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RESEARCH ARTICLE

Some engineering properties of wood apple (*Feronia limonia* L.)

■ **S.P. Divekar, M.H. Gajabe and Pooja Nimkarde**

SUMMARY

The wood apple (*Feronia limonia* L.) fruit is an underutilized fruit having extensive therapeutic and functional properties. But unfortunately, it is unpopular and underutilized fruit because of lack of mechanical technologies for plucking/ harvesting, picking, cracking, processing and transportation, separating and packing and for removing of pulp of wood apple. The engineering properties (physical, gravimetric, frictional and mechanical) of the wood apple fruit aids in the assessment of the internal and external structure of the fruit. Wood apple (*Limonia acidissima* L.) belongs to the family Rutacae and it is commonly found in dry plains of India, known by different vernacular names such as kavatha, Kaith, Kath bael, etc. The average moisture content of wood apple shell and pulp was found as 52.63 % and 76.12 %, (w.b), respectively. The average length, breadth and thickness were 70±8.33, 70.70±9.13 and 69.20±8.87 mm, respectively whereas the fruit is considered to be spherical-shaped fruit having sphericity and the mass of the fruit found as 0.96 and 222.9 g, respectively. The average bulk density, true density porosity and angle of repose were 0.6744 g/cc, 1.0017 g/cc and 0.3268, 5.33 degree, respectively. The fruit has less co-efficient of friction on galvanizes (0.0932). The mechanical properties *viz.,* compressive stress and shear stress were also measured as 1421.46 N and 1291.76 N, respectively. This research work on engineering properties conveys a broad area of information on wood apple fruit that can be positively recommended for design of processing equipment, storage structures, thermal processers, graders etc. and product development, beneficial to promote commercialization.

Key Words : Wood apple, Physical, Engineering properties

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Wood apple (*Feronia limonia* L.) commonly known as Kathbel (elephant apple) belongs to the family Rutaceae. Monkey fruit, curd apple, golden apple, stone apple, etc are the other common names of wood apple generally based on language, place and culture. However, Wood apple is native to India and common in dry plains of India, Ceylon, Pakistan and Sri Lanka, where it grows in the wild and is also cultivated along roads, the edges of fields and occasionally in orchards. It is also cultivated throughout Southeast Asia, particularly in Malaysia. The brown pulp has a strong smell but an excellent, slightly sour flavour when ripe, at this stage it is dark brown in colour. Wood apple was traditionally known as 'poor man's food' until processing techniques was developed in the mid-1950s (Vidhya and Kanagavalli, 2010). Wood apple is rich in acid, minerals and pectin. Wood apple pulp contains about 74% of moisture and 7.45% of carbohydrates. This fruit has great demand for medicinal purposes. In India it is a well known medicinal plant because of its several traditional known and unknown medicinal properties. In spite of above it is one of the unpopular and underutilized fruit grown in India (Khan *et al.,* 2019). Reviewing of the relevant available literature of post-harvest technology for wood apple processing and technology gap reveals that the most of the studies on wood apple are based on leaves, bark and roots for medicinal purposes. Very few studies related to pulp of the wood apple have been found. Proper and feasible technology for post-harvest processing of wood apple is still lagging. In addition, equipments for plucking, picking, cracking and scooping of pulp are needed so that processing of wood apple at commercial level can be possible. The extruded pulp further can be used for developments of various products such as concentrates, squash, jam, jelly, powder, IMF, etc. The physical and mechani-cal properties of wood apple is, therefore, have prime importance in designing, developing/fabricating of above equip-ments. There are very few studies found on physical and mechanical properties of wood apple in national as well as international level. However, various valuable studies of other fruits have been published on physical, mechanical and biochemical properties of similar fruits such as grape berry (Fava *et al.,* 2011), kiwifruit (Cangi *et al.,* 2011), peach (Ahmadi *et al.,* 2010), pomegranate (Celik and Ercisli, 2009), barberry (Celik and Ercisli, 2009a), etc. Considering the above traditional facts about the wood apple, the goal of this study was to evaluate some physical properties of wood apple necessary for designing and fabrication of various pro-cessing equipments.

