Use of Hard Wood With Bark And Anthraquinone Pulping

Shibahare P.K. & Patel M.

ABSTRACT

Bark content in hard woods range from 8-12%. The holocellulose percentage in hard woods with bark being 70%, it has been advocated that use of bark in pulp and paper manufacturing will help environmental preservation.

Results of proximate chemical analysis of casuarina, subabul, chakunda and mango wood with bark are given; highlighting holocellulose content of 68.1, 67.5, 69.6 and 71.3% respectively with other properties being in the acceptable range.

Extensive studies have been carried out on mango with and without bark. The pulp yield with bark is 48% while without bark it is 51.9%; the corresponding bleached yield being 39.3 and 44.8% respectively. The brightness difference between hand sheets with and without bark is only 0.8% El; the difference in strength properties is also marginal.

As part of further environmental preservation, attempt has been made to increase the pulp yield in mango (without bark) and casuarina, subabul and chakunda with bark. Experiments have been conducted with 15-17% AA and anthraquinone addition (0,0.05, 0.1, 0.15 and 0.2%). The increase in yield in mango upto 55.4%, in casuarina upto 55.09%, in subabul upto 55.2% and in chakunda upto 49.3% has been brought out to be interesting both from manufacturing and environmental preservation aspects. Financial gain and environmental preservation based on use of bark and anthraquinone pulping have been discussed.

INTRODUCTION

The acute raw material crisis for pulp and paper mills in the country and world-wide exigence for environmental preservation legislations are gradually obliging the mills in general to learn managing with less preferred raw materials and thus the bark also, which was not being used earlier. Undoubtedly, debarking is invariably employed abroad and debarked wood is used for paper manufacturing but the reasons are quite different in India namely:

1. Availability of raw material is not that big a problem in abroad as in India, specially at present.
2. Environmental conciousness in society as well as in government being exceptionally of prime importance in abroad, rapid forestations are going on, illegal felling of trees do not exist, use of recycled fibres is rising with process improvements and technologies.
3. As trees of 20-30 years or more are mostly used abroad the outer bark portion in particular

Pulp and Paper Research Institute, Jaykaypur-765 017, Orissa.

contains more of hard and dead cells while in India trees of 4-10 years are commonly used where the bark thickness is not only less but is fairly rich in fibrous fraction.

4. The bark produced abroad as waste is brought to the mill for incineration and used for power generation while in India such provision rarely exists and it is mostly thrown away by mills or the suppliers.

5. In trees like casuarina, debarking is very difficult. In all younger trees in general, the bark is in intimate contact with the wood portion. In any case, the mill has to bear the debarking cost.

A paper was published recently (1) advocating safe use of hard wood bark, specially in mills employing bamboo- hard wood with proportion of bamboo >50%. The present work is in continuation of earlier work with addition of mango in particular.

Bark is defined to be the outer covering or rind of woody stems and branches. Bark contains 3 types of tissue: Cortex, Periderm and Phloem (2). Bark is formed by cambium. Each year when the cambium generates a layer of wood from its inner surface, it also forms a layer of bark from its outer surface. The outer layers generally crack open because of stresses, caused on increasing girth. Thus younger trees have bark which is smooth and relatively thin while old trees have bark that has fissured and scaly appearance (3).

Most of the nonpolysaccharide components of bark are dissolved by alkaline pulping liquor. Therefore unlike in sulfite process, kraft cooking can accept bark easily (4). In fact, unbarked wood or wholetree chips have been suggested for use earlier in abroad also (4).

The second objective here has been on increasing pulp yield, in the raw materials containing bark which has rarely been reported in the literature, even using the well known chemical, anthraquinone (5-15). Use of bark accompanied by some saving of hemicellulose portions and increasing the pulp yield will naturally cause felling of lesser number of trees for same tonnage of pulp or paper manufacture than presently and thus help in environmental preservation. This has also bearing with financial benefit as cost for transportation, debarking will be reduced and simultaneously more wood equivalent to bark and pulp will be produced.

EXPERIMENTAL

The following samples, collected from the nearby mill, have been studied:

(1) Casuarina with bark

(2) Subabul with bark

(3) Chakunda with bark

(4) Mango with bark

(5) Mango without bark

Chipping was carried out in the mill chipper. For proximate chemical analysis, the chips were ground to powder in Wiley grinding mill.

The pulping was conducted in a Rotary digestor (15 Lt capacity) using white liquor from the mill and following to kraft process. The bleaching sequence adopted was CEpH. The strength and optical properties of the hand sheets have been determined as per Tappi standard methods.

Anthraquinone was added 0-0.2% in to the white liquor first and the resultant liquor was added to the chips in the digestor prior to cooking. AA concentration was varied from 15 to 17%.

