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Short communication

Ascertaining physico-mechanical properties of *Prunus nepalensis* Steud fruit and seed using image processing and experimental methods

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ABSTRACT

The physico-mechanical properties of *Prunus nepalensis* fruit and seed were determined at moisture content of 88.50 and 15.62%, respectively. Image processing technique was also used to measure major dimensions and data was compared and correlated with experimental data. Significant correlation was observed between length and width of fruit and seed measured by experimental and image processing technique. The true density, bulk density and porosity of fruit were measured as 1077.41; 598.08 kg m^{-3}; and 43.42%, respectively whereas, for seed these values were observed to be 1178.84; 508.80 kg m^{-3}; and 57.94%. The angle of repose of fruit and seed was found to be 26.43 and 22.13°, respectively. Frictional coefficient was found lower in aluminium sheet than other surfaces. The obtained properties can be helpful for designing of processing equipment for this fruit.

Key words: *Prunus nepalensis*, physical and mechanical properties, image processing.

Prunus nepalensis fruits, belong to family Rosaceae, is an important indigenous and nutritionally rich underutilized fruit of North Eastern Region of India and locally known as *Sohiong* in *Khasi*. The fruit is rich in β-carotene (257.1 µg %), vitamin C (608.9 mg %), antioxidant and minerals (Agrahar and Subbulakshmi, 1; Seal, 11). Fruits are drupe, fleshy, dark purple in colour at ripening and green to pinkish colour in beginning stage and contain round shape hard stone with smooth surface (Shankar and Synrem, 13). It is found in *Khasi* and Jaintia hills of Meghalaya between 1,500 to 2,000 m altitude. Fruit is eaten fresh by local people and fruit juice and pulp are used for preparation of squash, jam, RTS (ready-to-serve) and cheery wine.

Physico-mechanical properties of *P. nepalensis* fruits and seeds are essential in designing machines and equipment for post-harvest processing (Aviara *et al*., 2). Size and shape are important in the development of cleaning and grading machinery, bulk density and porosity in designing of drying and aeration system, angle of repose and coefficient of friction are important for mass flow and storage structures design (Kaleemullaha and Gunasekar, 4). Digital image analysis technique is a faster, non-destructive alternative to the traditional equipment currently used in the grain industry to determine the physical dimensions of seeds and grains (Mandal *et al*., 6; Razavi *et al*., 9). Therefore, the present investigation was undertaken to determine the physico-mechanical properties of *P. nepalensis* fruits and seeds by experimental as well as image processing technique and compare their results.

The work was carried out at the Division of Agricultural Engineering, ICAR Research Complex for NEH Region, Meghalaya. Matured ripen *P. nepalensis* fruits were procured from market at Shillong. Seeds were extracted manually by squeezing the fruits and cleaned thoroughly, and allowed to dry naturally for two days. Moisture content of the fruits and seeds were determined by using standard hot air oven method at 105 ± 5°C for 24 h and found to be 88.50 and 15.62%, respectively.

Length, width and thickness of the fruit were measured by a Vernier calipers with an accuracy of 0.02 mm. Average diameter of fruit and seed was calculated by using the arithmetic mean and geometric mean of length, width and thickness. Arithmetic mean diameter, geometric mean diameter and sphericity and surface area were calculated by using standard relationships. Unit mass of fruit and seed were determined by a digital electronic balance having accuracy of 0.01 g (Mettler Toledo, Switzerland, PB3002-SDR). Average mass of fruit and seed was calculated by weighing 100 numbers of randomly selected from a lot of 1000 fruits. Volume, true density and bulk density were determined by pycnometric method (Mohsenin, 7). Toluene was used instead of water because toluene has the advantages of little tendency to soak into fruits and

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seeds and a low surface tension thus enabling it to flow smoothly over the surface of fruits and seeds (Razavi *et al*., 10).

Porosity was calculated from bulk and true densities using the relationship given by Mohsenin (7). Angle of repose was determined using a hollow cylinder of 0.15 m diameter and 0.5 m height following the method described elsewhere (Razavi *et al*., 10). Static coefficient of friction was determined on three different frictional surfaces, aluminium, galvanized iron (GI) sheet and plywood using the method of tilting platform (Pradhan *et al*., 8). Texture characteristic of *P. nepalensis* fruits in terms of hardness was measured using a Stable Micro System TA-XT2 texture analyzer (Texture Technologies Corp., UK). Hardness value was considered as mean peak cutting force and expressed in kgf. The studies were conducted at a pre-test speed of 1.0 mm s^{-1}, test speed of 0.5 mm s^{-1}, distance of 2 mm, and load cell of 50.0 kg (Sirisomboon *et al*., 14).