Material and Methods

Freshly harvested wood apple fruit of variety CH-19 (elora) were taken from Department of Horticulture Dr. PDKV Akola Maharashtra (M.S., India). For the current research, 100 no of wood apple fruits of different sizes were used. It was ensured that the fruits were free from external defects and diseases. The mature fruits were kept at room temperature for couple of weeks so that ripening will be achieved.

Determination of engineering properties :

The engineering properties of wood apple required for the development of a wood apple cutting mechanism was studied which are listed as below.

Physical properties:

Moisture content (*M.C.*)

The moisture content of wood apple was determined by using gravimetric air oven method. The wood apple was exposed to a temperature of 180°C which was pre set in the oven. The moisture content of the sample determined by using the following eq. (Sahay and Singh, 1994).

$$\text{Moisture content, \% (wb)} = \frac{(W_2 - W_3)}{(W_2 - W_1)} \times 100 \qquad \ldots(1)$$

where, W_1 = Weight of sample box, g

W_2 = Weight of sample box with wood apple, g

W_3 = Weight of sample box and wood apple after heating in the oven, g.

Size and shape :

The size of the wood apple was measured so that the design of cleaners, graders, winnowers, etc. can be possible. In the present experiment, size of the wood apple used to design the feeder and cutting mechanism of the machine. The total 30 numbers of wood apples were taken for the experiment. The spatial dimensions of the wood apple were measured by using Vernier Calliper (Khan *et al.,* 2019).

Geometric mean diameter :

The size of the wood apple determined with the help of geometric mean of the three dimensions, *i.e.* length, breadth and thickness. To determine the geometric mean diameter of the wood apple, spatial dimensions like length (L), breadth (B) and thickness (T) measured with the help of Vernier Calliper. The geometric mean diameter (D_g) of samples determined by using the following formula (Mohsenin,1998).

$$D_g = (L \times B \times T)^{\frac{1}{3}} \qquad \ldots(2)$$

where, L = Length, mm

B = Breadth, mm

T = Thickness, mm.

Sphericity :

Sphericity is the ratio of diameter of sphere having same volume as that of the wood apple. The total 30 numbers of wood apple were taken for the experiment. The Sphericity (Sp) of wood apple was determined by using following formula (Mohsenin, 1998).

$$Sp = \frac{(l \times b \times t)^{\frac{1}{3}}}{l} \quad \ldots(3)$$

where, l = Length, mm

b = Breadth, mm

t = Thickness, mm.

Surface area :

The total surface area over the periphery of wood apple, calculated using equation given as below (McCabe *et al.,* 1986).

$$S = \pi (D_g)^2 \quad \ldots(4)$$

where, D_g is geometric mean diameter, mm.

Volume and specific gravity :

Volume of each wood apple fruit measured using water displacement method based on the Archimedes principle. Each wood apple fruit submerged in water filled in 500 cm^3 eureka container and the volume of displaced water was measured using graduated cylinder. After measuring the volume, the specific gravity of each fruit computed using the equation as below (Mohsenin,1998).

$$S_g = \frac{\text{Mass in air}}{\text{Volume of water}} \quad \ldots(5)$$

Roundness :

It is a measure of the sharpness of the corners of the sample. Total 30 number of wood apple were taken for the experiment. The following formula was used to determine the Roundness of wood apple (Mohsenin, 1998).

$$\text{Roundness} = \frac{A_p}{A_c} \quad \ldots(6)$$

where, A_p = Largest projected area of object in natural rest position, mm^2

A_C = Area of smallest circumscribing circle, mm^2.