RESULTS AND DISCUSSION

One of the reasons for not preferring bark is its high A-B extractive and low holocellulose content. Therefore the proximate chemical analysis was first carried out, results of which are given in **Table-1** for the 5 raw materials studied. The cold and hot water as well as 1% NaOH solubility value vary from sample to sample. In case of subabul and chakunda, 1% NaOH solubility values are as high as 24.9%, in case of mango, the difference between samples with and without bark is ~6%.

However, the A-B extractive values in the hard woods with bark are not very high; for casuarina it is 2.3%, 3.86% for subabul and 4.6% for chakunda. The comparison in mango with and

Table-1						
Proximate chemical analysis of casuarina, subabul, chakumda and mango with bark						
Particulars		Casuarina	Subabul	Chakunda	Mango	
					With bark	Without bark
Cold water solubility	%	5.7	9.45	12.23	3.4	3.3
Hot water solubility,	%	6.43	10.45	10.65	14.3	9.2
1% NaOH solubility,	%	19.4	24.9	24.88	19.2	13.2
A-B extractive,	%	2.3	3.86	4.6	4.5	3.9
Klason lignin,	%	26.4	24.9	28.9	21.9	21.0
Holocellulose,	%	68.15	67.5	69.6	71.3	71.1
Pentosan,	%	16.33	15.2	15.9	-	-
Ash,	%	0.82	1.71	1.03	2.1	1.6
-cellulose,	%	-	-	-	-	80.9
-cellulose,	%	-	-	-	-	15.5
-cellulose,	%	-	-	-	-	3.5

without bark show that former has 4.5% and the later, 3.9% i.e. difference of ~0.6% which is quite acceptable.

The lignin content in chakunda is comparatively very high i.e. 28.9%; next being in casuarina which is 26.4% and then in subabul (24.9%) and Mango (21.9% with bark and 21% without bark). Mango wood even with bark thus has lower lignin content and it should be quite acceptable for quality paper manufacturing. The holocellulose content **(Fig.1)** in mango is also more than in other hard woods studied; 71.3% and 71.1% in mango while it is 68.1% in casuarina, 67.5% in subabul and 69.6% in chakunda. The pentosan contents in casuarina, subabul and chakunda are 15-16% which are in the acceptable range for hard wood. The ash content of casuarina with bark is quite low (0.82%) compared to 2.1% in mango with bark and other hard woods. The α, β and γ-cellulose have been determined only in mango without bark. Based on the proximate chemical analysis, the hard woods with bark can very well be used for quality paper manufacturing. Properties of mango with bark; lignin and holocellulose in particular are superior to other hard woods. These results are comparable with our earlier results for subabul (16) and casuarina (1).

MANGO WITH AND WITHOUT BARK

The following part contains results of only mango with and without bark. In case of mango without bark **(Table-2)**, the fibre length is 0.8 mm with diameter of 10.01 μm which is normal for a hard wood.

Table-2		
Fibre morphology of mango without bark		
Particulars		
Average fibre length,	mm	0.8
Average fibre width,	μ	10.01

The pulping characteristics are given in **Table-3** at normal mill conditions used for kraft cooking. The total yield in mango with bark is 48% while it is 51.9% without bark, thus lower by 3.9% because of bark. However, 48% of yield for hard wood is quite good. Similarly though kappa no. of

Table-3			
Pulping characteristics			
Particulars		Mango with bark	Mango without bark
Active alkali as Na_2O,	%	17	17
Sulphidity,	%	15.4	15.8
Cooking temperature,	°C	165	165
Screened yield,	%	46.9	51.1
Rejects,	%	1.1	0.8
Total yield,	%	48.0	51.9
Kappa no.		24	17.2

