



Suitability of Malabar Neem (*Melia dubia*) for Industrial Pulping and Bleaching: A Potential Substitute to Traditional Wood Resources



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Abstract: This study evaluates the pulping and bleaching characteristics of Malabar Neem (*Melia dubia*) sourced from Andhra Pradesh (A.P.) and Telangana regions as a potential alternate raw material for pulp and paper manufacturing. Laboratory-scale pulping trials were conducted to determine active alkali demand, screened pulp yield, Kappa number, and unbleached pulp characteristics. Bleaching performance was assessed using an D0(Eop)D1 sequence and compared with Casuarina, Subabul, Debarked Eucalyptus, and plant mixed chips collected from the mill. Results indicate that Telangana-region Malabar Neem exhibits higher screened yield, better oxygen delignification response, and lower bleach chemical consumption. Final bleached pulp properties demonstrate competitive brightness and superior strength characteristics compared to conventional hardwood species. The study confirms Malabar Neem—particularly from Telangana and Andhra region—as a viable supplementary raw material for hardwood-based chemical pulping.

Keywords: *Melia dubia*, pulping, bleaching, oxygen delignification, hardwood, paper manufacturing.

Introduction

The Indian pulp and paper industry relies extensively on hardwood species such as Casuarina, Subabul, and Eucalyptus for chemical pulping. Increasing raw material demand necessitates identification of alternate, fast-growing species with acceptable pulping behaviour and pulp properties. Malabar Neem (*Melia dubia*) has emerged as a promising candidate due to its rapid growth cycle, high productivity, and expanding plantation coverage in Andhra Pradesh and Telangana.

This study aims to evaluate the pulping behaviour, bleachability, and final pulp strength properties of Malabar Neem sourced from these regions and to compare its performance with both standard mill chips and other conventional hardwoods.

2. Material and Methods

2.1 Raw Material Collection

Fresh Malabar Neem chips were collected from the mill chipper house—for Andhra Pradesh region and Telangana region. Mill-reference species (Casuarina, Subabul, Debarked Eucalyptus,).

2.2 Chip Preparation and Testing

Chips were air-dried for uniform moisture and classified using a laboratory chip classifier. Bulk density was measured for all species prior to cooking.

2.3 Pulping

Active alkali levels were optimised to achieve a target Kappa of ~18 at an H-factor of 1085. Final cooks were performed at optimized alkali charges: 19.5% (A.P.) and 19.0% (Telangana). Standard pulping conditions—including cooking temperature (162°C), sulphidity, cooking aid, and cycle time—were applied.

2.4 Bleaching

Unbleached pulps were subjected to oxygen delignification (ODL) at 30 kg/t oxygen and alkali addition targeted to achieve pH 10.5. Screened ODL pulps were bleached using a Do–Eop–D1 sequence. Chlorine dioxide doses in Do and D1 were applied based on Kappa Factor (0.27) and brightness targets.

2.5 Testing Methods

Unbleached and bleached pulps were analysed for: - Kappa number - Viscosity - Brightness (% ISO) - Screened yield - Strength properties at 30°SR (Burst factor, Breaking Length, Tear factor)

3.0 Results and Discussion

3.1 Pulping Performance of Malabar Neem

The pulping performance of Malabar Neem was evaluated and compared with commonly used conventional hardwood species such as Casuarina, Subabul, and debarked Eucalyptus. The results summarized in Table 1 clearly demonstrate that Malabar Neem is technically suitable for kraft pulping under standard mill operating conditions.

Chip classification data indicate that Malabar Neem chips fall predominantly within the desirable size range of 15–25 mm, accounting for more than 40% of the total fraction, which is comparable to Casuarina and Subabul. The proportion of over-thick chips (+45 mm) and fines (–3 mm) remained low, suggesting good chipping characteristics and uniform liquor penetration during cooking. This chip size distribution is favorable for achieving consistent delignification and minimizing rejects.

Bulk density varied significantly among the species studied. Casuarina exhibited the highest bulk density (207 kg/m³), whereas Malabar Neem from Andhra Pradesh showed the lowest value (145 kg/m³). Lower bulk density generally reflects a more open wood structure, which facilitates faster chemical penetration and improved delignification kinetics. Despite its lower bulk density, Malabar Neem achieved efficient pulping with low rejects, indicating effective utilization of cooking chemicals.

Malabar Neem required an active alkali charge of 19.5% as Na₂O, which is comparable to Subabul and slightly higher than Casuarina and Eucalyptus. This higher alkali demand can be attributed to the wood's chemical composition and lignin characteristics. However, the residual effective alkali (REA) values remained within acceptable limits, confirming that the applied alkali charge was sufficient without excessive chemical consumption.

The kappa number obtained for Malabar Neem from Andhra Pradesh was the lowest (17.6) among all the species evaluated, indicating superior delignification efficiency under identical cooking conditions. Malabar Neem from Telangana also showed a competitive kappa number (18.3), comparable to Casuarina and Subabul. These results highlight the favorable response of Malabar Neem lignin to kraft pulping.

