ISSN: 2347-467X, Vol. 5, No. (3) 2017, Pg. 214-222

Current Research in Nutrition and Food Science

Journal Website:www.foodandnutritionjournal.org

Physico-Chemical, Mechanical and Antioxidant Properties of *Kendu* (*Diospyros melanoxylon Roxb.*)

BABY ZAITHANPUII HMAR, SABYASACHI MISHRA* and RAMA CHANDRA PRADHAN

Department of Food Process Engineering, National Institute of Technology, Rourkela, Odhisa,796008, India.

Abstract

Kendu (*Diospyros melanoxylon Roxb.*) is considered to be a minor forest produce (MFP) in India. The *Kendu* plant is grown in plenty all over the eastern parts of India for commercialization of its leaves for making *bidi*, a traditional cigarette. However, most of the harvest goes waste as the fruit has never been explored for its nutritional aspects. Proper processing techniques need to be developed for value-addition of *Kendu*. The physico-chemical, mechanical, antioxidant properties and, mineral composition of the Kendu fruit were investigated. The fruit is of spherical shape with average sphericity, volume and surface area values of 0.97±0.02, 25.25± 1.37 cm^3, and 40.30±1.55 cm^2, respectively. The average moisture content of pulp was 66.17±1.84 % (db.). The energy value of the pulp was 491.75±2.0 KJ. Hardness of the fruit in axial direction was 9.5±1.85 N. Total phenolic content (TPC), 2, 2-diphenil-1-picrylhydrazyl (DPPH) activity and ferric reducing ability in plasma (FRAP) values of fruit were high. Mineral such as potassium, calcium and phosphorus were present in high concentration. Various physico-chemical and mechanical properties found can be used in designing proper equipment for value-addition of the fruit. The data on antioxidant properties suggests the nutritional importance of *Kendu* fruit.

Article History

Received: 09 September 2017
Accepted:18 December 2017

Keywords

Kendu,
Properties,
Physico-chemical,
Mechanical,
Antioxidant.

Introduction

Kendu (*Diospyros melanoxylon Roxb.*) fruit is consumed by the local tribes in different traditional forms such as pulp, paste, powder and fruit wine. It belongs to Ebenaceae family and Diospyros species. It is native to India and Sri Lanka[1,2]. It is also available in Philippines, Japan, China, and Thailand. Its trade name is *ebony, tendu/kendu* and is also called as coromandel ebony and contributes to socio-economic livelihood of tribal people in India[3,4].

Kendu is a seasonal fruit available mainly in summer during May and June[5]. The leaf, bark and fruit of the *Kendu* plant have also been used for traditional medicines[6,7]. The leaves are commonly used for making bidis (an indigenous traditional cigarette,

CONTACT Sabyasachi Mishra mishrasa@nitrkl.ac.in Department of Food Process Engineering, National Institute of Technology, Rourkela, Odhisa,796008, India.

To link to this article: http://dx.doi.org/10.12944/CRNFSJ.5.3.05

which uses the *kendu* leaf for rolling instead of paper)[8-9].The fruit has a pleasant and sweet taste when fully ripen. The fruits are gathered by the tribes in summer and are dried and stored for use in off-season. *Kendu* fruit is globose in shape with 3-4 cm diameter (Fig. 1). It usually contains 3 to 4 seeds which are brown in colour, compressed and oblong in shape[10,11]. The plant is distributed all across the Indian states of Bihar, Madhya Pradesh, Chhattisgarh, West Bengal, Odisha, and Jharkhand[9,12-14]. There are many nutritional use of various parts of this plant starting from leaves, fruits, bark and seeds. Leaves are used as styptic, in the treatment of scabies and old wounds, and as laxative and carminative medicine[7]. *Kendu* fruit also helps in stomach disorders. The dried fruit powder is used as carminative and astringent agent and is useful in treating urinary, skin and blood diseases. This may be attributed to high tannin content (15-23 %) of the fruit[12]. *Kendu* bark also contains various steroids, alkaloids, glycosides, proteins, phenolic compounds and tannins[4,5].

