International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(3): 2216-2220

Received: 04-03-2020
Accepted: 06-04-2020

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Wood variation in chemical properties of *Artocarpus heterophyllus* Lam. grown in Thrissur district, Kerala

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DOI: https://doi.org/10.22271/chemi.2020.v8.i3af.9540

Abstract
The study shows the variation in the chemical properties of jackfruit wood in which the properties like cold water solubility, hot water solubility, alcohol benzene extractives, cellulose, hemicellulose, holocellulose, klason lignin, NaOH soluble extractives and ash content are being determined. The quality and utility of the woods obtained from different zones are thus being analysed and the data can further be used for utilization of jackfruit wood.

Keywords: Wood, cellulose, lignin, extractives

Introduction
Artocarpus heterophyllus Lam. belonging to the family Moraceae and popularly known as jackfruit or Ceylon Jack tree, is one of the important and commonly found trees in the homegardens of certain parts of India and Bangladesh (Bose, 1985) [7]. The place of origin of jack tree is unknown, however it is believed to be indigenous to the rainforests of the Western Ghats (Morton, 1987) [14]. It is a mediumsized, evergreen tree that typically attains a height of 8m–25m and a stem diameter of 30cm–80 cm. The canopy shape is usually conical or pyramidal in young trees and becomes spreading and domed in older trees. It is monoecious and both male and female inflorescences are found on the same tree (Bose, 1985; Morton, 1987) [4, 14]. The assessment of the timber quality may involve the consideration of a large number of physical, chemical, anatomical and mechanical properties of wood. Though the jackfruit wood has been used extensively, little information is available on its properties. Thus the study of wood properties of jackfruit wood is important and very timely for the further effective utilization in future.

Materials and Methods
The present study was aimed at the collection trees of *Artocarpus heterophyllus* Lam. from three different zones based on altitudnal classes which are divided into Lowland, Midland and Highland of Thrissur district, Kerala (ENVIS, 2017) [8]. The samples were collected from the local markets based on three different girth classes i.e. 30cm-60cm, 60cm-90cm and 90cm-120cm. Three samples of each girth classes from different sites were collected which constitute 27 wood samples. Further studies on wood properties were conducted in the department of Forest Products and Utilization, College of Forestry, Kerala Agricultural University, Vellanikkara.
The proximate chemical analysis was carried out by employing TAPPI (Technical Association Pulp and Paper Industry) standard methods.

Determination of water soluble extractives
The water soluble extractives were determined by employing following methods
a) Cold water solubility (T1m-59-Anonymous, 1959a) [3].
Two grams of oven dry wood meal was weighed and transferred into a conical flask containing 300 ml of distilled water. The mixture was digested at room temperature with frequent stirring for 48 hours.

Then material was filtered through IG-1 crucible and washed thoroughly with cold distilled water and dried to a constant weight in an oven at 105 ± 2 ˚C. The cold water solubility was determined by calculating the loss in weight of sample taken and was expressed as percentage on the basis of oven dry weight of wood.

b) Hot water solubility (T1m-59-Anonymous, 1959a) [3].

Two grams of oven dry wood meal was taken in a flask having 100 ml of double distilled water filtered with reflux condenser. It was digested on boiling water bath for 3 hours. Then contents were filtered through IG-1 crucible and residue was dried in an oven at 105 ± 2 ˚C till constant weight. The solubility was determined by calculating the loss in weight of the sample taken and expressed as percentage.

Determination of Chemical soluble extractives

a) NaOH extractives (T 212 m-02- Anonymous, 1959b) [4].

Two grams of oven dry wood meal was weighed and transferred into a conical flask of 250 ml. Then 100 ± 1 ml of 1 percent NaOH solution was added to it and stirring was done with a glass rod. The flask was covered with a watch glass and place in a water bath maintained at 97° to 100 °C for one hour. Then, contents were filtered through Wattman filter paper. The sample was dried in an oven at 105 ± 2 ˚C to a constant weight. The solubility was determined by calculating the loss in weight of the sample taken and expressed as percentage.

b) Alcohol-benzene extractives (T6m-59-Anonymous, 1959b) [4].

Two grams oven dry powdered wood sample was placed in a porous thimble (oven dried and weighed). The thimble was placed in a Soxhlet Apparatus and extracted with 200 ml of alcohol-benzene (1: 2 v/v) for six hours. Then, porous thimble was taken out and allowed to dry in open air and finally in an oven at 105 ± 2 ˚C till constant weight. The alcohol-benzene solubility was determined by calculating the loss in weight of the sample taken and expressed in percentage.

c) Determination of Holocellulose (T9m-59-Anonymous, 1959) [2].