True density :

The true density determined by using the liquid displacement method. Total 30 number of wood apple were taken for the experiment. True density of the wood apple determined by using following formula (Kachru *et al.*,1994).

$$\text{True density} = \frac{\text{Weight of wood apple (Wd)}}{\text{Displaced volume of the water (Vw)}} \quad \ldots(7)$$

Bulk density :

It is the ratio of mass to the unit volume of the sample. Bulk density is important parameter in designing of different processing machineries like separators, handling equipments, dryers, storage and transportation machineries and systems. The bulk density of wood apple was used to determine capacity of drum and collection unit of the hopper. The bulk density determined with the help of Hectoliter apparatus. A cylindrical container of known volume (1000 ml) was used. It was filled with wood apple. After that the weight of the wood apple was measured using an electronic weighing balance of an accuracy of 0.001 g. The bulk density (ρ_b) calculated as the ratio of the weight of the wood apple to its volume (Chaudhari *et al.,* 2013).

Porosity :

The per cent void of an unconsolidated mass of the materials in terms of volume is called as porosity. The porosity of wood apple determined from the values of bulk density and true density by using the following relationship (Sahay and Singh,1994).

$$\text{Porosity} = \frac{\text{True density} - \text{Bulk density}}{\text{True density}} \times 100 \quad \ldots(8)$$

Co-efficient of friction :

The co-efficient of friction is an important property which helps to estimate the lateral pressure in storage silos, design the storage bins and hopper for the gravity discharge. These properties help to know flow ability of the sample in a machine. Total 30 number of wood apple were taken for the experiment (Sunmonu *et al*., 2015).

$$\mu = \tan \theta \quad \ldots(9)$$

where,

μ = Co-efficient of friction.

α = angle of tilt in degrees.

Mechanical properties :

The mechanical properties are used to determine the compressive strength, impact force, shear resistance etc. of the sample. The mechanical properties are important while designing the milling, cutting, handling, storage, transportation and food processing equipment (Sahay and Singh, 1994). Total 30 numbers of wood apples were taken for the experiment.

Stress :

Stress is force acting per unit area which is perpendicular to the direction of force. The Universal Testing Machine (UTM) used to measure the stresses developed in the wood apple. Stresses used to determine the rupture point of the wood apple with the help of Universal Testing Machine. The Universal Testing Machine has load cell, one moving platform, PC card Monitor, a driving unit and a data acquisition system. The procedure was used for testing of sample was as follows. Initially calibration of the UTM machine was done. The sample placed on the platform underneath load cell having probe attached. Due care taken so that the sample remain firm at its position during experimentation. Then the pre-programmed UTM machine allowed moving down the load cell with probe against the sample. The observations were recorded in the software *viz.,* the force required to initiate breaking and peak force required during breaking (Divekar and Bisen, 2016).

Results and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Physical properties of wood apple :

The physical properties of wood apple were measured and the results are presented as follows.

Fruit dimension :

The dimensions of wood apple fruit were measured along three axis *viz.,* major, minor and perpendicular to minor of wood using vernier calliper. The maximum, minimum and average length of wood apple fruit was found as 90.91, 59.75 and 70.50±8.33 mm whereas the maximum, minimum and average fruit's breadth was obtained as 89.46 51.8 and 70.70±9.13 mm, respectively. And the maximum, minimum and average value of the thickness of wood apple fruit was observed as 89.37, 51.62 and 69.20 ± 8.87 mm, respectively. Similar results were reported by Khan *et al.* (2019).

Wood apple dimensions such as length, breadth and thickness were correlated with the weight of the fruit and it was found that the correlation between dimension and fruit weight is satisfactory. The values of co-efficient of determination (R^2) found as 0.814, 0.813 and 0.829 for length (a), breadth (b) and thickness (c), respectively given in Fig.1 (a). Physical properties of wood apple fruit evaluated in this research have been given in (Table 1).