However, due to lack of proper processing techniques and consumer awareness on its nutritional aspects, most of the fruits are goes wasted and are forced to be utilised in a non-economical way[3,4]. There is a dearth of scientific literatures on the chemical and nutritional aspects of *Kendu* fruit. The information on the physico-chemical, textural and nutritional properties of Kendu would add to the scientific knowledge base. These information can be used for developing suitable techniques and practices for post-harvest management and processing of the fruit.

Fig.1: *Kendu* fruit

Materials and Methods

Sample Preparation

Kendu fruits were procured from local market of Rourkela (22°14′57″N, 84°52′58″E), Sundergarh, Odisha, India for further analysis of various physico-chemical, textural and nutritional properties. The average initial moisture content was determined by hot air oven method following AOAC,2000 protocols[15]. The fruits were weighed using an analytical balance (WENSOR, Model No: IND/09/08/558) with least count of 0.001g.

Physical Properties

Principle dimensions of fruit such as length (L) i.e. axial ends, and diameter (D) i.e. radial end, were measured using digital vernier calliper having a least count of 0.01cm. The principal dimensions were used to calculate the arithmetic (D_a) and the geometric (D_g) mean diameters. Sphericity (ϕ) and surface area (SA) were computed using the following relations that are previously used for spherical fruits[16];

$$D_a = (L + D) / 2 \quad ...(1)$$

$$D_g = (L\ D^2)^{1/3} \quad ...(2)$$

$$SA = \pi\ (L^{2/3} \times D^{4/3}) \quad ...(3)$$

The fruits were divided into three categories based on its size (i.e. Arithmetic mean X) satisfying the following conditions;

$$\text{Small: } X < X - \sigma \quad ...(4)$$

$$\text{Medium: } X - \sigma < X < X + \sigma \quad ...(5)$$

$$\text{Large: } X > X + \sigma \quad ...(6)$$

Where, X and σ are the experimental value and standard deviation, respectively[17-19]. The porosity (e) of bulk fruit was computed from the values of true density (ρ_b) and bulk density (ρ_t) using the relationship given as below[20];

$$e = \rho_t - \rho_b / \rho_t \times 100 \quad ...(7)$$

Angle of repose of the whole fruit was determined using the formula[20];

$\theta = \tan^{-1} (2H / D)$ ...(8)

Where, H is the height of the cone and D is the diameter of circular plate of apparatus.

Angle of inclination of the fruit was measured on three different surfaces such as plywood, aluminium and mild steel sheet .The measurements were made in two directions (radial and axial) with respect to calyx end and static coefficient of friction of whole fruit was determined from the following relationship[16];

$\mu = \tan \alpha$

Where, μ is the Static coefficient of friction and α is the angle of tilt in degree.

Colour of the fruit was measured using colorimeter (Flex EZ, Hunter Lab, USA). Fruit skin colour measurements were taken along the equatorial axis of each fruit. Readings of each colour index in the Hunter scale (L, a, b) were taken per fruit with three replications. The colour values represented whiteness or brightness/darkness (L), redness/ greenness (a) and, yellowness/blueness (b).

Mechanical Properties

Mechanical properties were measured using a texture analyser (CT3, Brookfield, USA) with a 6 mm diameter stainless steel probe (TA-41) and a 10 kg load cell. Insertion of probe through the surface, was taken as the surface hardness (N) of the fruits. Average force recorded by the probe is presented as pulp firmness (N) i.e. the energy (N/mm) required to pass the probe through the sample was measured[16-18].The operating conditions such as pre-test speed (0.5 mm/s), post-test speed (0.5 mm/s) and trigger load (0.05 N) were fixed.

Chemical Properties

Proximate Composition

Proximate parameters of the sample such as moisture, ash, crude protein and fibre, fat, ascorbic acid and, carbohydrate, were determined using AOAC, 2000[15]. Total soluble solids (TSS, °Brix) was determined using a temperature compensating hand-held refractometer (ERMA Inc., Japan). Titratable acidity (TA) was expressed as percent citric acid. Total sugar was determined by spectrophotometric method at 630 nm using anthrone reagent[21]. Reducing sugar was analysed by using 3, 5-Dinitrosalicylic acid (DNS) method[22]. The energy value (E in KJ/100g) of the kendu pulp was measured using the following empirical formula[23]. All measurements were in triplicate using analytical grade reagents.

