

## Research Article

# Some Physical Properties of Wood Apple (*Feronia Limonia L.*)

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## Abstract

Wood apple, traditionally known as poor man's food, is native to India and traditionally has great demand for medicinal purposes. 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. Physical properties (length, breadth, thickness, arithmetic mean diameter (AMD), geometric mean diameter (GMD), specific gravity, aspect ratio, pulp and peel content, etc) are necessary and important for fabrication/designing of such processing equipments. The mean values of length, breadth, thickness, arithmetic mean diameter (AMD), geometric mean diameter (GMD), specific gravity, aspect ratio and pulp/peel ratio, etc. were evaluated as 72.3mm, 66.03mm, 56.09mm, 65.09mm, 64.65mm, 89.7%, 91.78% and 2.314, respectively, in this study. High value of sphericity (found between 74.3 and 99.7%) indicates that the wood apple fruit might follow the combination of rolling and sliding action on their flat surfaces. But, the high aspect ratio of 109.62 % indicates that wood apple will rather roll than slide on their flat surfaces. Similarly, the colour values (L, a, b, hue, chroma and total colour change) of raw and ripe fruits and area (Jean & Ball and McCabe) of wood apple were also evaluated. In addition, fruit's weight was also correlated with some physical parameters of wood apple for direct estimation of properties. But, the value of coefficient of determination ( $R^2$ ) showed the unsatisfactory fit of the data. This study, thus, could be the basis to provide fundamental knowledge for commercial level design of machines for post-harvest processing of wood apple.

## Keywords

Hunter Color; Physical Properties; Regression; Wood Apple

## Introduction

Wood apple (*feronia limonia*) 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. For instance, in Malaysia it is called gelinggai or belinggai, in Thailand ma-khwit, in Cambodia kramsang, in Laos ma fit, in French, it is called pommed' elephant, pommede bois or citron des mois [1]. 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 [2]. 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 [3].

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 which are meagre. Proper and feasible technology for post-harvest processing of wood apple is still lagging. In addition, equipment's for plucking, picking, cracking and for removing of pulp are also needed to develop for processing of wood apple at commercial level. The technique or equipment for juice extraction from the

pulp of wood apple are also would be importance during the developments of various type of product such as concentrates, squash, jam, jelly, powder, IMF, etc. The physical and mechanical properties of wood apple is, therefore, have prime importance in developing/fabricating or designing of above discussed equipment's. But there is no study has been found based 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 based on physical, mechanical and biochemical properties. For instance, grape berry [4], kiwifruit [5], peach [6], pomegranate [7], barberry [8], persimon [9], apricot [10], guna fruit [11], aonla [12], myrtle [13], fresh oil palm [14], strawberry [15], tomato [16], peach, nectarines, plums [17], cidar apple [18], Orange [19], pear [20], 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 its processing equipments. Consequently, the extraction of nutritional and medicinal value of wood apple, so that, become easier.

## Material and Methods

Fresh harvested wood apple fruit were procured from the local market of Hardoi districts of Uttar Pradesh (U.P., India). For the current research, 250 no of wood apple fruits of different sizes were used. It was ensured that the fruits were free from external defects and diseases during procurement. However, the fruit's maturity was not ensured during the procurement. Hence, to confirm their maturity/immaturity, fruits were dropped on the solid surface (cemented floor) from a height of 30 cm (1 foot) at ambient temperature. Immature fruits were bounced back while the mature fruits did not. After confirmation of their maturity, selected matured fruits were kept in the sun light for 10-14 days to fully ripen [1].

## Determination of Physical Properties

Linear dimensions of selected samples, i.e. length (a), breadth (b) and thickness (c) were measured using a digital vernier calipers (model no CD-6" CSX, Mitutoyo-Japan) having least count of 0.01 mm. Arithmetic mean diameter ( $D_a$ ) and size of wood apple in terms of geometric mean diameter ( $D_g$ ) were calculated using equation (1) and (2), respectively [2]:

$$D_a = \frac{a+b+c}{3} \quad (1)$$

$$D_g = (abc)^{1/3} \quad (2)$$

Where; a = longest intercept; b = longest intercept normal to a; c = longest intercept normal to a and b.