An HP scanjet (Hewlett-Packard model # C7716A) document scanner was used to take images of the fruits and seeds and the images were analysed using the MATLAB 7.8.0 (The Math Works, Inc., Natick, MA, USA) software. The dimensions were determined using the procedure described by Mandal *et al*. (6). The scanned and analyzed images of *P. nepalensis* fruits and seeds are shown in Fig. 1. Sphericity and roundness were calculated using standard formula (Razavi *et al*., 10). The results of the image analysis were compared to the data obtained by experimental method by using SPSS statistical software (IBM, version 20.0.0).

RESULTS AND DISCUSSION

The mean and standard deviation values of all physico-mechanical properties of *P. nepalensis* fruits and seeds measured experimentally and by image processing technique are summarized in Tables 1 and 2, respectively. Length of fruit in experimental method ranged from 17.41 to 22.62 mm, whereas, in image analysis it ranged from 15.83 to 21.20 mm. Length of *P. nepalensis* seed in experimental method was found in the range of 13.70 to 18.72 mm. By image analysis technique, seed length was found in the range of 14.21 to 18.24 mm. Width of *P. nepalensis* fruits and

Table 1. Physico-mechanical properties of *Prunus nepalensis* fruit at 88.50% moisture content.

Trait	Experimental method			Image analysis method	
	No. of obs.	Mean	SD	Mean	SD
Length (mm)	100	19.82	1.09	18.87	1.37
Width (mm)	100	19.53	1.14	17.03	0.88
Thickness (mm)	100	18.20	1.30		
Surface area (mm^2)	100	1156.61	127.92		
Projected area (mm^2)	100	-	-	252.33	26.47
Geometric mean dia. (mm)	100	19.16	1.05		
Arithmetic mean dia. (mm)	100	19.18	1.05		
Sphericity	100	0.97	0.02	0.85	0.03
Roundness	100	-	-	0.90	0.06
Unit mass (g)	100	5.09	0.77		
Mass of 1000-seed (g)	5	5141.14	163.96		
Volume (cc)	10	4.89	1.14		
True density (kg m^{-3})	10	1057.68	29.24		
Bulk density (kg m^{-3})	10	598.08	13.21		
Porosity (%)	10	43.42	2.02		
Angle of repose (°)	5	26.43	2.08		
Static coefficient of friction on					
Aluminium	5	0.421	0.004		
Plywood	5	0.434	0.004		
Galvanized iron	5	0.477	0.012		
Hardness (kg)	9	0.966	0.089		

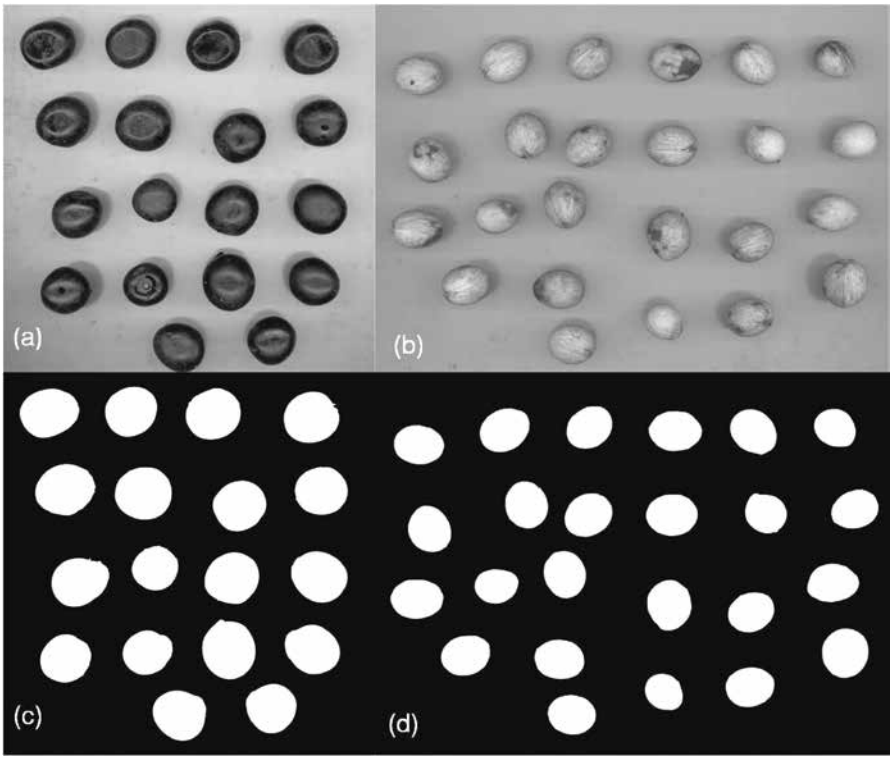

Fig. 1. Scanned and processed binary images of *P. nepalensis* fruits (a, c) and seeds (b, d).

