International Journal of Advanced Biochemistry Research 2024; SP-8(1): 221-232

International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; SP-8(1): 221-232
www.biochemjournal.com
Received: 10-10-2023
Accepted: 15-12-2023

Saurabh Sharma
1. Department of Forest Products, Wood Science and Technology (Composite Wood), Forest Research Institute (FRI), Dehradun, Uttarakhand, India
2. Pt. Deendayal Upadhayay College of Horticulture & Forestry, Piprakothi, Dr. RPCAU, Bihar, India

Anil Negi
ICFRE, Dehradun, Uttarakhand, India

Mohit Shukla
1. Department of Forest Products, Wood Science and Technology (Composite Wood), Forest Research Institute (FRI), Dehradun, Uttarakhand, India
2. Dr. YSP UHF Nauni, Solan, Himachal Pradesh, India

Akshay Pingale
Department of Forest Products, Dr. YSP UHF Nauni, Solan, Himachal Pradesh, India

Jayashree Behera
Department of Silviculture and Agroforestry, Dr. YSP UHF Nauni, Solan, Himachal Pradesh, India

Corresponding Author:
Jayashree Behera
Department of Silviculture and Agroforestry, Dr. YSP UHF Nauni, Solan, Himachal Pradesh, India

Utilization of Kattha (*Acacia catechu*) extracted wood chips in combination with PF (Phenol-Formaldehyde) resin as a binder to produce a medium-density particle board

Saurabh Sharma, Anil Negi, Mohit Shukla, Akshay Pingale and Jayashree Behera

DOI: https://doi.org/10.33545/26174693.2024.v8.i1Sd.319

Abstract
The primary purpose of this work was to investigate the physical-mechanical properties of particle boards manufactured from *Acacia catechu* (Khair) particles. They were made at two different pressures of 17.5 kg/cm^2 and 21 kg/cm^2 with 10% and 12% resin content. Their physical qualities (moisture content, density, water absorption, general swelling, and thickness swelling), as well as mechanical properties (Modulus of rupture, Modulus of elasticity, Internal bonding, Screw pullout strength), were evaluated. The particle board densities ranged from 0.69 to 0.76 g/cm^3. The highest physical and mechanical properties were found in particle boards manufactured from kattha-extracted wood chips of khair at 21 kg/cm^2 and 10% resin content. The chemical elements of wood had the greatest influence on the qualities of the particle boards produced. The results showed that waste material can be used to make high-quality particle boards with excellent strength and dimensional qualities, indicating the necessity for further research in this area. Additional treatments, such as coating the surface with melamine-impregnated paper or chemical alteration of particles, may be required to improve panel quality, particularly dimensional stability.

Keywords: *Acacia catechu*, composites, impregnated, Kattha and particle boards

Introduction

The three main types of wood-based panels created in India are plywood, blockboard, flush door, and particle boards (Pandey *et al*., 2011) [11]. Demand for such items is increasing significantly since, in addition to their physical and mechanical capabilities, they have an advantage over solid wood. Particle board is an excellent option to repurpose forest and industrial wood waste since it is similar to wood and can be created from a wide variety of softwood and hardwood species. Particle board manufacturing is sustainable due to the quantity of raw resources, processing, and product qualities (Lee *et al*., 2022) [8]. Particle boards will have a huge demand in wood-based sectors as an alternative to solid wood goods due to carbon emissions and dwindling forest resources within the country. Composite wood materials, notably particle board, are increasingly being used in construction, cabinets, tabletops, vanities, sliding doors, speakers, table tennis, stair treads, kitchen worktops, labs, and other industrial products (Alam *et al*., 2015). Marginal R&D efforts, both in industry and at the institutional level, are potential causes of India's particleboard sectors' poor growth. The majority of Khair, however, is used to make kattha and cutch (a dyeing and preservation agent) (Tewari, 1994) [20].

Khair heartwood is inherently long-lasting, making it a useful economic structural timber. This species has been classed as major timber and is the primary choice for permanent buildings (ISI, 1962) [6]. The primary elements of heartwood range from 4 to 7 per cent and are dispersed throughout the heartwood from root to branch. This can be found throughout India in dry mixed forests on a range of geological formations and soils. The third commodity is acquired as kheersal, a white powder that appears as a deposit in the wood. It is specifically used to cure coughs and sore throats (Siva, 2007) [17]. Uday *et al.* (2011) [21] evaluated *Melia dubia* potential for plywood fabrication and discovered that type-B surface veneers may be made by peeling and drying without significant degradation.

Particle boards can be made from any lignocellulosic source, including underutilised wood species (e.g. *Acacia catechu*). Nasser (2012) [10] researched *A. catechu* basic qualities and potential as a raw material in the fabrication of composite panels. *A. catechu* is a hardwood with a high specific gravity of 0.874g cm^{-3} in 29-year-old trees (Mayuree, 1990) [9]. Except for the most wet and arid areas of India, the species can be found all over the country. There is no information on the utilisation of this species other than for fuel and the extraction of kattha and cutch (Tewari, 1995) [19]. It is the most important source of catechu (a medicinal herb) and cutch. The bark of fast-growing *Acacia* species can be ground into a powder and used to manufacture PVC composites, which might be used as a low-cost substitute to wood while preventing deforestation. To make testing samples, compression moulding was utilised. Tensile strength and percentage elongation at break dropped as bark flour content rose, whereas modulus increased. The storage modulus (E) rose dramatically with the addition of filler (Saini *et al*., 2010) [15]. At a wood/cement ratio of 1:2.5, the addition of 2% aluminium sulphate or magnesium chloride improved board characteristics (Wan-Asma-Ibrahim and Rahim-Sudin, 1990) [12].

If pressed at a density of 750 kg m^{-3}, all of the species under consideration can be used in the particle board industry; however, their dimensional stability properties may be improved by additional treatments, such as coating surfaces with melamine-impregnated papers or laminates to achieve a more stable product (Hegazy and Aref, 2010) [5]. IS 3087:2005 (Iwakiri *et al*., 2012) [7] was used to test the boards, which explored the manufacturing of homogeneous and multilayer particleboard from *Melia azedarach* (*Cinnamomum*) and *Pinus taeda* with various resin concentrations. Particle board, which is similar to wood in quality and comprises a wide range of species, enables the use of mixed plantation species. By Indian Standard Specification (IS 2380-1977), Choudhary *et al.* (2015) [3] conducted a study that was primarily concerned with evaluating the physical and mechanical characteristics of particleboard made from admixtures of *Populus deltoides* and *Melia composita* at various proportion levels and resin contents.

Classification of Particle Board

Particle board is composed of distinct particles of wood or other lingo-cellulosic material which is bonded together with synthetic resin adhesive. The particle may be fine sliver-like components approaching fibre and fibre bundle, slivers produced by hammers milling wood, planner shaving. Particle board can also be called a board material manufactured from particles of wood or other lignocellulose material, agglomerated, formed, and pressed together with an organic binder with one or more agents like heat, pressure, moisture, and catalyst.

The classification of particle boards is depicted below in Table No. 1.