E = [(% CH X 17) + (% P X 17) + (% F x 37)] ...(10)

Where, CH, P and F represents available carbohydrate, protein and fat content, respectively.

Antioxidant Content

Total Phenolic content (TPC) was determined using Double Beam UV-VIS Spectrophotometer, (AU 2701, Systronics, India) by Folin-Ciocalteu reagent (FCR) method[24]. The carotenoid (*Beta-carotene*) content of fruits was measured in 85 % acetone extract of the fresh sample [34]. *2, 2-diphenil-1-picrylhydrazyl (DPPH) radical scavenging activity* was determined using DPPH with slight modifications[25]. Ferric reducing ability in plasma (FRAP) activity was measured by standard UV-spectrophotometry[26] with absorbance measured at 595 nm wavelength.

Mineral Content

The minerals (Ca, P, Mg, Fe, Zn, Na, Pb, and Cu) were analysed by atomic absorption spectrophotometry (AAS Analyst 200, Perkin Elmer, USA) by wet digestion method. Potassium (K) was analysed by the spectrophotometer method using ammonium molybdate solution[27,28]. All mineral standards used for this were of analytical grade (Sigma-Aldrich, India).

Results and Discussion

Physical Properties

Individual principle dimensions of fruit mass, length and mid-section diameter of the *Kendu* fruit were studied. Fruit size distribution at an average initial moisture content of 66.17±1.84 % (db.) is shown in Table 1. Fruit samples were divided into three sizes (small, medium and large) according to their arithmetic mean diameter (D_a). The fruit has an average sphericity, volume and surface area of 0.97±0.02, 25.25±1.37 cm^3, and 40.30±1.55 cm^2 respectively. Frequency distribution curves of length and width show more numbers of fruits of medium range (Fig. 2). The curves were narrow with high

peaks, indicating that the seed has a dimension close to their corresponding means. About 63.4 % of the *Kendu* fruit samples were of medium size with average length and width of 3.61±0.13 and 3.57±0.13 respectively.

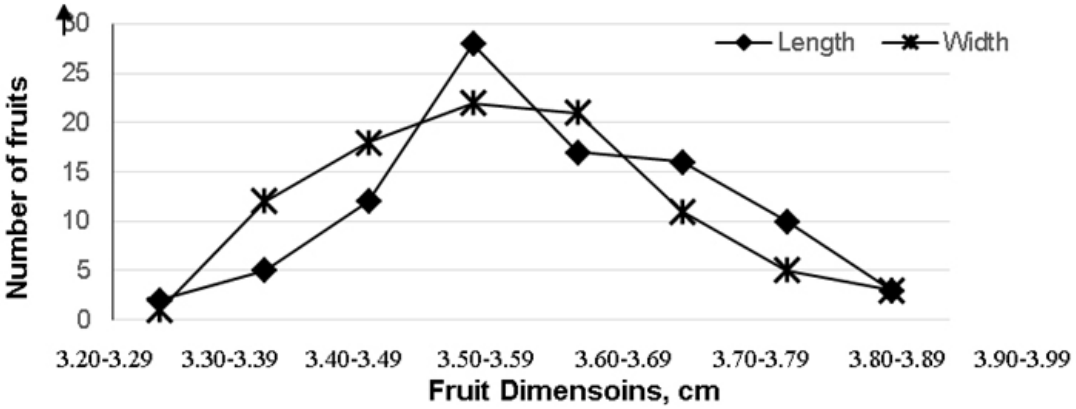

Fig. 2: Frequency distribution curve of *kendu* fruit dimensions at 66.17 ±1.84 %.(db.) moisture content

The average values of bulk density and true density were 1155.91±2.47 kg/m^3 and 1280.90±3.81 kg/m^3 respectively (Table 2). The average porosity of the fruit was found to be 11.51±0.90 %. These characteristics can be used to separate fruit from other foreign materials and can be helpful in air and heat flow studies. These parameters are important for determining the capacity of storage and transport.