Five grams of oven dried sample pre-extracted with alcohol-benzene (1:2 v/v) was taken in a conical flask and 160 ml of distilled water was added to it. Then contents were treated with 1.5 gram of Sodium chlorite and 10 drops of acetic acid at 70-80 ˚C on a water bath for one hour. The process was repeated four times till the meal became white. Then contents were filtered through IG-2 crucible, washed with water and finally with acetone. The sample was dried in an oven at 105 ± 2 ˚C to a constant weight. The per cent holocellulose content was calculated on the basis of the oven dry weight.

d) Determination of Klason-lignin content (T12m-59-Anonymous, 1959c) [5].

Two grams oven dry sample pre-extracted with alcohol-benzene (1:2 v/v) was treated with 15 ml of 72 per cent sulphuric acid for 2 hours at 18-20 ˚C with constant stirring. The material was brought down to 3 per cent by adding 345 ml of double distilled water. The solution was refluxed for 4 hours and then allowed to settle. The contents were filtered, washed with hot distilled water and dried in an oven at 105 ± 2 ˚C till constant weight and expressed in percentage on oven dry weight basis.

e) Determination of Cellulose

Cellulose content of the wood was estimated following Sadasivam and Manikam (1992) [18]. For this finely powdered pre extracted saw dust were taken After taking the pre extracted saw dust, prepare Acetic/Nitric Reagent by mixing 150 ml of 80% acetic acid and 15 ml of conc. Nitric acid. Prepare fresh Anthrone reagent by dissolving 200 mg anthrone in 100 ml concentrated sulphuric acid and chill for 2 hours before use. Prepare 67% sulphuric acid by mixing 68 ml Conc. Sulphuric acid and 32 ml distilled water. After preparing the above solutions add 3 ml acetic/nitric reagent to a known amount (100 mg) of the sample in a test tube and mix in a vortex mixer for 5 minutes. Place the tube in a waterbath at 100 ºC for 30 minutes and then centrifuge the contents for 15-20 minutes. Discard the supernatant. Wash the residue with distilled water. Then add 10 ml of 67% Sulphuric acid and allow it to stand for 1 hour. Dilute 1 ml of the above solution to 100 ml. To 1 ml of this diluted solution, add 10 ml of anthrone reagent and mix well. Heat the tubes in a boiling water bath for 10 minutes. Cool and measure the colour at 630 nm in spectrophotometer by setting a blank with anthrone reagent and distilled water. Then take 100mg cellulose powder in a test tube and proceed the steps of creating the standard by addition of sulphuric acid to anthrone reagent as above procedure.

Results and Discussion

The data on average cold water soluble extractives of wood of different treatments are presented in Table 1. A critical observation of the data revealed no significant variations among the treatments. The cold water soluble compounds in wood are generally sugars, salts, tannins and gums. The species which contain large amount of extractives have better durability, dimensional stability and plasticization. The content, type and position of extractives affect the strength properties of wood (Narayanamurti and Verma, 1964) [15]. The highest value showed for highland with 4.55% for 60-90cm girth class and lowest value of 1.81% for 30-60 cm. Values for hot water soluble extractives were higher than those of cold water. The difference insolubility is due to hydrolysis and corresponding increase in solubility of wood substance during the boiling with water. Similar results have been reported by Nazri *et al.* (2009) [16] in *Leucaena* species. Higher values for hot water extractives is due to the reason that hot-water extraction eliminates greater quantities of materials, removes a portion of the cell structure and extracts some inorganic extractives (Shebani *et al.* 2008) [19]. The data on percentage of hot water extractives are represented in the table 2. The results revealed no significant difference between the zones and between girth classes.

Table 1: Variation in cold water solubility (%) of *Artocarpus heterophyllus* Lam. wood from three different zones

Girth classes	Zones		
	Lowland	Midland	Highland
30cm-60cm	1.81 (1.32)	2.19 (1.44)	2.31 (1.51)
60cm-90cm	2.19 (1.47)	2.39 (1.50)	4.55 (2.09)
90cm-120cm	1.91 (1.38)	2.50 (1.56)	3.32 (1.81)
Zone mean	1.97	2.36	3.40
F value	4.44^{ns} (Zones)	0.82^{ns} (Girth classes within zones)	

*Value in parenthesis is square root transformed value

Table 2: Variation in hot water solubility (%) of *Artocarpus heterophyllus* Lam. wood from three different zones

Girth classes	Zones		
	Lowland	Midland	Highland
30cm-60cm	3.75 (1.92)	6.05 (2.46)	6.94 (2.63)
60cm-90cm	6.47 (2.53)	6.77 (2.59)	7.28 (2.69)
90cm-120cm	5.59 (2.36)	6.16 (2.47)	7.11 (2.65)
Zone mean	5.27	6.33	7.11
F value	3.22^{ns} (Zones)	1.56^{ns} (Girth classes within zones)	

*Value in parenthesis is square root transformed value

The highest value for hot water extractives is obtained from highland which belongs to girth class of 60-90 cm with 7.28% and the lowest for lowland which belongs to girth class of 30-60 cm with 3.75%. The data on Table 3 shows the values for the alcohol benzene extractives from the jackfruit wood obtained from different zones.