Table 1: Classification of Particle boards

Sl. No.	Basis of Classification	Categories	Range/Type
1.	Density	Low	< 0.4 gm/cm^3
		Medium	0.5-0.9 gm/cm^3
		High	0.9-1.2gm/cm^3
2.	Formation	Flat Platen Pressed	Single Layer
			Three Layer
			Multi-Layer
		Extruded	Solid Core
			Hollow Core
		Veneered	
		Pre-laminated	

Materials and Methods

Lignocellulosic Raw Material

The raw material used for the preparation of particles was offcuts of Khair (extracted), derived during the making of kattha *i.e. Acacia catechu*.

Chemical Raw Material

The chemical used for the preparation of PF (phenol-formaldehyde) resin is:

Phenol
Formalin
Sodium hydroxide

Methodology

1. Particle preparation
2. Preparation of resin
3. Analysis of resin
4. Resin blending
5. Drying of resin blended particle
6. Mat formation
7. Hot pressing
8. Conditioning
9. Preparation of samples from boards for different test
10. Testing of samples

The most important factor in particle board manufacture is particle preparation. Since the properties of the final product depend on the type of particle used. Particle geometry (shape and size) has its due effect on the board's properties.

Particle preparation

Particles were prepared from dark (kattha extracted) wood chips of *Acacia catechu* (khair). Wood chips of Khair were brought from the kattha and cutch factory in H.P. state & were used for particle preparation:

1. Chipping.
2. Grinding.
3. Screening of particles.
4. Drying of particles

Chemical Raw Material

Phenol-formaldehyde (PF) resin preparation

In a bath of boiling water, three phenol bottles were heated. The flask was then filled with 2500 g of phenol, 3000 ml of formalin, and 3000 ml of water. By adding 125 g of sodium

hydroxide (NaOH) flakes diluted in 150 ml of water, the pH of the entire solution was kept between 9 and 9.5.
The solution-filled spherical flask was placed on a pan of boiling water, and the reaction was watched until it occurred. When the solution started to bubble for the first time, the true reaction began.
For 30 minutes, the solution was refluxed. The resin was chilled for a whole day. A variety of components and factors were examined in the cooled resin analysis.

Resin evaluation
To gather information on the different resin production parameters, six tests were conducted. The exams are listed below:

The resin's solid composition
The following formula was used to determine how much solid resin was present in 100 ml of the resin solution:

$$\text{Solid content \%}=\frac{\text{Weight of the solid resin}}{\text{Weight of liquid resin}}\times 100 \quad (1)$$

Ash content of the resin
The amount of inorganic particles in 100 g of solid resin is known as the ash content. It is calculated as follows and expressed in percentages:

$$\text{Ash content (\%)} = \frac{\text{Weight of the ash}}{\text{Weight of solid resin}}\times 100 \quad (2)$$

Water tolerance
The amount of water needed to precipitate a specific amount of resin is known as the water tolerance.

$$\text{Water tolerance of the resin}=\frac{V_2}{V_1} \quad (3)$$

pH
Using pH indicator paper, the pH was measured and determined to be 10.

Flow time
Ford cup viscometer was used to test the flow rate. It is the amount of time the resin needs to flow through the Ford cup. Seconds are used to measure it. Water was observed to flow for an average of 11.15 seconds, while resin flowed for an average of 15.79 seconds.

Viscosity
A fluid's resistance to gradual deformation by shear or tensile stress is measured by its viscosity. A viscometer is used to determine viscosity.

Specific gravity
A substance's specific gravity is calculated by dividing its density (in this case, resin) by the density of water, which serves as a standard. The weight of the resin and water in the relative density (RD) bottle is used to compute it. The formula is as follows:

$$\text{The specific gravity of resin}=\frac{\text{Weight of resin}}{\text{Weight of water}}\times 100 \quad (4)$$

Amount of resin needed for each board
For 10% of resin content:

$$\text{10\% of 2000 gm material} = \frac{10}{100} = 200\text{ gm} \quad (5)$$

Since the resin is 35% solids, the amount of resin needed per board is as follows:

$$\text{Weight of resin} = \frac{200\times100}{35.04} = 570.77\text{ gm} \quad (6)$$

When the resin content is 12%:

$$\text{12\% of 2000 gm material} = \frac{1200}{100}\times 2000 = 240\text{ gm} \quad (7)$$

Since the resin manufactured contains 35% solids, the quantity of resin needed per board is as follows:

$$\text{Weight of resin} = \frac{240\times100}{35.04} = 684.93\text{ gm} \quad (8)$$

Blending of resin
For particleboards, about 2000 gm of dried *Acacia catechu* wood chips were obtained; 25g more was taken because some material is lost during the blending process. Additionally, 5g extra resin was applied. In a rotary blender, the resin was sprayed onto the particle at a pressure of 100 lbs/in^2.

Drying
After that, air drying was used to achieve a moisture content of 6-8% for the resin-blend particles. After being mixed, the resin-infused particles were then evenly distributed on lengthy aluminium sheets for 24 hours. In order to properly dry the particles before using them in the mat-formation process.

Mat formation
Wax was added after the caul plates as a whole were heated up in a hot press. Then a 2" x 21" wooden frame was set on top of them. The resin-mixed particles were levelled from the edges to the centre and evenly distributed to form a mat in the wooden frame. Using a levelled wooden board, the particles were manually pre-pressed for two minutes before the wooden frame was removed. The mat was covered with a second caul plate that had been applied with wax. The mat was then retained in the press, sandwiched between two caul plates.

Hot pressing
Before being crushed in a hot press at pressures of 17.5 kg cm^{-2} and 21 kg cm^{-2}, the mats were pre-fixed at a temperature of 150 °C for 15 minutes.

Conditioning
The particle boards were taken out of the hot press and allowed to cure for two days at room temperature and humidity before being sampled. The boards were put on top of one another, and the entire stack was weighted for two days.

Making test specimens for each board
The medium-density particleboard test specimens' sizes and numbers for various tests are listed below (Table 2). Also described is the specimen dimension as per IS 3087:2005.