Angle of repose for the average moisture content of 66.17±1.84 % (db.) was 25.50 ±1.22^o (Table I). The static co-efficient of friction was highest for plywood and lowest for aluminium sheet. The least static co-efficient of friction may be due to the smooth and polished surface of the aluminium sheet used. Due to the spherical nature of fruits, the rolling resistance was found to be low but the tendency to roll was higher when kept in radial direction than the axial direction. Similar results were found in other spherical fruit[16].

Fruit Colour and Composition

The fruit pulp colour for fresh sample was determined on Hunter Lab. A yellowness coloration (b value) of the fruit pulp was found significant indicating the fruit pulp is yellow in colour (Table 2). The fleshy portion of the fruit consists of pulp (44.23±0.03 %) and seed (25.53±0.59 %). Each fruit contains about three to five seeds.

Table1: Physical dimensions on size distribution of *Kendu* fruit

Particulars	Values*		
	Small	Medium	Large
Arithmetic mean of fruit (D_a), cm	< 3.48	3.48-3.70	>3.70
Percentage of fruits %	18.3	63.4	18.3
Average dimensions			
Length (L),cm	3.48±0.08	3.61±0.13	3.78±0.12
Width (D),cm	3.40±0.09	3.57±0.13	3.72±0.12
Arithmetic mean diameter (D_a),cm	3.44±0.03	3.59±0.06	3.75±0.03
Geometric mean diameter (D_g),cm	3.42±0.05	3.58±0.07	3.74±0.05
Sphericity (ϕ)	0.98±0.02	0.97±0.02	0.97±0.02
Surface area (SA),cm^2	36.83±0.98	40.30±1.55	43.93±1.07

*Values are means, ± Standard Deviation for three replicates

Table 2: Physical Properties of *Kendu* fruit

Properties	Observation		Average Values*
Volume(cm^3)	50		25.25 ±1.37
Bulk density(kg/m^3)	50		1155.91±2.47
True density(kg/m^3)	50		1280.90±3.81
Porosity (%)	50		11.51±0.90
Angle of Repose (°)	50		25.50±1.22
Color	L		47.53±1.80
	a		6.99±1.30
	b		27.03±3.19
Coefficient of friction (μ)	Plywood	Radial	0.16±0.04
		Axial	0.26±0.05
Coefficient of friction (μ)	Aluminium	Radial	0.13± 0.02
		Axial	0.20 ±0.03
Coefficient of friction (μ)	G.I steel	Radial	0.14± 0.02
		Axial	0.22± 0.03

*Values are means, ± Standard Deviation for three replicates

Mechanical Properties

The force- deformation curve of kendu fruit shows surface or skin hardness was higher than the pulp (Fig. 3). Due to the fibrous nature of the fruit, the graph has several peaks. The non-uniform and continuous small peaks signifies the different harness value of different layers. The probe was subjected to a depth of 18 mm. The highest peak was found to be 9.50±1.85 N at a distance of 2 mm which was found to be the skin hardness. The pulp firmness was found to be 9.06±1.74 N which was higher in radial direction than the axial. This may be due to the orientation of fibre in the pulp. Similar trend has also been reported for nuts, strawberry, and mango[28-30]. Same range of fruit hardness was found oil palm fruits[18]. There is an increase in load to compress the fruit as we go deeper due to its own compaction (Table 3). We can conclude that for an averaged size *Kendu* fruit, an average load of 17.49 ±1.58 N is required for ≥50 % deformation.