## Sphericity and Aspect Ratio

The sphericity ( $S_p$ ) and aspect ratio ( $R_a$ ) of fruits were computed using equation given by Mohsenin [21] and Maduako and Fabrocode [22] as below:

$$S_p (\%) = \frac{\text{Geometrical mean diameter}}{\text{Longest intercept}} \quad (3)$$

$$R_a (\%) = \frac{100 \times \text{Breadth}}{\text{Longest Intercept}} \quad (4)$$

## Surface Area

Surface area (S), the total area over the outside of wood apple, was theoretically calculated using two equations (5) and (6) given by Jean & Ball (1997) and McCabe *et al.* [23], respectively:

$$S_1 (\text{McCabe}) = \pi(D_g)^2 \quad (5)$$

$$S_2 (\text{Jean\&Ball}) = \pi \frac{Ba^2}{2a-B} \quad (6)$$

Where B = (ab)<sup>0.5</sup> and D<sub>g</sub> is geometric mean diameter

## Volume and Specific Gravity

Volume of each wood apple fruit was measured using water displacement method based on the Archimedes principle. Each wood apple fruit was submerged in a 500 cm<sup>3</sup> eureka container and the volume of water displaced was measured using graduated cylinder. Water temperature during measurements was kept at 25°C. After measuring the volume, the specific gravity of each fruit was computed using the equation (7) as below:

$$S_g = \frac{\text{Mass in air}}{\text{Volume of Water}} \quad (7)$$

Pulp content, peel content and the pulp to peel ratio of wood apple fruit were also calculated by using an electronic balance.

## Colour Values of Wood Apple Pulp

In addition, colour values ('L', 'a' and 'b') of wood apple pulp were also determined with the help of Hunter Lab Mini Scan XE plus colorimeter (HAL, USA, model 45%-L). The 'L' colour value measures lightness/darkness (100 for perfect white to zero for black) of product, a-value measures redness when positive; grey when zero; and greenness when negative and b-value, similarly, measures yellowness when positive; gray when zero; and blueness when negative in the Hunter scale. Before, analysis the colour values, the colorimeter was calibrated with standard black and white calibration tiles provided with the instrument and displayed values were matched with the values reported in the operating manuals. The total colour change ( $\Delta E$ ), chroma and hue angle were calculated from the Hunter 'L', 'a', and 'b' values using Eq. (8), Eq. (9) and Eq. (10).

$$\Delta E = \sqrt{(L_o - L_r)^2 + (a_o - a_r)^2 + (b_o - b_r)^2} \quad (8)$$

Where, L<sub>o</sub>, a<sub>o</sub>, b<sub>o</sub> are the color values of matured raw wood apple and L<sub>r</sub>, a<sub>r</sub>, b<sub>r</sub> are the color values of matured ripe wood apple

$$\text{Chroma} = (a_r^2 + b_r^2)^{0.5} \quad (9)$$

$$\text{Hue Angel} = \tan^{-1} \left( \frac{b_r}{a_r} \right) \quad (10)$$

## Data Analyses

All experiments were carried out in triplicate. Experimental data obtained were statistically analyzed using SPSS software (version 16). The maximum, minimum and coefficient of variation (CV) were obtained using Microsoft Excel (2007) software.

## Result and Discussion

### Fruit's Dimension

Physical properties of wood apple fruit evaluated in this research have been given in (Table 1). Value of maximum, minimum and average length of wood apple fruit was found to be 87.34, 56.87 and 72.35 mm while the value of maximum, minimum and average fruit's breadth was obtained as 78.52, 54.34 and 66.03 mm, respectively. From table 1, it is also evident that the maximum, minimum and average value of thickness of wood apple fruit was 68.95, 41.06 and 56.90 mm, respectively.