Arithmetic mean diameter and geometric mean diameter :

It was observed that the value of maximum, minimum and average arithmetic mean diameter of wood apple fruit was found as 89.91, 54.39 and 71.47±8.62 mm whereas the maximum, minimum and average geometric mean diameter was 89.91, 54.26 and 71.41±8.63 mm, respectively. The arithmetic mean diameter and geometric mean diameter values were correlated with the fruits weight and the co-efficient of determination of both (arithmetic mean diameter and geometric mean diameter) was found as 0.848. The comparison between arithmetic mean diameter and

Table 1 : Physical properties of wood apple

Particular	Sample size	Minimum	Maximum	Average	STD (±)	CV
Length (mm)	30	59.75	90.91	70.50	8.33	11.17
Breadth (mm)	30	51.8	89.46	70.70	9.13	12.90
Thickness (mm)	30	51.62	89.37	69.20	8.87	12.83
GMD (mm)	30	54.26	89.91	71.41	8.63	12.09
AMD (mm)	30	54.39	89.91	71.47	8.62	12.06
Sphericity (%)	30	0.893	0.995	0.957	15.55	18.68
Weight (g)	30	97.3	411	222.99	74.32	33.32
Volume (cm^3)	30	77	415	206.66	79.18	38.31
Sp. Gravity (g/mm^3)	30	0.820	1.34	1.100	0.10	9.21
Moisture content of shell, % (w. b.)	3	50.12	54.11	52.63	1.65	3.15
Moisture content of pulp, % (w. b.)	3	74.89	75.31	75.13	0.18	0.023