Table 2: Specimen Dimension

Sl. No	Parameters	No. of specimen samples from each board	Size of each test specimen	IS Standards
1	Density	2	150mm ×75mm	IS 2380:1977 (part III)
2	Moisture Content	2	150mm ×75mm	IS 2380:1977 (part III)
3	Water Absorption	2	100mm ×200mm	IS 2380:1977 (part XVI)
4	General Swelling	2	150mm ×75mm	IS 2380:1977 (part XVII)
5	Surface Swelling	2	150mm ×75mm	IS 2380:1977 (part XVII)
6	MOR and MOE	2	24×thickness+50mm	IS 2380:1977 (part IV)
7	Screw Withdrawal Resistance	1	150mm ×75mm	IS 2380:1977 (part XIV)

(MOE = modulus of elasticity, MOR = modulus of rupture)

Methods of testing the board

Particle board standards in India

The following Table no. 3 lists the minimal requirements for particle boards for various physical and mechanical qualities:

Table 3: Minimum requirement according to IS 3087:2005

Sl. No.	Properties	Flat Pressed Single Layer
1.	Density Variation, per cent	±10
2.	**Water Absorption, per cent**	
	a) 2h soaking	25
	b) 24h soaking	50
3.	**Linear Expansion (Swelling in water), 2h soaking, percent**	
	a) Length	0.5
	b) Width	0.5
4.	Thickness swelling, percent,2h soaking	10
5.	Swelling in thickness due to surface absorption, per cent	9
6.	**Modulus of rupture, N/mm²**	
	a) Average	11
	b) Minimum	10
7.	**Modulus of elasticity, N/mm²**	
	a) Average	2000
	b) Minimum	1800
8.	**Screw withdrawal Strength, N**	
	a) Face	1250
	b) Edge (foe thickness > 12mm)	850

The moisture content of the board

The following formula calculates the moisture content as a percentage of the oven-dry mass:

$$\text{Moisture Content \%} = \frac{M_1 - M_0}{M_0} \times 100 \quad (9)$$

Where,

M_1= initial mass, M_0= oven-dry mass

The board's density, each test specimen's dimensions, and each specimen's weight were all measured with an accuracy of not less than +/- 0.2% and +/- 0.3%, respectively.

Calculation

$$\text{Density} = \frac{\text{Massoftestspecimen (gm)}}{\text{Length}\times\text{Width}\times\text{Thickness}} \quad (10)$$

Water absorption

Each test specimen's absorption of water after two and twenty-four hours was calculated. This is how it is put:

$$\text{Water Absorption \%} = \frac{M_1 - M_0}{M_0} \times 100 \quad (11)$$

Where,

M_1=initial mass of test specimen before submersion

M_0= oven-dry mass of test specimen after submersion

Swelling resulting from widespread absorption

The average values of thickness, length and width were obtained for the changes in thickness, length, and width as a percentage of the original average thickness, length, and width. It is expressed as follows:

$$\text{Swelling in thickness \%} = \frac{T_0 - T_1}{T_1} \times 100 \quad (12)$$

$$\text{Swelling in length \%} = \frac{L_0 - L_1}{L_1} \times 100 \quad (13)$$

$$\text{Swelling in width \%} = \frac{W_0 - W_1}{W_1} \times 100 \quad (14)$$

Swelling resulting from surface absorption

As a proportion of the initial average thickness, length, and width, the average values of thickness, length, and width were derived. It is stated in the following way:

$$\text{Swelling in thickness \%} = \frac{T_0 - T_1}{T_1} \times 100 \quad (15)$$

Where,

T_1=Average thickness before the experiment

T_0=Average thickness after the experiment.

Test for static bending (modulus of rupture)
Specimen Size
Length = 24 times the board's thickness plus 50 mm; width = 5 mm to 6 mm or 6 mm and above to 75 mm; thickness = the full thickness of the board. The dimensions were measured with an accuracy of at least 0.3% for length, breadth, and thickness.

Span and support
For each test, the span (the distance between the centres of the supports) was 24 times the nominal thickness. The support was set up in a way that prevented the specimen from being significantly crushed during the test. With rollers and plates under the specimen, the support could be either rounded or knife-edged.

Rate of loading
The testing machine's moving crosshead was used to apply the load continuously during the test at a constant rate of motion, and the load was computed as follows:

$$N = ZL^2/6t \qquad (16)$$

Where,
N = rate of loading in cm/min
Z = unit rate of fibre strain of outer fibre length/minute = 0.005,
L = span in cm
t = thickness of the specimen in cm

Calculation
For each specimen, the modulus of rupture was determined as follows:

$$N = 3PL/2bd^2 \qquad (17)$$

Where MOR is the modulus of rupture, P is the load in kilogrammes, b is the specimen's breadth in millimetres, L is its span length, and d is its thickness in millimetres.

Internal bonding test: tensile strength perpendicular to the surface: For each specimen, the stress at failure was computed based on the maximum load. The following formula was used to determine the tensile strength perpendicular to the surface:
Tensile strength perpendicular to the surface ($N\ mm^{-2}$) = Load in kg × 9.8/ Area of the specimen in mm^2 (18)

Test for screw withdrawal resistance
The specimen retaining fixture was fastened to the testing device's lower plate.
The specimen was placed inside the fixture, which is fastened to the testing machine's upper platen and has a slot for the screw head to engage with ease.

Statistical evaluation
According to Gomez and Gomez (1984) [4], a statistical analysis of all the data resulting from the current inquiry was performed.

Results and Discussion
A total of 4 types of boards were prepared using *Acacia catechu* kattha extracted wood chips with 10 and 12% resin content at 17.5 and 21 kg/cm^2 pressure for 15 minutes. The details of the boards prepared are given below in Table No. 4.

Table 4: Details of the Particleboards

Sl. No	Board No (Sample No)	Resin Content	Pressure used
1	1	12%	21 kg/cm^2
2	2	10%	21 kg/cm^2
3	3	12%	17.5 kg/cm^2
4	4	10%	17.5 kg/cm^2

Physical properties
The values of different physical characteristics, such as moisture content, density, water absorption, swelling per cent, and swelling owing to surface absorption of particle boards made from *Acacia catechu* with varying pressures and 10% and 12% content, are shown in Tables no. 5, 6, 7 and 8 below, respectively. The calculations followed the IS specification.

Table 5: Moisture content and density of *Acacia catechu* particle boards at various resin concentrations and pressure.

	Sl. No	Initial Wt (Mi) (gm)	Oven Dry Wt (Mo) (gm)	M.C. %	M.C. % Avg	Volume (cm^3)	Density (g/cm^3)	Density Avg.
1	1a	84	81	3.70	3.46	129.8	0.64	0.69
	1b	96	93	3.22		126.7	0.75	
2	2a	75	74	1.35	4.05	99.90	0.74	0.76
	2b	80	75	6.66		93.99	0.79	
3	3a	85	83	2.40	2.34	118.28	0.70	0.72
	3b	89	87	2.29		116.33	0.74	
4	4a	83	80	3.75	4.07	111.6	0.71	0.72
	4b	95	91	4.39		124.28	0.73	
SD					0.81			0.03
CV					23.30			3.98