In terms of yield, Malabar Neem from Telangana produced the highest screened yield (51.2%), which is significantly higher than that of plant Subabul (47.5%) and comparable to Eucalyptus. Reject levels were consistently low (<0.3%) for both Malabar Neem samples, demonstrating good chip impregnation and uniform cooking. Unbleached pulp viscosity values for Malabar Neem remained above 15 cps, indicating minimal cellulose degradation and good pulp strength potential

3.2 Comparison of Key Pulping Parameters

A comparative assessment of critical pulping parameters further confirms the suitability of Malabar Neem as an alternative raw material. Although Malabar Neem exhibits lower bulk density than Casuarina, it compensates through improved delignification efficiency, as reflected by lower kappa numbers at comparable H-factors.

The screened yield advantage observed for Telangana Malabar Neem is particularly noteworthy, as higher yield directly translates into improved pulp mill economics. The combination of acceptable alkali requirement, low rejects, competitive kappa number, and high screened yield positions Malabar Neem favorably against established hardwood species used in the pulp and paper industry.

Table 1. Pulping Results of Malabar Neem and Conventional Species

S.NO	PARTICULARS	Unit	MALABAR NEEM		CASUARINA	SUBABUL	DB EUCALYPTUS
			AP	TELANGANA			
1	Malabar Neem	%	100.0	100.0		--	--
	Casuarina		--	--	100.0	--	--
	Subabul		--	--	--	100.0	--
	Debarked Eucalyptus (Regular)		--	--	--	--	100.0
	With bark Eucalyptus (Regular)		--	--	--	--	--
2	Dry material (Internal+ Depo Wood)		--	--	--	--	--
3	Chip Classification						
	+ 45 mm	%	2.7	Nil	0.7	0.0	Nil
	-45,+35 mm	%	5.5	3.0	1.5	1.0	0.3
	-35,+25 mm	%	20.0	23.7	5.2	9.2	3.7
	-25,+15 mm	%	42.3	45.4	34.2	47.0	30.2
	-15,+3 mm	%	27.3	27.0	55.5	40.8	63.9
	-3 mm(Dust)	%	2.2	0.9	2.9	2.0	1.9
4	Bulk Density (on OD Basis)	Kgs/M ³	145	162	207	150	166
5	Active Alkali as Na ₂ O	%	19.5	19.0	17.5	19.5	16.0
6	White liquor Sulphidity	%	20.92	19.35	20.78	19.61	19.74
7	Cooking temperature	°C	162	162	162	162	162
8	Cooking Aid	%	0.05	0.05	0.05	0.05	0.05
9	Cooking cycle	Hrs. Mts	3Hrs.31Mts	3Hrs.31Mts	3Hrs.31Mts	3Hrs.31Mts	3Hrs.31Mts
10	H. Factor	--	1085	1085	1085	1085	1085
11	R.E.A as Na ₂ O	Gpl	11.50	14.50	8.11	14.0	4.5
12	Kappa number	--	17.6	18.3	18.3	18.8	17.8
13	Total Yield	%	49.3	51.3	47.7	48.3	49.4
14	Total rejects	%	0.3	0.1	0.2	0.3	0.3
15	Screened yield	%	49.0	51.2	47.5	48.0	49.1
16	Unbleached Pulp Brightness	% ISO	26.7	32.8	24.8	26.5	29.4
17	Unbleached pulp viscosity	Cps	15.6	15.2	14.2	14.8	15.0

3.3 Bleaching Performance

The bleaching behaviour of Malabar Neem pulp was evaluated using a conventional Do–Eop–D₁ bleaching sequence, and the results are presented in Table 2. The oxygen delignification (ODL) stage showed efficient lignin removal for all species; however, Malabar Neem from Telangana exhibited the highest kappa reduction (57.4%), indicating superior response to oxygen delignification. This suggests that Malabar Neem lignin is more amenable to oxidative delignification, which is beneficial for reducing downstream bleaching chemical demand.

After the Do stage, Malabar Neem from Telangana achieved the highest brightness (75.6% ISO), outperforming debarked Eucalyptus and Subabul. This higher brightness gain at comparable chlorine dioxide dosage indicates better bleachability of Malabar Neem pulp.

One of the most significant observations is the lower overall chlorine dioxide consumption for Malabar Neem from Telangana. The total ClO₂ requirement (Do + D₁) was only 10.0 kg/t, which is substantially lower than Casuarina (14.5 kg/t) and Subabul (14.1 kg/t). Reduced chlorine dioxide consumption has both economic and environmental advantages, making Malabar Neem an attractive option for elemental chlorine-free (ECF) bleaching sequences.

All pulps achieved final bleached brightness in the range of 86–87% ISO, confirming that Malabar Neem pulp can meet standard brightness requirements for printing and writing grades. Bleached pulp viscosity values for Malabar Neem remained above 10 cps, indicating good preservation of cellulose integrity throughout the bleaching process

3.4 Strength Properties of Bleached Pulp

The strength properties of bleached pulps refined to 30°SR further validate the papermaking potential of Malabar Neem. Telangana Malabar Neem exhibited the highest burst factor (62.8) and an exceptional breaking length of 9949 m, surpassing all conventional species evaluated. These superior strength properties indicate strong fiber bonding and favourable fibre morphology.