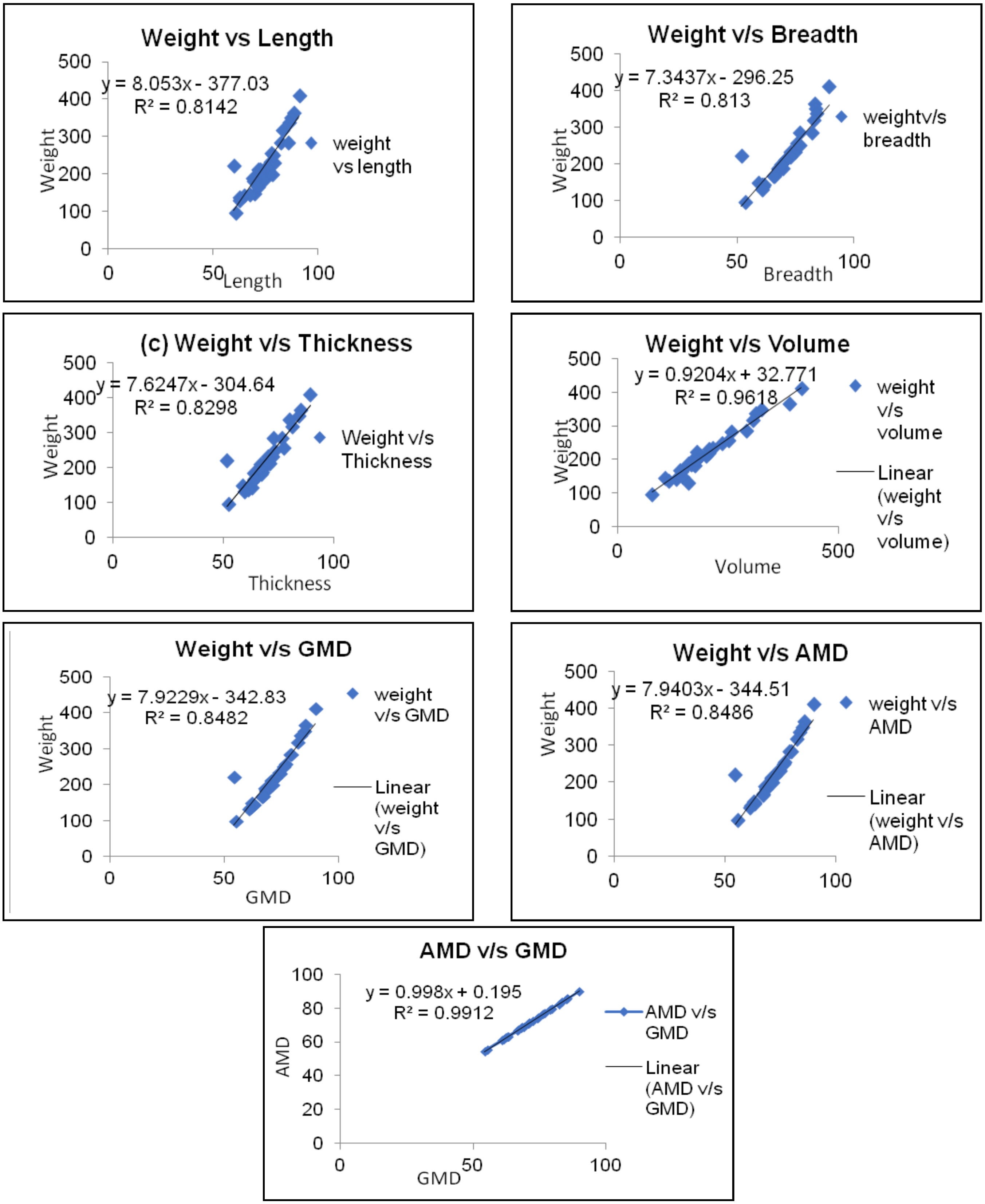

Fig. 1 : **Correlation between length (a), breadth (b), thickness (c), volume (d), AMD (e) and GMD (f) of fruit with the weight of the wood apple (g) Correlation between AMD and GMD**

geometric mean diameter was evaluated using regression model. The result obtained and the best fit of data with co-efficient of determination 0.9912 as given in Fig. 1.

Sphericity :

The sphericity was found in the range of 0.89 to 0.99 with the average value calculated as 0.95±15.55. The sphericity is near to one indicates that the fruit is oval to round in shape and can easily roll or slide on flat smooth surface.

Weight and volume :

The average values of weight and volume were found as 222.99±74.32g and 206.66±79.18 cm^3, respectively. Maximum weight of the wood apple was recorded as 411 g having volume of 415 cm^3. The weight and volume values are recorded at average moisture content of wood apple fruit as 75.13 %. The co-efficient of variation for weight and volume estimated as 33.32 % and 38.31 %, respectively.

Specific gravity:

The specific gravity of wood apple calculated, the maximum, minimum and average specific gravity of wood apple was found as 1.34, 0.820 and 1.10±0.10, respectively.

Moisture content :

The moisture content of wood apple measured using hot air oven. The temperature set in the oven at 180°C for 6 h. The measurements were replicated thrice and the average moisture content of wood apple shell as 52.63±1.65 % (w.b) and wood apple pulp mixture was determined as 75.13±0.18 % on (w.b), respectively. The moisture content is directly related to fruit weight. The moisture content helps in predicting fruit maturity; the immature fruit has more weight and greenish in colour compared to mature fruit which is relatively low in weight and brownish in colour.

Gravimetric properties :

Bulk density and true density :

Bulk density and true density of wood apple were determined. The process was replicated thrice and the average true density and bulk density was calculated as 1.0017 and 0.6744 g/cc, respectively. The average porosity of wood apple determined as 32.67 %.

Angle of repose :

The angle of repose of the wood apple was measured using the friction apparatus. As the wood apple is oval to round in shape, it can easily roll on plane surface. The average value for angle of repose of wood apple was found to 5.33 degree.

Mechanical properties of wood apple :

The mechanical properties includes compressive and shear stress. The results of compressive stress and shear stress are discussed as follows.

Compressive stress :

The compressive stress of matured wood apple was measured using an Universal Testing Machine. The compressive stress obtained in the range of 213.67 N to 2600.86 N. The average compressive stress of matured wood apple fruit obtained as 1421.72±710.58 N.

Shear stress :

The shear stress of matured wood apple fruit was in the range of 764.601 N to 1733.83 N whereas the average shear stress of matured wood apple fruit obtained as 1296.84±295.67 N. The obtained value of shear stress was higher compared than the value of compressive stress.