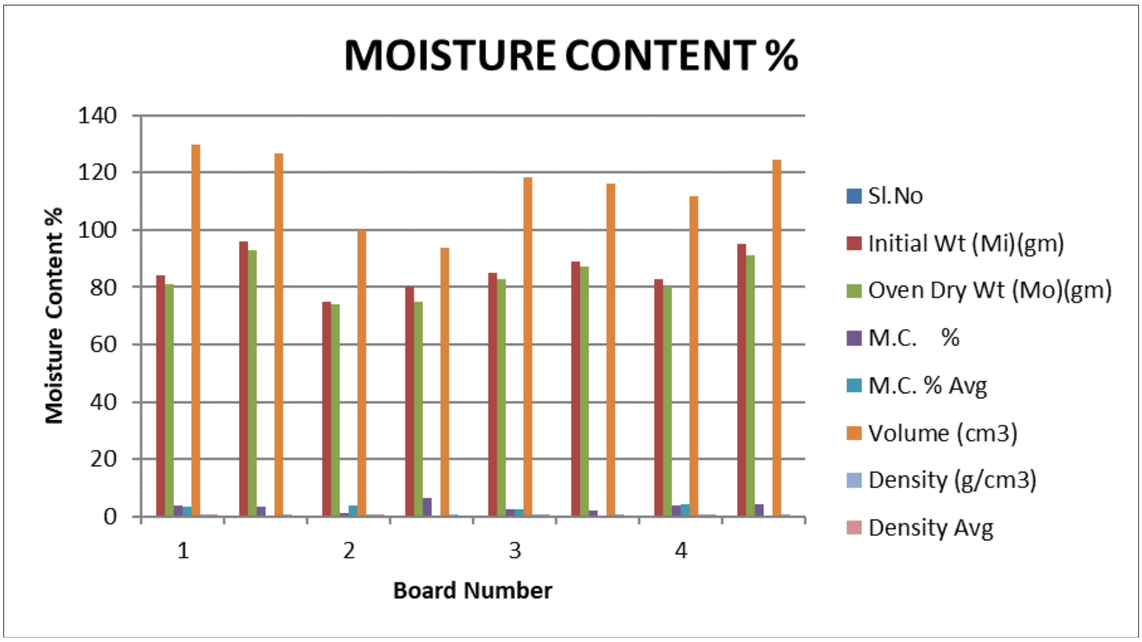

Fig 1: Moisture content of the board samples.

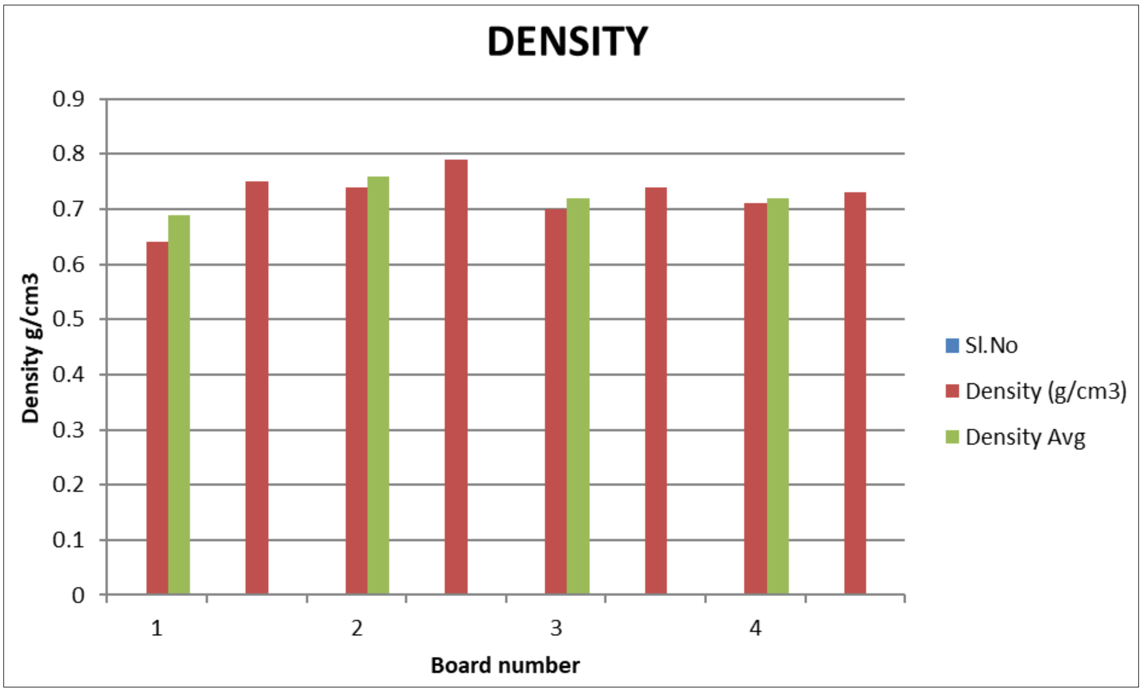

Fig 2: Density of the Board Samples.

Particleboards' average moisture content ranged from 2.34% to 4.07%. Board 4 had the largest percentage of moisture content, whereas Board 3 had the lowest. Particle boards' average density ranged from 0.69g/cm^3 to 0.76g/cm^3. Board 2 displayed the highest density, whereas Board 1 displayed the lowest. All blocks differed 0.81 from the average moisture content value according to the 0.81 standard deviation of moisture content. The variance coefficient was 23.30, which indicates that there is a 23.30% dispersion around the mean.

Similar to that, the average variance of density across all blocks was 0.03, or its standard deviation. The level of dispersion around the mean was 3.98 per cent, as indicated by the value of the coefficient of variation. The current findings were consistent with those of Warmbier *et al.* (2013) [22], who investigated the impact of density and resin content on the mechanical characteristics of particleboards with a willow (*Salix viminalis*) core layer. Particle boards' internal bond (IB), modulus of elasticity (MOE), and modulus of rupture (MOR) were studied. According to quadratic functions, the results demonstrated that these attributes grew as board density and resin content rose.

Table 6: Water absorption of *Acacia catechu* particle boards at various resin concentrations and pressure.

Board No	Sl. No	Initial Wt (gm)	After 2hr Wt (gm)	After 24hr Wt (gm)	WA% after 2hr	WA% after 2hr Avg	WA% after 24hr	WA% after 24hr Avg
1	1a	144	211	228	46.52	49.74	58.33	60.79
	1b	147	225	240	53.06		63.26	
2	2a	147	213	228	44.89	46.28	55.10	57.02
	2b	151	223	240	47.68		58.94	
3	3a	141	213	228	51.06	51.18	61.70	61.77
	3b	152	230	246	51.31		61.84	
4	4a	134	216	225	61.19	56.10	67.91	64.90
	4b	147	222	238	51.02		61.90	
SD						4.07		3.24
CV						8.01		5.31