Table 3: Variation in alcohol benzene extractives (%) of *Artocarpus heterophyllus* Lam. wood from three different zones

Girth classes	Zones		
	Lowland	Midland	Highland
30cm-60cm	10.69 (3.27)	12.44 (3.53)	10.49 (3.22)
60cm-90cm	15.91 (3.99	12.54 (3.54)	13.47 (3.67)
90cm-120cm	15.13 (3.88)	11.58 (3.40)	12.84 (3.58)
Zone mean	13.91	12.19	12.27
F value	0.70^{ns} (Zones)	5.08^{*} (Girth classes within zones)	

*Value in parenthesis is square root transformed value, *level of significance at 0.05

Table 4: Variation in holocellulose (%) of *Artocarpus heterophyllus* Lam. wood from three different zones

Girth classes	Zones		
	Lowland	Midland	Highland
30cm-60cm	66.19 (8.13)	72.67 (8.52)	69.41 (8.33)
60cm-90cm	70.55 (8.40)	76.13 (8.72)	69.47 (8.33)
90cm-120cm	70.06 (8.37)	65.46 (8.09)	70.24 (8.38)
Zone mean	68.93	71.42	69.71
F value	0.38^{ns} (Zones)	2.53^{*} (Girth classes within zones)	

*Value in parenthesis is standard deviation values. *level of significance at 0.05

The alcohol-benzene solubility of wood constitutes the waxes, fats and resinous matter. Alcohol-benzene solubility of wood is an important character representing extractives present in wood which affect the quality of pulp. The components which are generally soluble in alcohol-benzene are oleoresins, fats and waxes.

Table 5: Variation in cellulose (%) of *Artocarpus heterophyllus* Lam. wood from three different zones

Girth classes	Zones		
	Lowland	Midland	Highland
30cm-60cm	38.95 (6.23)	44.46 (6.68)	44.20 (6.39)
60cm-90cm	42.65 (6.20)	43.19 (6.54)	46.02 (6.53)
90cm-120cm	43.24 (6.56)	39.24 (6.25)	42.76 (6.07)
Zone mean	41.61	42.30	44.33
F value	0.54^{ns} (Zones)	0.846^{ns} (Girth classes within zones)	

*Value in parenthesis is standarad deviation values

Table 6: Variation in hemicelulose (%) of *Artocarpus heterophyllus* Lam. wood from three different zones

Girth classes	Zones		
	Lowland	Midland	Highland
30cm-60cm	27.24 (5.22)	28.21 (5.26)	25.21 (5.29)
60cm-90cm	27.90 (5.62)	32.95 (5.75)	23.45 (5.14)
90cm-120cm	26.82 (5.08)	26.22 (5.11)	27.49 (5.76)
Zone mean	27.32	29.12	25.38
F value	0.068^{ns} (Zones)	0.61^{ns}(Girth classes within zones)	

*Value in parenthesis is square root transformed value

The results of the present investigations are in conformity with the studies conducted by Liang and Joshi (2004) [11] on Aspen tree, Mahdavi *et al*. (2004) [12] on *Eucalyptus camaldulensis*, Hernandez and Salazar (2006) [10] in *Quercus coccolobifolia*, *Q. rugosa* and *Q.oleoides* and Fakhrian *et al.* (2005) [9] on *Alnus glulmosa.* The highest value for the alcohol benzene obtained from lowland with 15.91% which belongs to girth class of 60-90cm and lowest value for lowland i.e. 13.91% which belongs to 30-60cm girth class. There is significant difference between the alcohol benzene soluble extractive contents within girth classes. Holocellulose, which constitute cellulose and hemicelluloses is the major portion of fibrous raw material. Cellulose and hemicellulose together described as holocellulose is used to denote the polysaccharides in wood. The holocellulose content is a quantitative indication of fibrous raw material influencing consideration of its suitability for pulp. Whereas, lignin is a phenolic substance consisting of an irregular array of variously bonded hydroxyl- and methoxy-substituted phenyl-propane units, which is distributed throughout the secondary cell wall with the highest concentration in middle lamella and is responsible for providing stiffness to the cell wall (Rowell, 2005) [17]. It also serves to bond individual cells together in the middle lamella region.