The difference among the length, breadth and thickness dimension of wood apple is not much. *Mohsenin* [21] and *Omobuwajo et al.* [24] have discussed the importance and various applications of these dimensions of fruit in fabrication and designing of equipment's. Among them (applications), in determining aperture size of machines, particularly in separation of materials have been discussed. It may be useful in estimating the number of fruits to be engaged at the time separation, the spacing of slicing discs and number of slices expected from the average fruit. The major axis has been found to be indicating the natural rest position of the material and hence in the application of compressive force to induce mechanical rupture. This dimension will also be useful in applying shearing force during slicing

[25]. Fruit dimension length (L), breadth (B) and thickness (T) were correlated with the weight of fruit and found that the correlation between dimension and fruit weight is not satisfactory. The values of coefficient of determination ( $R^2$ ) were found to be 0.45, 32 and 0.17 for length (a), breadth (b) and thickness (c), respectively (Figure 1). Only 45% variation in fruit's weight can be explained using regression model based on fruit's length, which shows least fit of the data.

### Weight and Volume

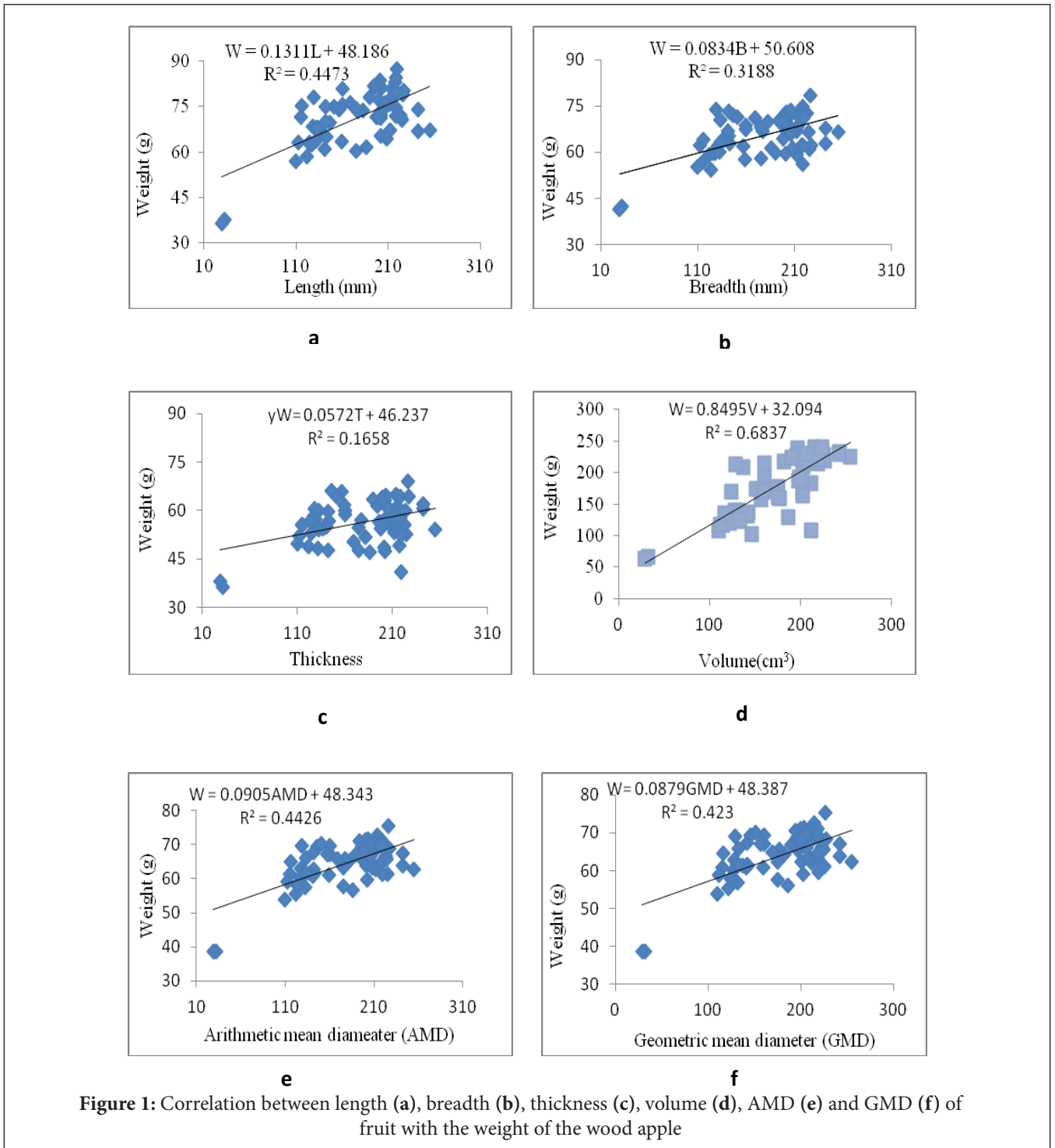
From the table 1, it is evident that the average weight and volumes of wood apple were recorded as  $181.02 \pm 21.66$ g and  $182.22 \pm 23.44$ cm<sup>3</sup>, respectively. However, wood apple recorded with maximum weight was 255.00g and volume of 240.00cm<sup>3</sup>. The variability in weight and volume were noticed maximum than the other attributes. Coefficient of variations in weight and volume was computed as 21.66% and 23.44%, respectively. The importance of analysis of weight and volume is in easy computation of fruit density which is a useful measure for identifying the presence of hidden defects such as frost-damage and internal damage caused by insects. Such a system would be useful, for example, for oranges, the eating quality of which is related roughly proportionally to the density of the fruit [26]. A regression model was also developed between fruit's weight and Volume (Figure 1d) and found that about 68% variation in fruit weight/volume can be explained by volume/weight of fruit.