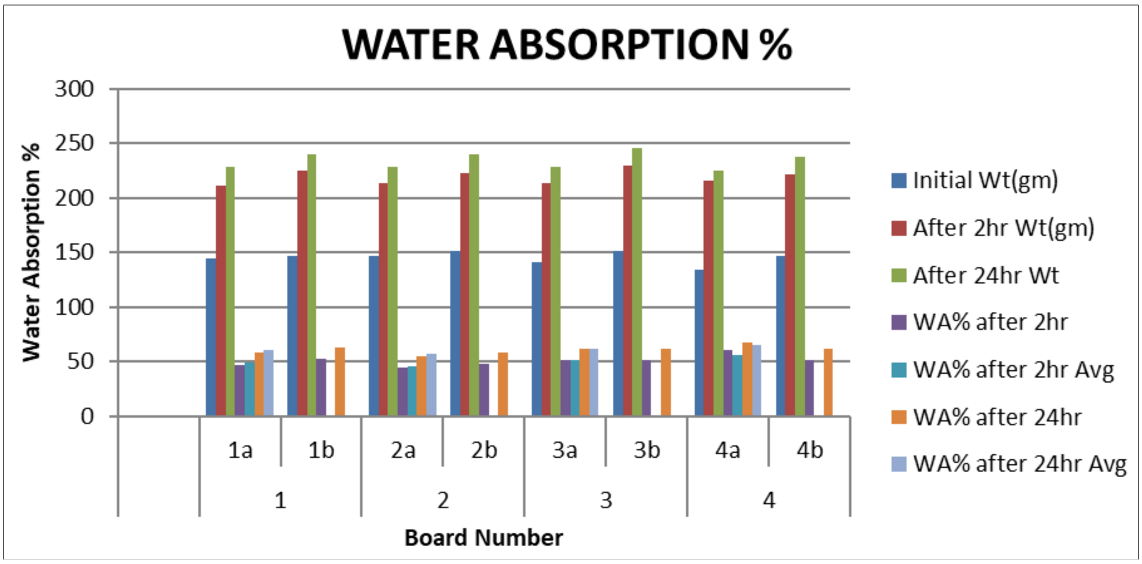

Fig 3: Water Absorption of the board samples.

Board 2 from *Acacia catechu* has water absorption values of 46.28% and 57.02%, which are within the critical values for 2 hours and 24 hours as per IS 3087:2005. After two hours, all blocks had a 4.07 standard deviation in terms of water absorption, which is 4.07 more than the average (2-hour water absorption value). The level of dispersion around the mean was 8.01%, as indicated by the coefficient of variation of 8.01. The standard deviation of water absorption after 24 hours was also 3.24; all blocks varied by 3.24 from the average water absorption value (24 hours). The level of dispersion around the mean was 5.31%, as indicated by the coefficient of variation's value of 5.31. The water absorption ratings for other acacia-based boards were high. The intrinsic property of oil palm as a hygroscopic material causes high water absorption in goods (Sulaiman *et al.*, 2009) [18].

Table 7: Swelling percentage of *Acacia catechu* particle boards with various resin content and pressure.

Swelling Percent							
Board No	Sl. No	In Length (mm)	Length Avg	In Width (mm)	Width Avg	In Thickness (mm)	Thickness Avg
1	1a	0.46	0.69	0.53	0.60	18.18	19.53
	1b	0.93		0.67		20.83	
2	2a	0.53	0.46	0.26	0.53	19.4	15.67
	2b	0.40		0.80		11.95	
3	3a	0.19	0.22	0.39	0.46	19.04	18.56
	3b	0.26		0.53		18.09	
4	4a	0.13	0.16	1.07	0.73	12.4	15.29
	4b	0.19		0.39		18.18	
SD			0.24		0.28		2.10
CV			63.41		63.15		12.18

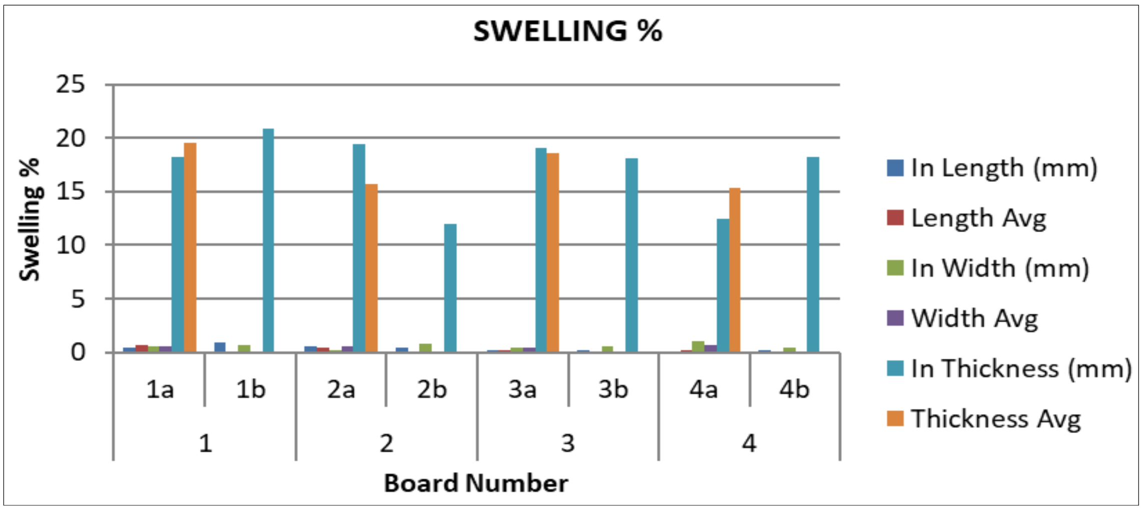

Fig 4: Linear expansion of the board samples.

Board 4 from *Acacia catechu* has a general swelling value of 0.16% for length, Board 2 has a linear swelling value of 0.53%, and Board 4 has a thickness swelling value of 15.29%, all of which are within the crucial value for a 2-hour soaking asset in IS 3087:2005. The linear and thickness swelling values for other boards with variable resin content and pressure were rather high. All of the blocks' lengths varied by 0.24 standard deviations from the average value. The level of dispersion around the mean was 63.41%, as indicated by the coefficient of variation, which was 63.41.

The standard deviation of width was also 0.28, meaning that each block differed by 0.28 from the average width value. The level of dispersion around the mean was revealed to be 63.15% by the coefficient of variation, which was 63.15. Additionally, the thickness standard deviation was 2.10, meaning that every block differed by that much from the average thickness value. The level of dispersion around the mean was 12.18%, as indicated by the coefficient of variation, which was 12.18. The qualities of particleboard made from *Neolamarckia cadamba* and *Leucaena leucocephala* in a 50:50 ratio with melamine urea-formaldehyde were reported by Rahman *et al.* (2019) [13] at various resin percentages (10, 12, and 14%) and particle sizes (1 mm, 2 mm, and unscreened particle). The findings demonstrated that increasing resin concentration and particle size considerably enhanced the mechanical characteristics of particle boards. As resin content rose, the thickness swelling value decreased, improving the board's stability.

Table 1: Swelling caused by surface absorption of *Acacia catechu* particle boards at various resin concentrations and pressure.