Table 2. Physico-mechanical properties of *Prunus nepalensis* seed at 15.62% moisture content.

Trait	Experimental method			Image analysis method	
	No. of obs.	Mean	SD	Mean	SD
Length (mm)	100	17.09	1.23	16.57	1.03
Width (mm)	100	14.01	0.97	13.96	0.75
Thickness (mm)	100	13.96	0.81		
Surface area (mm^2)	100	701.17	53.80		
Projected area (mm^2)	100	-	-	180.79	19.97
Geometric mean dia. (mm)	100	14.93	0.57		
Arithmetic mean dia. (mm)	100	15.02	0.58		
Sphericity	100	0.877	0.055	0.601	0.16
Roundness	100	-	-	0.837	0.03
Unit mass (g)	100	1.83	0.51		
Mass of 1000-seed (g)	5	2050.40	183.24		
Volume (cc)	10	1.62	0.42		
True density (kg m^{-3})	10	1178.84	109.25		
Bulk density (kg m^{-3})	10	508.80	13.82		
Porosity (%)	10	57.94	3.41		
Angle of repose (°)	5	22.13	1.47		
Static coefficient of friction on					
Aluminium	5	0.369	0.025		
Plywood	5	0.414	0.004		
Galvanized iron	5	0.435	0.014		

seeds ranged from 17.11- 22.02 mm and 12.01-17.62 mm, respectively in experimental method whereas, in image analysis these values were 15.20-18.80 mm and 11.92-15.22 mm, respectively for fruit and seed.

Regression between image processing and experimental method for length and width of fruit and seed are presented in Table 3. Length of fruit and seed in image processing technique was 4.79 and 3.04% lower, respectively than experimental method. Width of seed was lower by 0.36% in image analysis method; however, width of fruit was lower by 12.80%. The correlation between the methods for length and width of fruit was 0.943 and 0.805, whereas for seeds these values were 0.941 and 0.936, respectively. This shows that there is strong correlation between image processing technique and experimental method for length and width of *P. nepalensis* fruits and seeds. Similar findings were reported by previous researchers for various seeds (Keefe, 5; Mandal *et al*., 6; Shahin, 12; Tańska *et al*., 15).

Arithmetic mean diameter, geometric mean diameter, sphericity and surface area of fruits were calculated to be 19.18 mm, 19.16 mm, 0.97 and 1156.61 mm^2, respectively. In case of seeds, these values were found to be 15.02 mm, 14.93 mm, 0.877 and 701.17 mm^2, respectively. Both the fruits and seeds of *P. nepalensis* were found spherical as sphericity values were more than 0.80 and 0.70 (Dutta *et al*., 3). Roundness and projected area were determined using image analysis technique and found 0.904 and 252.33 mm^2 of *P. nepalensis* fruit and 0.837 and 180.79 mm^2 of seed, respectively. Unit mass and volume of *P. nepalensis* fruit ranged between 3.55-7.05 g and 3.6-6.5 cm^3, while that of seed between 0.99-2.25 g and 0.8-2.1 cm^3, respectively. Bulk density, true density and porosity of *P. nepalensis* fruit were 598.08 kg m^{-3}, 1057.68 kg m^{-3} and 43.42%, respectively. Both bulk and true density values were lower than arecanut kernels (Kaleemullaha and Gunasekar, 4) with its highest moisture content. Average bulk density of *P. nepalensis* seed (508.80 kg m^{-3}) was lower than fruit but true density (1178.84 kg m^{-3}) and porosity (57.94%) were higher, which justify its less sphericity than fruit.

Table 3. The relationship between experimental (y, mm) and image processing data (x, mm) for length and width of *Prunus nepalensis* fruits and seeds.

Dimension	Regression equation	R^2
Fruit length	Y = 1.177x - 4.795	0.943
Fruit width	Y = 0.869x - 0.427	0.805
Seed length	Y = 1.116x - 1.365	0.941
Seed width	Y = 0.911x + 1.254	0.936

The angle of repose of *P. nepalensis* fruit varied between 23.44° to 28.68° and of seed between 20.15° to 23.76°. GI sheet surface had the highest coefficient of friction (0.477 for fruit and 0.435 for seed), and it was found that the static coefficient of friction was lowest against aluminium (0.429 for fruit and 0.369 for seed) with both fruit and seed. This was due to the smoother and polished surface of aluminium sheet compared to other sheets used. Fruit had higher friction than seed due to higher moisture content. The hardness of *P. nepalensis* fruit was found to vary between 0.879 to 1.184 kg with a mean value of 0.966 kg, which was lower compared to other fruits reported. This suggests that separation of pulp from kernel will be easier when done mechanically (Pradhan *et al*., 8).

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