### Size or AMD and GMD

Table 1 displays the mean values of AMD (65.09 mm) and GMD (64.65mm) of wood apple fruits. The coefficient of variability in fruits geometric mean diameter and arithmetic mean diameter

Attributes	No of fruits	Minimum	Maximum	Average	STD (±)	CV	
Length (mm)	100	56.87	87.34	72.35	6.95	9.61	
Breadth (mm)	100	54.34	78.52	66.03	5.56	8.42	
Thickness (mm)	100	41.06	68.95	56.9	10.16	17.85	
Weight (g)	100	110	255	181.02	39.21	21.66	
Volume (mm <sup>3</sup> )	100	103	240	185.67	43.52	23.44	
SG (g/mm <sup>3</sup> ) (Raw)	50	0.46	0.916	0.794	0.139	17.5	
SG (g/mm <sup>3</sup> ) (Ripe)	100	0.914	1.963	1.053	0.169	16.1	
AR (%)	100	66.61	109.62	91.78	8.62	9.39	
Sphericity (%)	100	74.3	99.7	89.7	5.6	6.25	
GMD (mm)	100	53.85	75.36	64.65	4.52	7	
AMD (mm)	100	53.94	75.51	65.09	4.53	6.96	
Area (mm <sup>2</sup> )	(Jean & Ball)	250	8676.23	17081.89	1741.17	12166.58	14.311
	(McCabe)	250	9106	17833.8	1829.03	13190.11	13.86
Pulp (g)	150	63.02	181.12	126.98	29.72	23.4	
Peel (g)	150	35.36	77.6	55.48	10.53	18.99	
Pulp/peel (%)	150	1.32	3.71	2.314	0.53	23	

**Table 1:** Some physical properties of wood apple fruit.



of wood apple is noticed as 7% and 6.96% with their standard deviation 4.52 and 4.53. As the figure 2 indicates, the average diameter calculated by the arithmetic mean and the geometric mean formulas were almost same, either, AMD or GMD of wood apple fruits can be used to calculate the equivalent diameter of wood apple fruits during consideration and fabrication of processing equipment. However, for the better results, success and to avoid failure of equipment's, should use mean diameter which has larger value. The comparison between AMD and GMD were also assessed using regression relationship analysis method and obtained correlation coefficient between them showed the best

fit of data (Figure 2). Further, the AMD and GMD are correlated with the fruits weight. The coefficient of determination of both parameters (AMD and GMD) was found almost same (Figure 1 e, 1f) similar to fruits length and weight model (Figure 1 a).