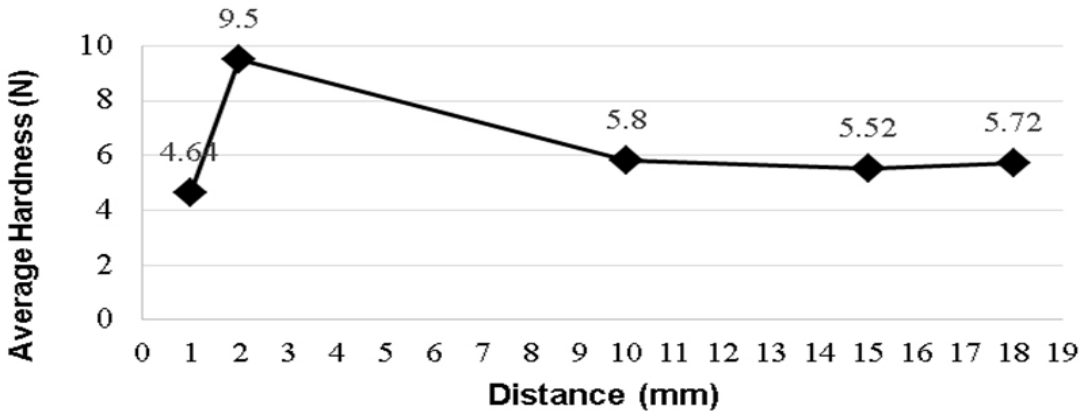

Fig. 3: Hardness properties of fresh *kendu* fruit at 66.17 ±1.83 %.(db.) moisture content

Table 3: Compression test at five distances from the surface of Kendu fruit

Sl	Target distance (mm)	Values at 1st Deformation*			Values at Target distance*		
		Hardness (N)	Deformation (mm)	Work (J)	Load at Target(J)	Deformation at Target(mm)	AveragePeak Load(N)
1	2	3.61±0.95	1.33±0.58	0.00	3.61± 0.95	1.33±0.58	3.61±0.95
2	4	11.71±1.33	2.00±0.00	0.01±0.01	11.71±1.33	2.00±0.00	11.71±1.3
3	8	21.31±2.26	7.18±0.60	0.09±0.02	17.76±3.45	7.96±0.04	21.31±2.2
4	16	17.59±1.48	7.69±1.75	0.19±0.02	12.73±2.18	15.98±0.03	17.49±1.58
5	32	27.29±2.86	18.60±3.00	0.31±0.06	7.99±1.90	27.99±0.01	27.29±2.8

*Values are means, ± Standard Deviation for three replicates.

Chemical Properties

The average moisture content, ash content, crude fibre, fat, carbohydrate, protein were analysed (Table 4). Acid levels are expressed frequently in terms of pH and titratable acidity (TA) while sugar concentrations are reported as total soluble solids (TSS). The values of TA (%) and pH are 0.16±0.02 and 5.474±0.15 respectively. Similar range of values have been reported for mango, apple and medlar[32-34].

The TSS level of the pulp was 16.45±0.50 °Brix, which is in the same range of that of cherry and mango[35]. It is generally recognized earlier that the fruits have higher sugar-acid ratio that shows the fruit is of high quality[36]. TPC and β-carotene of fresh fruit was 125.912±0.56 mg GAE/100g and 416.04±1.08 µg/ 100g pulp respectively (Table IV). Similar values of phenolic content were found for guava, plum and star fruit[36,37] and beta carotene content was found similar to different variety of mangoes[38,39]. The average value of DPPH scavenging activity of 83.806 ± 1.03 (%) was in the same range of orange, papaya, pineapple and apple. FRAP value of *Kendu* was 5876.02 ± 0.52 mg TE/100 g of DW. Similar value has been reported for kiwi, guava, red apple, banana[40,41].The bark of the Kendu plant is reported to have total phenolic and ascorbic acid content of 44.32±0.103 (mg/g) and 5.12±0.117 (mg/g), respectively, much lower than that of the fruit[42].

Mineral composition of *kendu* fruit pulp is shown in Table 5. The fruit pulp has high content of calcium (58.42±0.50) and phosphorus (20.00±0.41). It can be a good source of calcium and phosphorus required for development and maintenance of bones. Similar trend of mineral composition can be found in mango and passion fruit[41]. The potassium content of *Kendu* fruit is 123±0.01 mg/100g. The bark of the plant is reported to have only 0.55±0.04 mg/100g of potassium[42].