Board No	Sl. No	Initial Thickness Average (mm)	Thickness after 2hr Average (mm)	Swelling after 2hr(mm)	% Swelling after 2hr	% Swelling Average
1	1a	11.62	13.23	1.61	13.85	14.13
	1b	11.10	12.7	1.60	14.41	
2	2a	9.85	10.67	0.82	8.32	4.73
	2b	10.35	10.47	0.12	1.15	
3	3a	10.30	11.42	1.12	10.87	12.05
	3b	10.42	11.8	1.38	13.24	
4	4a	10.25	12.38	2.13	20.78	16.30
	4b	10.48	11.72	1.24	11.83	
SD						5.03
CV						42.57

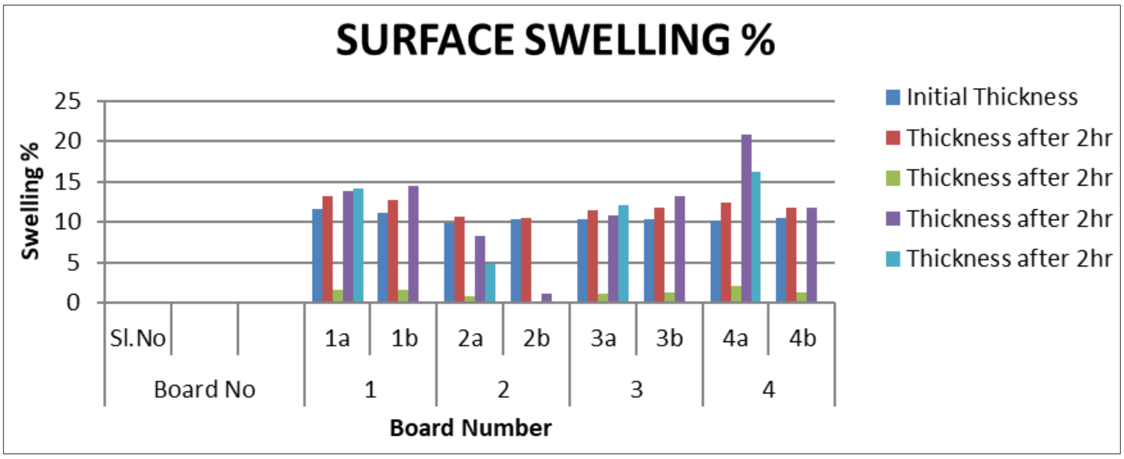

Fig 5: Surface swelling of the board samples.

According to IS 3087:2005, all boards, except Board No. 2, have surface swelling over the critical value. Board 2 displays the lowest surface swelling value of all the boards at 4.73%. All of the blocks differed by 5.03 from the average value of surface swelling, which is the standard deviation of surface swelling. The coefficient of variation, which is 42.57, indicates that there is a 42.57% dispersion around the mean. The fact that oil palm is a naturally hygroscopic substance may be the cause of the thickness of swelling in goods (Sulaiman *et al*., 2009) [18].

Mechanical properties: The mechanical characteristics of particleboards made from *Acacia catechu* particles at various resin contents and pressures, including static bending strength, tensile strength perpendicular to the surface, and screw and nail pullout strength, are shown in Tables 9 and 10 below, respectively.

Table 2: Static Bending Strength of *Acacia catechu* particle boards at different resin content & pressure.

Board No	Sl. No	Max. Load (N)	MOR (N/mm^2)	MOR Avg (N/mm^2)	MOE (N/mm^2)	MOE Avg (N/mm^2)
1	1a	297	13.33	13.20	1548.52	1642.31
	1b	305.50	13.08		1736.11	
2	2a	275.50	14.57	18.17	1506.22	2021.82
	2b	477.50	21.77		2537.43	
3	3a	393	17.85	12.13	1863.16	1394.98
	3b	139.50	6.42		926.81	
4	4a	396	17.93	16.15	1917.54	1681.07
	4b	312	14.37		1444.61	
SD				2.78		257.81
CV				18.63		15.30

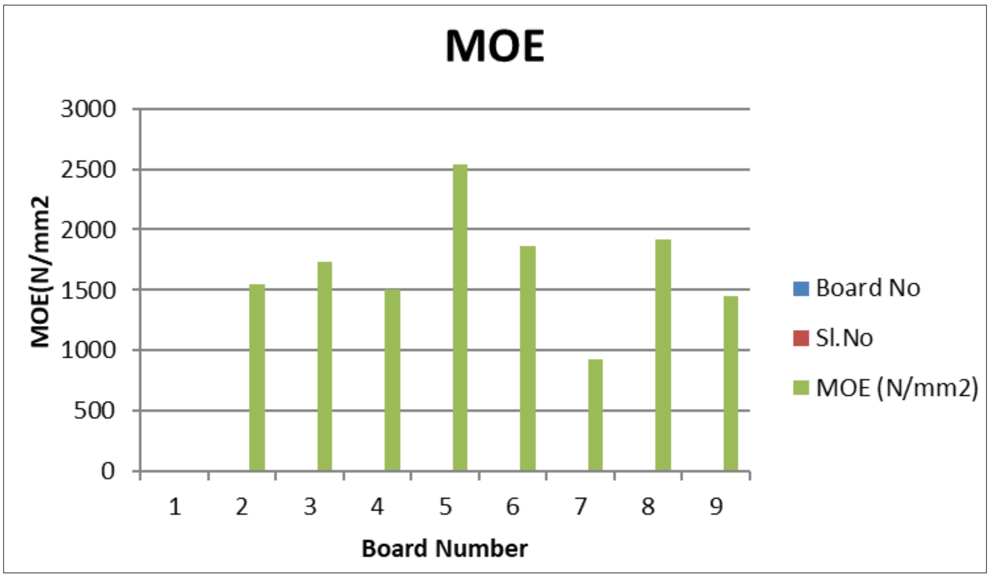

Fig 6: Modulus of Elasticity of the board samples

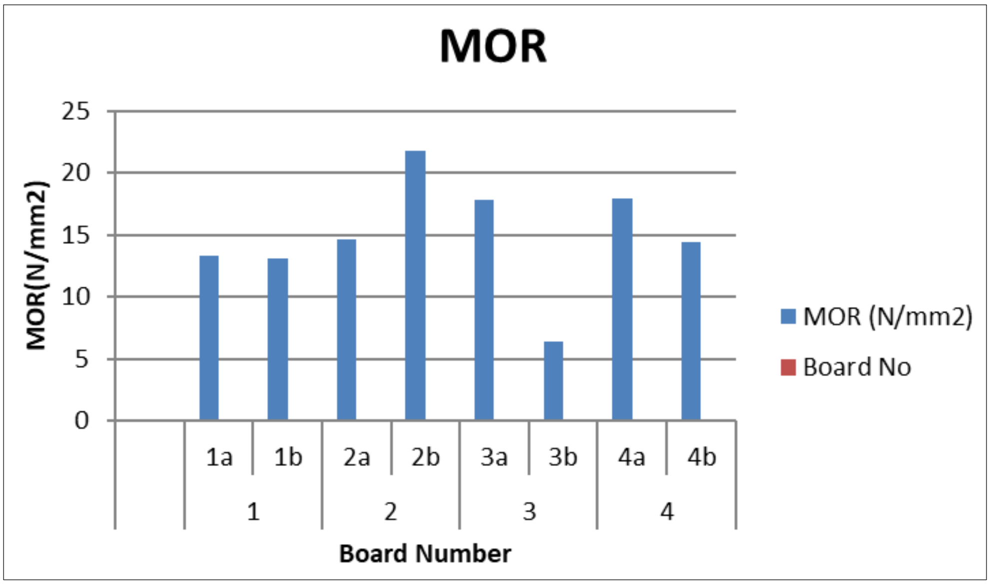

Fig 7: Modulus of Rupture of the board samples

Board 2 has the highest MOR and MOE values, 18.17 N/mm² and 2021.82 N/mm², respectively. All of the blocks' deviations from the average MOR value were 2.78, or the standard deviation of MOR. The level of dispersion around the mean was 18.63%, as indicated by the coefficient of variation of 18.63. Similar to this, the MOE's standard deviation was 257.81, meaning that every block differed by that amount from the length's average. The level of dispersion around the mean was 15.30%, as indicated by the coefficient of variation, which was 15.30. Samples of all boards passed the critical value for MOR and only Board No. 2 have passed the critical value MOE as per requirements of IS-3087-2005. Better values were obtained at Board no. 2 indicating that 10% resin & with a pressure of 21kg/cm² might be optimal for giving the best mechanical properties. The binding quality and performance of panels are influenced by the type and quality of resin (Ratkha *et al*., 2012, Salari *et al*., 2013, Anisuzzaman *et al*., 2014) [14, 16, 1].