### Sphericity and Aspect Ratio

To analyze the wood apple fruit whether roll or slide on their flat surfaces, the knowledge of aspect ratio is important. If the value of the aspect ratio is being close to the value of sphericity, the fruit will undergo a combination of rolling and sliding action



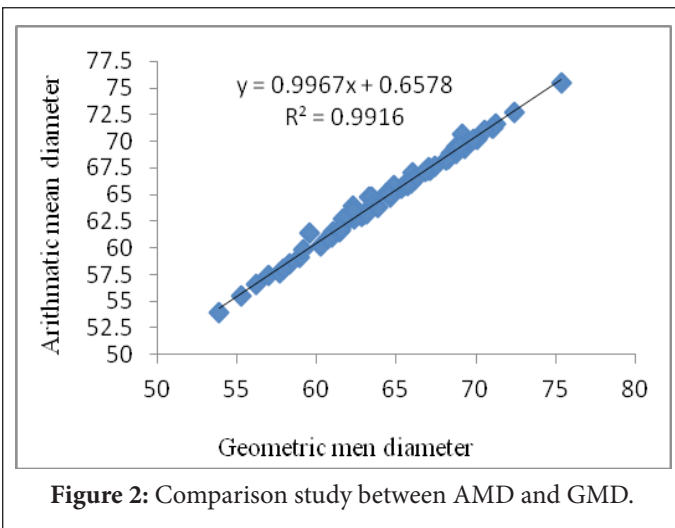


Figure 2: Comparison study between AMD and GMD.

on their flat surfaces [27]. The average value of sphericity and aspect ratio of wood apple (Table 1) were computed as 89.7% and 91.78%, respectively. High sphericity of the wood apples is indicative of the tendency towards a sphere. In addition, these values also indicated that the wood apple fruit might follow the combination of rolling and sliding action on their flat surfaces. The high aspect ratio (which relates the fruit width to length) of 109.62%, may be deduced that wood apple will rather roll than slide on their flat surfaces. However, the value of aspect ratio (91.78%) was found to be close to the sphericity (89.7%) value may also mean that the wood apple fruit will undergo a combination of rolling and sliding action on their flat surfaces.

### Specific Gravity

Specific gravity (SG), which is an expression of density, is the most widely accepted measurement of fruits quality. Table 1 shows, minimum (0.914), maximum (1.960) and average (1.05) value of specific gravity of ripened wood apple fruit. In contrast, the minimum (0.460), maximum (0.916) and average (0.794) value of specific gravity of raw wood apple was found lower in comparison to ripened fruits. However, the variability in specific gravity of both raw and ripe fruits was found almost similar i.e. 17.5% and 16.1%, respectively.

As, fruit's specific gravity is directly related to the internal characteristics (dry matter, soluble solids or physical disorders). Being a source of several medicinal values, the importance of analysis of the specific gravity of wood apple increased more. And, in this work it is revealed that the specific gravity of fully ripped wood apple is higher. In addition, specific gravity has been used as basis for the grading of mango and potato at commercial level [28]. The specific gravity of mango [29], dragon fruit [30], apple, feijoa, grape [31], tomato, kiwifruit and avocados has also been investigated for their grading purposes.

### Surface Area and Pulp/Peel Content

Surface area of wood apple was computed by using Jean & Ball and MaCabe equation. Maximum surface area was recorded by MaCabe method was 17833.8 mm<sup>2</sup> and similarly by Jean & Ball,

the maximum value computed was 17081.9mm<sup>2</sup>. Almost similar results were given by both methods. Thus, both methods can be used interchangeably for the calculation of surface area of wood apple.