Table 4: Chemical and Antioxidant properties of fresh *Kendu* pulp

Composition	Experimental value*
Moisture (% db.)	66.17 ± 1.84
Ash content (%)	3.24 ± 0.318
Crude fiber (%)	2.77 ± 0.22
Fat (%)	0.71 ± 0.12
Carbohydrate (%)	26.93 ± 0.21
Protein (%)	0.652 ± 0.56
Energy value (KJ/100g)	491.75± 2.0
pH	5.474 ± 0.15
Acidity (%)	0.16 ± 0.02
TSS (°Brix)	16.45 ± 0.50
Total Sugar (%)	29.10± 1.68
Reducing Sugar (%)	11.10± 0.23
Ascorbic acid (mg/100mg)	14.30± 0.02
TPC (mg GAE/100g DW)	125.91± 0.56
β-carotene(µg/100gfresh pulp)	416.04± 1.08
DppH Activity (%)	83.80 ± 1.03
FRAP(mg TE/100 g DW)	5876.02± 0.52

*Values are means, ± Standard Deviation for three replicates

TSS, total soluble solids; FRAP, ferric reducing antioxidant power; ORAC, oxygen radical absorbance capacity; TPC, total phenolic content; db- dry basis; KJ- kilo joule; mg GAE/100g - gallic acid equivalent per hundred gram dry weight; mg TE/100 g of DW-trolox equilvalent per hundred gram dry weight.

Table 5: Mineral composition of fresh *Kendu* pulp

Sl.	Parameters	Quantity*(mg /100g)
1	Potassium	123±0.01
2	Calcium	58.42±0.50
3	Phosphorus	20.00±0.41
4	Magnesium	10.8±0.35
5	Iron	0.263±0.02
6	Zinc	0.122±0.42
7	Sodium	0.092±0.03
8	Lead	0.014±0.01
9	Copper	0.004±0.00

*Values are means, ± Standard Deviation for three replicates

Conclusion

In conclusion, the physico-chemical parameters such as moisture content, ash, crude fibre, crude fat, protein, carbohydrate, total soluble solids (TSS), acidity, pH, and colour are important for further processing and value addition of *Kendu* fruit. A combination of a number of physico-chemical parameters are required to specify the quality of *Kendu* fruits. These properties were consistent with that of similar fruits. More studies on physical, chemical, textural and nutritional relationship among different varieties and maturity levels of *Kendu* need to be undertaken that may help in designing process and equipment for harvesting, transportation, storage and processing of fresh *Kendu* fruits. Proper value-addition techniques and processing facilities for this ethnic fruit can contribute to the socio-economic livelihood of tribal people.

Acknowledgement

The authors would like to thank Department of Food Process Engineering, National Institute of Technology, Rourkela, Odisha, India for providing laboratory facilities to conduct the experiments.

Conflict of Ineterest

The authors have no conflicts of interest to declare.

References

1. Saxena, N. C., Livelihood diversification and non-timber forest products in Orissa: Wider lessons on the scope for policy change. Overseas Development Institute, London, UK, (2003).
2. Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Simons, A., Agroforestree database: a tree species reference and selection guide version 4.0. World Agroforestry Centre ICRAF, Nairobi, KE, (2009).
3. Rathore, J. S., *Diospyros melanoxylon*, a bread-winner tree of India. *Economic Botany:* ***26***(4): 333-9: (1972).
4. Gupta, V., Maithili, V., Vishwakarma, P.K., Comparative study of analgesic activity of *Diospyros melanoxylon (Roxb.)* bark and root bark. *Journal of Natural Remedies:* ***13***(1):15-8: (2013).
5. Sahu, U. C., Panda, S. K., Mohapatra, U. B. and Ray, R. C., Preparation and evaluation of wine from tendu (*Diospyros melanoxylon* L) fruits with antioxidants, *Internatinal Journal of Food Fermentation Technology:* ***2***(2): 167: (2012).
6. Maridass, M., Ghanthikumar, S. and Raju, G., Preliminary phytochemical analysis of Diospyros species, *Ethnobot Leaflets:* ***1***: 118: (2008).
7. Utsunomiya, N., Subhadrabandhu, S. Yonemori, K., Oshida, M., Kanzaki, S., Nakatsubo, F. and Sugiura, A., Diospyros species in Thailand: their distribution, fruit morphology and uses. *Economic Botany:* ***52***(4): 343-351: (1998).

