methods for tomato

Parameter	Size	Average difference (mm^3)	Standard deviation of difference (mm^3)	P value	95% confidence intervals for the difference in means (mm^3)
Tomato	150	6879.79	5249.52	0.723	6031.98, 7727.61

correlated. The same result was obtained by Omid et al (2010) while estimating mass and volume of citrus fruits using image processing. The data was concluded to be best fit for mass determination based on volume of fruit using image processing technique.

CONCLUSIONS

The two methods were presented for estimating the volume of tomatoes. Both the methods were relatively general and may be applied for volume calculation of other ellipsoidal agricultural crops such as peaches, eggs, onion, lemons and kiwifruit etc. The volume calculated from the images of different grades of tomato showed good correlation with the volume measured by water displacement method. Also, the results for various tomato fruits showed that the volume and mass are highly correlated. Mass can be predicted easily using image processing data. The paired samples t-test results showed that parameters determined by image processing method was not significantly (P>0.05) different from the those measured using vernier caliper. This information can be used to design and develop sizing systems.

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