Conclusion:

Physical characteristics of wood apple were evaluated in this work. The average length, breadth and thickness were 70±8.33, 70.70±9.13 and 69.20±8.87 mm, respectively. The average sphericity and weight found as 0.9578 and 222.9 g, respectively. The average bulk density, true density and porosity, angle of repose and co-efficient of friction were 0.6744 g/cc, 1.0017 g/cc and 0.3268, 5.33 degree, 0.09329, respectively. The mechanical properties *viz.,* compressive stress and shear stress were measured as 1421.46 N and 1291.76 N, respectively. Finally, this research concluded that the parameters discussed in this work have very crucial role

Table 2 : Mechanical properties of wood apple

Sr. No.	Property	Average	STD (±)	CV
1.	Compressive stress (N)	1421.46	710.58	49.98
2.	Shear stress (N)	1291.76	295.67	22.88

in designing and developing of machine/equipments for sorting, grading and processing of agricultural produces. This research, thus, explored the knowledge of valuable physical parameters of wood apple which are prime and foremost important to make it popularize at commercial level through mechanical application in processing plants.

REFERENCES

Ahmadi, E., Ghassemzadeh, H.R., Sadeghi, M., Moghaddam, M. and Neshat, S.Z. (2010). The effect of impact and fruit properties on the bruising of peach. *J. Food Engin,* **97** : 110-117.

Cangi, R., Altuntas, E., Kaya, C. and Saracoglu, O. (2011). Some chemical and physical properties at physiological maturity and rip-ening period of kiwifruit ('Hayward'), *African J. Biotechnol.,* **10** : 5304-5310.

Celik, A. and Ercisli, S. (2009). Some physical properties of pomegran-ate cv. Eksinar. *Int Agrophysics,* **23** : 295-298.

Chaudhari A. P., Thakor, N.J., Sonawane, S. P. and Sawant, A. A. (2013). Physical properties of cashew nut shells, *Internat. J. Agric. Engg.,* **6** (1) : 254–260.

Divekar, S.P. and Bisen, R.D. (2016). Engineering properties of locally available mango stone, *Internat. J. Appl. & Pure Sci. & Agric.,* **2** (12) : 121-130.

Fava, J., Hodara, K., Nieto, A., Guerrero, S. and Alzamora, S.M. (2011). Structure (micro, ultra, nano), colour and mechanical properties of *Vi-tis labrusca* L. (grape berry) fruits treated by hydrogen peroxide, UV–C irradiation and ultrasound, *Food Res. Int.,* **49** : 2938-2948.

Khan, M.A., Ashraf, M., Singh, K., Patel, K.K. and Siddiqui, M. (2019). Effect of storage on quality parameters of wood apple (*Feronia limonia* L.)- Lemon (*Citrus limon*) Squash, *Res. J. Food. Nutri.,* **3** : 18-27.

Khan, M.A., Singh, K., Patel, K.K. and Siddiqui, M. (2019). Some physical properties of wood apple (*Feronia limonia* L.), *Recent Advancement in Food Science & Nutrition Research*, pp. 79-86.

Kachru, R. P., Gupata, R. K. and Alam, A. (1994). *Pysico-chemical constituent and engineering properties of food crops,* Scientific Publishers, New Delhi, India, pp. 41-85.

McCabe W.L., Smith, J.C. and Harriot, P. (1986). *Unit operations of chemical engineering*, McGraw Hill, New York, U.S.A.

Mohsenin, N.N. (1998). *Physical properties of plant and animal materials,* Gordon Breach Press, London-New York. 113-145 pp.

Sahay, K.M. and Singh, K.K. (1994). *Unit operation of agricultural processing* (II[nd] Ed.), Vikas Publication House Pvt. Ltd., New Delhi, India, pp. 6-15.

Sunmonu, M.O., Iyanda, M.O., Odewole, M.M. and Moshood, A.N. (2015). Determination of some mechanical properties of almond seed related to design of food processing machines, *Nigerian J. Technological Development,* **12**(1) : 22-26.

Vidhya, R., Jayanthi, M. and Kanagavalli, U. (2010). Protective effect of captopril against cisplatin induced nephrotoxicity in rats. *Pharmacol online,* **21**: 112-115.