8. Janick, J., and Paul, R.E., The Encyclopedia of Fruit and Nuts. CABI Publication, UK (2008).
9. Behera, M. C. and Nath, M. R., Financial valuation of non-timber forest products flow from tropical dry deciduous forests in Boudh district, Orissa, *International Journal of Farm Sciences:* ***2***(2): 83-94: (2014).
10. Rout, S. D., Panda, S. K., Mishra, N. and Panda, T., Role of tribals in collection of commercial non-timber forest products in Mayurbhanj District, Orissa. *Studies of Tribes and Tribals:* ***8***(1): 21-25: (2010).
11. Parija, S., Mohanty, A. K., Misra, M and Nayak, S. K., Evaluation of physico-mechanical properties of biodegradable kendu gum dust filled polyolefin blends, *Polymer degradation and stability:* ***67***(1): 7-12: (2000).
12. Pal, R., Ghosh, S. N., Kendu: an underutilized and lesser known fruit of West Bengal. In Proceedings of the International Symposium on Minor Fruits and Medicinal Plants for Health and Ecological Security held on Bidhan Chandra Krishi Viswandyalaya, West Bengal, India, (2011).
13. Hecht, S. B., Anderson, A. B. and May, P., The subsidy from nature: shifting cultivation, successional palm forests, and rural development. *Human Organ.****47***: 25-35: (1988).
14. Production of Kendu Leaves. Press Information Bureau. 2014 [Cited 2017 Feb 18], Available from: http://pib.nic.in/newsite/PrintRelease.aspx?relid=113506
15. Horwitz, W. L., Official Methods of Analysis, Association of Official Analytical Chemists, 17th edn. (AOAC, Maryland): (2000).
16. Çahsir, S., Aydın, C.Some physico-mechanic properties of cherry laurel (*Prunus lauracerasus* L.) fruits. *Journal of Food Engineering:* ***65***(1), 145-50: (2004).
17. Pradhan, R. C., Naik, S. N., Bhatnagar, N and Vijay, V. K., Moisture-dependent physical properties of jatropha fruit. *Industrial Crops Products:* ***29***(2): 341-7: (2009).
18. Owolarafe, O. K., Olabige, M. T. and Faborode, M. O., Physical and mechanical properties of two varieties of fresh oil palm fruit. *Journal of Food Engineering:* ***78***(4): 1228-32: (2007).
19. Topuz, A., Topakci, M., Canakci, M., Akinci, I. and Ozdemir, F., Physical and nutritional properties of four orange varieties. *Journal of Food Engineering:* ***4***: 519-23: (2005).
20. Mohsenin, N. N., Physical properties of plant and animal materials. Vol. 1. Structure, physical characteristics and mechanical properties. Gordon and Breach Publications, New York, (1970).
21. Rangana. S., Manual of analysis of fruit and vegetable products. Tata McGraw-Hill Plublication, USA, (1979).
22. Negrulescu. A., Patrulea, V., Mincea, M. M., Lonascu, C., Vlad-Oros B A and Ostafe V., Adapting the reducing sugars method with dinitrosalicylic acid to microtiter plates and microwave heating. *Journal of the Brazilian Chemical Society:* ***23***(12): 2176-82: (2012).
23. James, S. C., Analytical Chemistry of Foods. Aspen Publication Inc, Maryland, USA, (1999).
24. Lutz, M., Hernandez, J. and Henriquez C., Phenolic content and antioxidant capacity in fresh and dry fruits and vegetables grown in Chile. *Journal of Food:* ***13***(4): 541-7: (2015).
25. Hegazy, A. K., Al-Rowaily, S. L., Faisal, M., Alatar, A. A., El-Bana, M.I. and Assaeed, A.M. Nutritive value and antioxidant activity of some edible wild fruits in the Middle East. Journal of Medicinal Plants Research: 7(15): 938-46: (2013).
26. Priecina, L. and Karklina, D., Natural antioxidant changes in fresh and dried spices and vegetables. *International Journal of Agricultural and Biological Engineering:* ***8***: 480-487: (2014).
27. Musa, K. H., Abdullah, A., Jusoh, K., Subramaniam, V., Antioxidant activity of pink-flesh guava (*Psidium guajava* L.): effect of extraction techniques and solvents, *Food Analytical Methods:* ***4***(1): 100-7: (2011).
28. Latimer, G. W. and Horwitz, W., Official Methods of Analysis, Association of Official Analytical Chemists, 18th edn, AOAC, Maryland, (2010).
29. Braga, G. C., Couto, S.M., Hara, T. and Neto, J. T., Mechanical behaviour of macadamia nut under compression loading, *Journal of Agricultural research:* ***72***(3): 239-45: (1999).
30. Ozcan, M. M. and Hacıseferogullari, H., The strawberry (*Arbutus unedo* L.) fruits: chemical