Tear factor values for Malabar Neem were comparable to those of Eucalyptus and Subabul, demonstrating balanced strength characteristics suitable for a wide range of paper grades. The combination of high burst strength, excellent tensile properties, and acceptable tear resistance confirms that Malabar Neem pulp is well suited for high-strength paper and specialty grades.

Overall, the results clearly demonstrate that Malabar Neem, particularly from the Telangana region, is a technically viable and performance-competitive alternative hardwood raw material for kraft pulping and ECF bleaching applications

Table 2. Bleaching Results (Do–Eop–D₁ Sequence)

S.NO	PARTICULARS	Unit	MALABAR NEEM		CASUARINA	SUBABUL	DB EUCALYPTUS
			AP	TELANGANA			
I	OXYGEN DELIGNIFICATION STAGE						
a	Alkali added as NaOH	Kgs/T	18.3	18.3	18.3	18.3	18.3
b	Oxygen	Kgs/T	30.0	30.0	30.0	30.0	30
c	pH (Initial / Final)		12.0/10.6	12.0/10.7	12.0/10.8	11.7/10.6	11.8/10.8
d	Brightness	%, ISO	44.7	53.0	43.2	42.6	50.9
e	Viscosity	Cps	14.0	13.8	13.6	13.8	14.0
f	Kappa No.	Cps	8.9	7.8	10.2	9.1	9.8
g	Reduction of Kappa No.	%	49.4	57.4	44.3	51.5	44.9
II	Do STAGE:						
a	H ₂ SO ₄ added	Kg/T	18.3	18.3	18.3	18.3	18.3
b	Chlorine dioxide dosage	Kg/T	9.1	8.0	10.5	9.3	10.0
c	Kappa Factor (as active chlorine)		0.27	0.27	0.27	0.27	0.27
d	pH (Initial / Final)	--	2.7/2.4	3.1/2.8	2.9/2.7	2.8/2.6	2.3/2.1
e	Chlorine dioxide Consumed	Kg/T	9.08	7.95	10.45	9.28	9.98
f	Brightness	%ISO	70.1	75.6	67.0	68.1	72.9
III	Eop STAGE:						
a	Alkali added as NaOH	Kg/T	6.6	6.6	6.6	6.6	6.6
b	Hydrogen Peroxide (50%)added	Kg/T	10.0	10.0	10.0	10.0	10.0
c	pH (Initial / Final)	--	11.6/10.5	11.2/10.6	11.3/10.6	11.2/10.2	11.0/10.6
d	Oxygen dosage	Kg/T	5.0	5.0	5.0	5.0	5.0
e	Alkali Consumed	Kg/T	5.67	4.86	5.02	5.31	4.3
f	Hydrogen Peroxide Consumed	Kg/T	9.40	9.34	9.34	9.72	8.07
g	Brightness	%ISO	76.0	81.8	78.2	79.4	81.1
IV	D₁ STAGE:						
a	Chlorine dioxide dosage as Dioxide	Kg/T	5.0	2.0	4.0	3.5	2.5
b	pH (Initial / Final)	--	6.0/4.9	6.5/6.0	6.0/5.3	6.2/6.0	5.8/5.5
c	Chlorine dioxide Consumed	Kg/T	4.98	1.96	3.96	3.22	2.24
d	Total ClO ₂ added as ClO ₂ (Do+D ₁)	Kg/T	14.1	10.0	14.5	12.8	12.50
e	Total ClO ₂ consumed as ClO ₂	Kg/T	14.06	9.91	14.41	12.50	12.22
f	Brightness	%ISO	86.2	86.2	86.6	86.2	86.8
g	Whiteness Index	--	68.5	71.1	72.3	71.3	75.1
h	Yellowness Index	--	8.1	7.1	6.1	7.8	6.1
i	Viscosity	Cps	10.2	10.4	10.6	10.8	11.0
j	Bleached yield	%	43.9	45.2	44.2	43.8	45.3
V. STRENGTH PROPERTIES OF BLEACHED PULP AT 30°SR:							
a	Basis weight	Gsm	59.5	60.2	59.5	59.0	58.7
b	Bulk	cc/gm	1.20	1.25	1.46	1.36	1.41
c	Burst factor	--	41.2	62.8	45.5	51.6	46.0
d	Breaking Length	meters	6798	9949	7373	6874	6210
e	Tear factor	--	70	80	85	82	80

4.0 Conclusion

The study demonstrates that Malabar Neem (*Melia dubia*), particularly from Telangana, is a strong candidate as an alternate hardwood raw material:

1. High screened pulp yield, higher than all conventional species tested.
2. Lower bleaching chemical consumption, especially chlorine dioxide.
3. Superior ODL response with highest Kappa reduction.
4. Excellent pulp strength properties, especially burst factor and breaking length.

Malabar Neem plantations in Andhra Pradesh and Telangana region can effectively supplement existing hardwood supply, offering both economic and operational advantages for chemical pulp production.

Acknowledgement:

The author wish to thank the Andhra Paper Ltd. Management for according the permission to Publish this paper

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