Table 10: Tensile strength perpendicular to the surface of *Acacia catechu* particle boards at various resin concentrations and pressure.

Board No.	Sl. No.	Length (mm)	Width (mm)	Area (mm²)	Load (kg)	Load (N)	Tensile Strength (N/mm²)	Average Tensile Strength
1	a	50	50	2500	167	1597	0.63	0.74
	b	49.8	50	2490	217	2126	0.85	
2	a	49.8	49.8	2480	245	2401	0.96	1.28
	b	50	50	2500	410	4018	1.60	
3	a	49.5	49.4	2445.3	200	1960	0.80	0.88
	b	49.6	49.7	2465.1	242	2371.6	0.96	
4	a	49.4	49.4	2440.36	224	2195.2	0.89	0.92
	b	49.6	49.7	2465.12	242	2371.6	0.96	
SD								0.23
CV								24.08

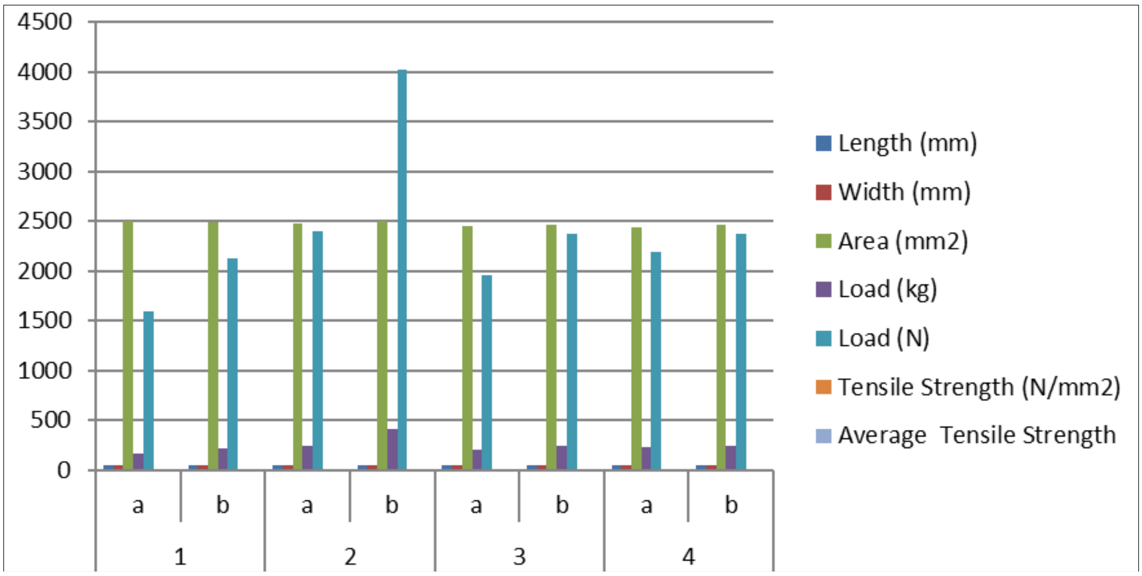

Fig 8: Tensile strength of the board samples

The particle and how it interacts with the adhesive determine the strength of the internal binding. Board 2 displays a value of 1.28 N/mm² in internal bonding, which is the highest value attained out of all the boards. The tensile strength's standard deviation was 0.23, meaning that each block differed by that much from the average value. The level of dispersion around the mean was 24.08 per cent, as indicated by the coefficient of variation. Additionally, for boards made with 12% resin content, the internal bond strength value lowers. Only Board 1 out of the boards that were made didn't match the requirements of IS.3087:2005. Other boards all met the minimal standard.

Table 11: Screw and nail withdrawal strength of *Acacia catechu* particle boards at various resin concentrations and pressure.

Board No.	Sl. No.	Withdrawal Load (kg/cm²)					
		Face			Edge		
		Screw 1	Screw 2	Avg	Screw 1	Screw 2	Avg
1	1	182	144	163	117	161	139
2	1	230	266	248	250	251	250.5
3	1	184	185	184.5	232	235	233.5
4	1	281	270	275.5	230	256	243
SD				52.77			52.13
CV				24.23			24.07

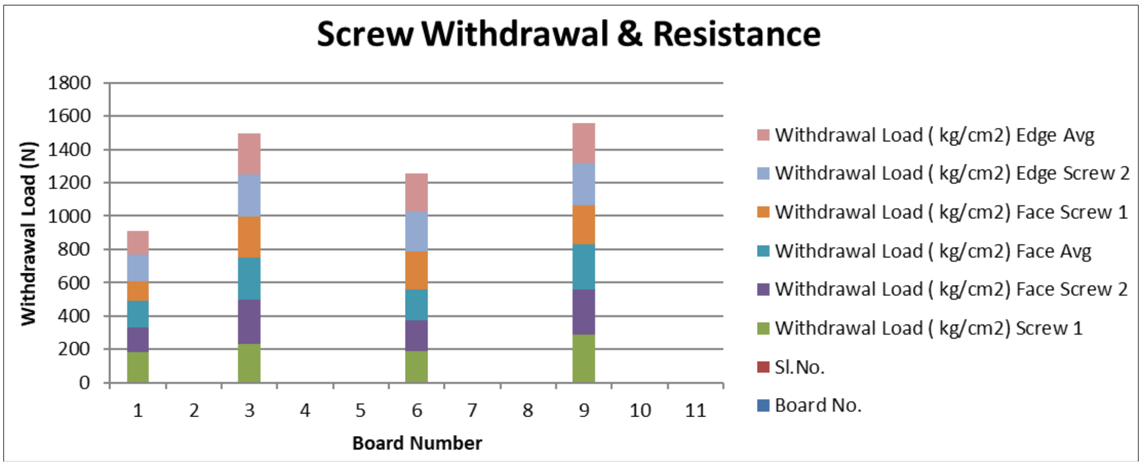

Fig 9: Screw Withdrawal Strength of the board samples

Samples 4 & 2 of the *Acacia catechu* boards displayed the highest results for screw withdrawal resistance, or 275.5 kg/cm^2 for the face and 250.5 kg/cm^2 for the edge, respectively. The face's standard deviation was 52.77, and each block differed from the face's average by 52.77. The coefficient of variation was 24.23, indicating a dispersion of 24.23% around the mean. The edge's standard deviation was also 52.13, meaning that every block diverged from the average edge by 52.13. The level of dispersion around the mean was 24.07%, as indicated by the coefficient of variation's value of 24.07. All of the samples from boards 1, 2, 3, and 4 complied with IS 3087:2005's specifications. Board no. 1 had the lowest face screw withdrawal resistance and the same edge screw withdrawal resistance. According to Chaharmahali *et al.* (2008) [2], this is because the phases are incompatible with one another. The overall physical and mechanical properties of all the particleboards produced are summarized below in Tables no. 12 and 13.