Table 7: Variation in lignin (%) of *Artocarpus heterophyllus* Lam. wood from three different zones

Girth classes	Zones		
	Lowland	Midland	Highland
30cm-60cm	27.67 (5.26)	30.77 (5.53)	25.23 (5.02)
60cm-90cm	30.65 (5.53)	24.27 (4.91)	29.11 (5.38)
90cm-120cm	26.32 (5.12)	29.41 (5.42)	23.47 (4.84)
Zone mean	28.21	28.15	25.93
F value	0.61^{ns} (Zones)	1.93^{ns} (Girth classes within zones)	

*Value in parenthesis is square root transformed value

The data in Table 4 shows the percentage of holocellulose content in the wood obtained from different zones which belongs to the respective girth classes which showed no significant variation. The highest value for holocellulose obtained i.e. 76.13% from midland which belongs to girth class of 60-90 cm and lowest value of 65.46% for midland which belongs to girth class of 90-120 cm. There is significant difference between the holocellulose contents within girth classes. In case of the percentage of cellulose content which is analysed from different showed significant difference between the zones.

From the Table 5, the highest value for cellulose i.e. 46.02% which is obtained from highland which belongs to 60-90 cm girth class whereas the lowest 38.95% from lowland which is of 30-60cm girth class. For hemicellulose as from the Table 6, the highest value of 32.95% which is obtained from midland which belongs to 60-90 cm. The lowest value of 23.45% which is obtained from 60-90cm girth class of highand. As cellulose, the hemicellulose content showed significant difference between zones. In case of pulp and paper making or bioethanol production, isolation of lignin become an important factor. Lignin can reduce paper strength because it could be a barrier for hydrogen bonding in the fiber formation. Lgnin content in *Meranti* bunga, kulit hitam was lower than that of *Meranti* bakau and *Meranti* sangkan (Adi *et al*., 2011) [1]. Hence, any wood that has low lignin content and high α-cellulose content would be a good potential to be utilized as raw material for pulp and paper making and bioethanol production.

Table 8: Variation in NaOH soluble extractives (%) of *Artocarpus heterophyllus* Lam. wood from three different zones

Girth classes	Zones		
	Lowland	**Midland**	**Highland**
30cm-60cm	19.83 (5.46)	15.32 (5.31)	19.92 (4.45)
60cm-90cm	23.76 (4.85)	19.79 (5.454)	22.70 (4.76)
90cm-120cm	17.34 (5.23)	19.67 (5.93)	21.82 (4.99)
Zone mean	20.31	18.26	21.48
F value	5.69^{*} (Zones)	1.68^{ns} (Girth classes within zones)	

*Value in parenthesis is square root transformed value, *level of significance at 0.05

Table 9: Variation in ash content (%) of *Artocarpus heterophyllus* Lam. wood from three different zones

Girth classes	Zones		
	Lowland	**Midland**	**Highland**
30cm-60cm	0.52 (0.71)	0.66 (0.81)	0.58 (0.76)
60cm-90cm	0.76 (0.85)	0.80 (0.88)	0.50 (0.70)
90cm-120cm	0.74 (0.86)	0.94 (0.97)	0.89 (0.94)
Zone mean	0.67	0.80	0.66
F value	0.68^{ns} (Zones)	1.68^{ns} (Girth classes within zones)	

*Value in parenthesis is square root transformed value

Beleam and Harkin (1975) [6] have reported that lignin content varies among species, individuals and within plant. The possible reason for variation in cell wall constituents can be assigned to the varied production of dry matter. In the case of jackfruit wood, the lignin content which is estimated from the different zones given in Table 7 showed highest value for midland with 30.77% which belongs to 30-60 cm girth class and the lowest for highland of 90-120 cm girth class i.e. 23.47% with n significant variation between the zones and girth classes. Table 8 and Table 9 shows the value of sodium hydroxide soluble extractives and ash content of the jackfruit wood obtained from the different girth classes respectively. The results shows that the highest value of 22.70% for NaOH soluble extractives is from highland wood which belongs to 60-90 cm girth class whereas the lowest value for midland i.e. 15.32%. Several common wood species have ash contents ranging from 0.43% (aspen) to 0.87% (white oak) (Mishra *et al*., 2004) [13]. The highest value of 0.94% for ash content is from midland of 90-120 cm girth class whereas the lowest value of 0.5% is from highand which belongs to 60-90 cm girth class.

Conclusion

The data on wood properties obtained from the analysis from the three different zones revealed that the strength depends on the water soluble and chemical soluble extractives. The maximum value for cold water soluble extractives is observed in highland whereas the lowest in lowland. Same was the case of hot water soluble extractives which was obtained. In case of alcohol benzene extractives, the maximum extractives are obtained from lowland and lowest from midland. Holocellulose content was maximum for the wood obtained from midland and lowest for lowland whereas the cellulose content was highest for highland and lowest for lowland. The hemicellulose content was highest for midland and lowest for highland. As far as NaOH soluble extracts the highest value was obtained for highland and lowest for lowland. The ash content was found maximum for midland wood and lowest for highland wood.

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