composition, physical properties and mineral contents. *Journal of Food Engineering:* ***78***(3): 1022-8: (2007).

31. Naz, S., Anjum, M. A., Chohan, S., Akhtar, S., Siddique, B., Physico-chemical and sensory profiling of promising mango cultivars grown in peri-urban areas of Multan, Pakistan. *Pakistan Journal of Botany:* ***46***(1): 191-8: (2014).
32. Akhtar, S., Riaz, M., Ahmad, A., Nisar, A., Physico-chemical, microbiological and sensory stability of chemically preserved mango pulp. *Pakistan Journal of Botany:* ***42***(2): 853-62: (2010).
33. Abdualrahman, M. A., Comparative Study between Local and Imported Apple (*Malus domestica*) Fruits and their Uses in Juice Production. *Science International:* ***3***(2): 69-72: (2015).
34. Haciseferogullari, H., Ozcan, M., Sonmete, M. H., Ozbek., Some physical and chemical parameters of wild medlar (*Mespilus germanica* L.) fruit grown in Turkey, *Journal of Food Engineering:* ***69***(1): 1-7: (2005).
35. Shafique, M. Z., Ibrahim, M., Helali, M. O. H. and Biswas, S. K., Studies on the physiological and biochemical composition of different mango cultivars at various maturity levels. *Bangladesh Journal of Scientific and Industrial Research:* ***41***: 101-108: (2006).
36. Alothman. M., Bhat, R. and Karim, A. A., Antioxidant capacity and phenolic content of selected tropical fruits from Malaysia, extracted with different solvents. *Food Chemistry:* ***115***: 785-788: (2009).
37. Lim, Y. Y, Lim, T. T. and Tee, J. J., Antioxidant properties of several tropical fruits: A comparative study. *Food Chemistry.* ***103***: 1003-1008: (2007).
38. Ribeiro, S. M. R., Barbosa, L. C. A., Queiroz, J. H., Knodler, M. and Schieber, A., Phenolic compounds and antioxidant capacity of Brazilian mango (*Mangifera indica* L.) varieties. *Food Chemistry:* ***110***: 620-626: (2008).
39. Ribeiro, S. M. R, Queiroz, J. H., De-Queiroz, M. E. L. R., Campos, F. M. and Santana, H. M.P., Antioxidant in mango (*Mangifera indica* L.) pulp. *Plant Foods for Human Nutrition:* ***62***: 13-17: (2007).
40. Guo, C., Yang, J., Wei, J., LiY, X.J. and Jiang ,Y., Antioxidant activities of peel, pulp and seed fractions of common fruits as determined by FRAP assay. *Nutritional Research:* ***23***: 1719: 1726: (2003).
41. Fu, L., Xu, B.T., Xu, X. R., Gan, R.Y., Zhang, Y., Xia, E. Q. and Li, H. B., Antioxidant capacities and total phenolic contents of 62 fruits. *Food Chemistry:* ***129***: 345-350: (2011).
42. Rath, S. K., Patra, J. K., Gouda, S., Sahoo, S, K., Thatoi. H., and Dutta, S. K., Evaluation of Antioxidant Potential, Phytochemical Analysis and Chromatographic Separation of Bark Extracts of Diospyros melanoxylon Roxb. *Journal of Biologically Active Products from Nature:* ***4*** (5-6): 377-390: (2014).