Table 12: Physical properties of *Acacia catechu* particle boards with various resin concentrations and pressure.

Board No.	Parameters					
	Moisture Content	Density	Water Absorption		Thickness Swelling (In mm)	Surface Swelling (In mm)
			2hrs	24hr		
1	3.46	0.69	49.74	60.79	19.53	1.60
2	4.05	0.76	46.28	57.02	15.67	0.47
3	2.34	0.72	51.18	61.77	18.56	1.25
4	4.07	0.72	56.10	64.90	15.29	1.68

For Board, Number refer to Table No. 4.

Table 13: Mechanical properties of *Acacia catechu* particle boards at various resin concentrations and pressure.

Board No.	MOR (N/mm^2)	MOE (N/mm^2)	Screw Withdrawal Test (N)	
			Face	Edge
1	13.20	1642.31	163	139
2	18.17	2021.82	248	250.50
3	12.13	1394.98	184.5	233.50
4	16.15	1681.07	275.5	243

For Board, Number refer to Table No. 4.

Conclusion

The suitability of particle board made from kattha-extracted chips converted into *Acacia catechu* (Khair) particles was examined in this study using varying percentages of phenol-formaldehyde (PF) resin and at varied pressures. The results showed that suitable particle board can be prepared from particles of kattha extracted wood chips of *Acacia catechu* (Khair) with 10% resin content, 150°c temperature at 21 kg/cm^2 specific pressure for 15 minutes, which met most of the requirements of medium density particle board, namely modulus of rupture, modulus of elasticity, tensile strength perpendicular to the grain (Internal Bond), and screw holding strength as per Indian Standard IS 3087:2005 except physical qualities such as swelling which can be improved by adding appropriate sizing material during board preparation. Because particleboards are made from the waste material left behind after extracting kattha from *Acacia catechu* (Khair) wood chips, they may be a good substitute for solid wood. This will almost probably close the massive gap between demand and availability of solid wood.

Acknowledgement

The human resources required for the study were provided by the authors' colleagues at the Forest Research Institute (FRI). The authors gratefully acknowledge Negi, A. of the ICFRE's Directorate of Education in Dehradun for his immaculate advice. The laboratory personnel received the authors' sincere gratitude and best wishes for their assistance and support during the research.

References

1. Anisuzzaman SM, Bono A, Krishnaiah D, Noor Maizara I, Mansuit H. The performance of melamine urea-formaldehyde (MUF) based particleboard with wheat flour as filler. Journal Technology. 2014;68(1):61-69.
2. Chaharmahali M, Mehdi T, Saeed KN. Mechanical properties of wood plastic composite panels made from

waste fibreboard and particleboard. Polymer composites. 2008;29(6):606-610.
3. Choudhary CL, Negi A, Yadav SM, Sihag K. Role of resin content in the manufacturing of particleboard from mixed plantation species. International Journal on Biological Sciences. 1915;6:132-135.
4. Gomez KA, Gomez AA. Statistical Procedure for Agricultural Research. 2nd edition. Willey Inter science, New York; c1984.
5. Hegazy S, Ibrahim MA. Suitability of some fast-growing trees and date palm fronds for particleboard production. Forest Products Journal. 2010;60(7-8):599-604.
6. ISI. Indian Council of Forestry Research and Education, Dehradun. Khair (Acacia catechu). Forest Research Institute, Dehradun; c1962.
7. Iwakiri S, Matos JL, Trianoski R, Prata JG. Production of homogeneous and multilayer particleboard from Melia azedarach (*Cinamomo*) and Pinus taeda with different resin contents. Cerne. 2012;18(3):465-470.
8. Lee SH, Lum WC, Boon JG, Kristak L, Antov P, Pędzik M, *et al*. Particleboard from agricultural biomass and recycled wood waste: A review. Journal of Materials Research and Technology. 2022;20:4630-4658.
9. Mayuree D. Properties of medium-density fibreboard manufactured from extracted and unextracted Acacia Catechu wood chips. Ph.D. thesis. University Pertanian Malaysia, Serdang; c1990.
10. Nasser RA. Physical and mechanical properties of three-layer particleboard manufactured from the tree pruning of seven wood species. World Applied Sciences Journal. 2012;19(5):741-753.
11. Pandey CN, Nath SK, Sujatha D. Wood based panel products: technology road map. Journal of the Indian Academy of Wood Science. 2011;8(2):62-67.
12. Rahim-Sudin. WAN-Asma-Ibrahim. Journal of Tropical Forest Science. 1990;2:267-273.
13. Rahman W, Yatim A, Zin A, Kasim J, Yunus NYM. Effect of resin content and particle size on the properties of particleboard made of Neolamarkia and Leucaena particles. Bio Resources. 2019;14(3):6079-6087.
14. Ratkhe J, Sinn G, Harm H, Teischinger A, Weigl M, Muller U. Effects of alternative raw materials and varying resin content on mechanical and fracture mechanical properties of particleboards. BioResources. 2012;7(3):2970-2985.
15. Saini G, Bhardwaj R, Choudhary V, Narula AK. Poly (vinyl chloride)-Acacia bark flour composite: Effect of particle size content on mechanical, thermal, and morphological characteristics. Journal of Applied Polymer Science. 2010;117(3):1309-1318.
16. Salari A, Tabarsa T, Khazaeian A, Saraeian A. Improving some of the applied properties of oriented strand board (OSD) made from underutilised low-quality paulownias (Paulownia fortune) wood employing nano-SiO2. Industrial Crop and Products. 2013;42:1-9.
17. Siva R. Status of natural dyes and dye-yielding plants in India. Current Science. 2007;916-925.
18. Sulaiman O, Salim N, Hashim R, Yusof LHM, Razak W, Yunus NYM. Evaluation of the suitability of some adhesives for laminated veneer lumber from oil palm trunks. Material Design. 2009;30(9):3572-3580.
19. Tewari DN. A Monograph on Khair (Acacia catechu Wild). International Book Distributors, Dehradun; c1994.
20. Tewari DN. A Monograph on Khair (Acacia catechu Wild). International Book Distributors, Dehradun; c1995.
21. Uday DN, Sujatha D, Pandey CN. Suitability of Melia dubia for plywood manufacture. Journal of the Indian Academy and Wood Science. 2011;8(2):207-211.
22. Warmbier K, Wilczyński A, Danecki L. Properties of one-layer experimental particleboards from willow (*Salix viminalis*) and industrial wood particles; c2013.