Further, the edible portion of wood apple was calculated by evaluating peel and pulp content. The average, minimum and maximum pulp content in wood apples (150 ripe) was computed as 126.98±29.7g, 63.02g and 181.12 g while the peel content of wood apples was also computed as 55.48±10.3g, 35.36g and 77.60 g. The both pulp and peel content found to be varied fruit to fruit with the coefficient of variation 23.40% and 18.99%, respectively. Similarly, the pulp to peel ratio was found to be varied as 23.00% and average pulp to peel ratio was recorded as 2.314±0.53 when both ripe and raw wood apple fruit were considered in combination. The pulp to peel ratio in the matured ripe wood apple varied between 1.96 and 3.71 while in raw it was found between 1.33 and 2.08.

Thus, it can be concluded that the rawness (immaturity) level of the wood fruit can also be assessed on the basis of value of pulp to peel ratio. Since, if there is less pulp to peel ratio in fruit, it is immature. In contrast, higher the pulp to peel ratio content indicates good maturity level of the fruit. Furthermore, during the experimentation it was found that if any fruit had pulp to peel ratio more than 3.20, it was over mature.

### Color Values of Wood Apple Pulp

The whiteness or brightness/darkness (L value), redness/greenness (a value) and yellowness/blueness (b value) of wood apple pulp when immature and mature are presented in table 2.

This study reveals that the lightness of pulp of ripe-matured fruit (21.1±6.38) was lower than the raw fruit (24.81±4.78). It means that as the fruit's maturity prolonged, the brightness/darkness (L value) of wood apple pulp decreased. But, this reduction in the 'L' values was slight. Similarly, the yellowness/blueness (b-value) and hue values of pulp of ripe matured wood apple fruit were found slightly lower than the pulp of raw fruit. The change in 'b' value may be due to the decomposition of chlorophyll and carotenoids pigments, non-enzymatic Maillard browning, and formation of brown pigments. Further, the hue angle of 0 or 360° represents red hue, while angles of 90, 180 and 270° indicate yellow, green and blue hues, respectively [32]. Here the hue angles of raw and ripe wood apple pulp are about 67° and 58° yellowish-red predominantly yellowish. The hue angle shifts toward redness after ripening. In contrast 'L' and 'b' values, the redness (a-value) and the chroma of ripe wood apple pulp were found to be little higher than that of raw fruit. Chroma indicates color saturation and it is proportional to color's intensity or purity [32]. The average total colour change of fruits at maturity/ripe with respect to the immature/raw was found as 6.69 (Table 2).

### Conclusion

Physical characteristics of wood apple were evaluated in this work. The average values of length, breadth, thickness, weight, volume, arithmetic mean diameter, geometric

Attributes	Raw/Ripe WA	No of fruits	Minimum	Maximum	Average	STD (±)	CV
L	Raw	50	19.17	28.41	24.81	4.78	19.27
	Ripe	100	13.16	25	21.11	6.38	30.24
a	Raw	50	2.84	4.44	3.76	0.82	21.35
	Ripe	100	2.81	6.17	5.03	1.78	35.39
b	Raw	50	6.78	10.12	8.64	1.72	19.66
	Ripe	100	4.89	9.26	7.78	2.33	29.95
Chroma	Raw	50	7.35	11.03	9.42	-	-
	Ripe	100	5.64	11.13	8.96	-	-
Hue angle (°C)	Raw	50	63.01	67.31	66.58	-	-
	Ripe	100	56.35	60.15	57.88	-	-
ΔE		150	3.13	16.22	6.69	-	-

**Table 2:** Colour values of pulp (raw/ripe) of wood apple fruit.

mean diameter and specific gravity of wood apple fruit were found to be 72.3±6.95mm, 66.03±5.56mm, 56.90±10.16mm, 181.02±39.21gm, 185.67±43.52mm<sup>3</sup>, 65.09±4.53mm, 64.65±4.52mm, 0.79±0.14/1.05±0.17 (raw/ripe) g/mm<sup>3</sup>, respectively. Similarly, the average values of wood apple's sphericity, aspect ratio and pulp/peel ratio were also evaluated as 89.7±5.6%, 91.78±8.62% and 2.314±0.53, respectively. This research explored, that the maturity level of wood apple can be predicted on the basis of pulp/peel ratio and specific gravity. Finally, this research concluded that the parameters discussed in this work have very crucial role in designing and developing of machine/equipment's 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.

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