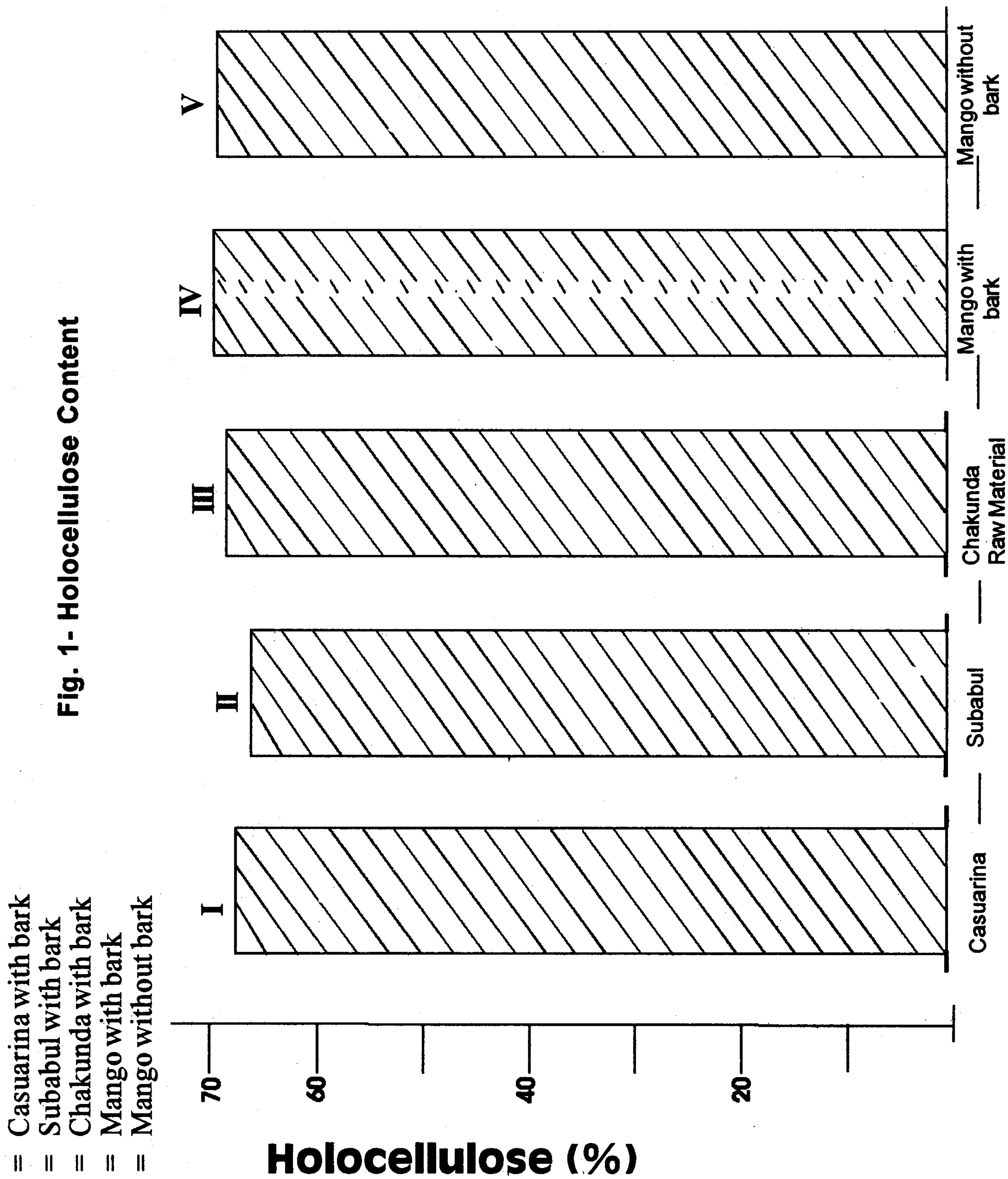


Fig. 1- Holocellulose Content

Table-4		
Bleaching characteristics		
Particulars	Mango with bark	Mango without bark
Sequence used	CEpH	CEpH
Total chlorine applied, %	9.70	6.88
Total chlorine consumed, %	9.36	5.70
H_2O_2 added, %	0.30	0.30
Shrinkage, %	4.50	3.50
Bleached yield, %	39.30	44.84
Brightness, % El	82.0	82.8
Viscosity (0.5M CED), cP	3.6	4.1
P.C. Number	8.4	4.6

mango without bark is 17.2 and with bark is 24; the kappa number of 24 is acceptable for hard wood. It is, however, remarkable to find kappa number as low as 17.2 in mango wood. Such low kappa number and high yield are rarely observed in hard woods in kraft cooking.

The bleaching characteristics **(Table-4)** obtained with CEpH sequence again show remarkably low chlorine consumption (6.8% applied and 5.7% consumed) in mango wood. However, with bark, Cl_2 consumed is 9.36% which is acceptable for hard wood.

The bleached yield of wood is 44.84% while with bark, it is 39.3%. Here again, the value of 39.3% is acceptable for hard wood though it is on the lower side.

The brightness of hand sheets made from mango with bark is 82% and without bark, it is 82.8%, thus difference of 0.8% only exists between the 2 samples. Viscosity of bark containing pulp is 3.6 Cp while it is 4.1 Cp in sample without bark, showing that the strength of wood will be marginally lowered on using bark. P.C. No. of 4.6 in mango signifies that mango wood has exceptionally low colour reversion which is rarely observed in other hard woods. On the otherhand, P.C. No. of 8.4, observed in mango with bark is normal for hard wood.

The physical strength properties of both the samples are presented in **Table-5** at initial, 30°SR and 40°SR. The bulk property in the 2 samples differ in initial and 30°SR of freeness but these have quite close values (1.46 and 1.43 cc/g) at 40°SR. The tear factor of mango without bark at 40°SR is 35.1 in stead of 28.4 with bark; however the corresponding burst factors are 27.3 and 24.4; breaking lengths are 5283 m and 5064 m. Thus the strength deterioration due to addition of bark is negligible.

The double fold values are low in both the cases. FS factor determined in Pulmac trouble shooter for samples at 30°SR indicate that mango without bark has stronger fibres (FS factor=15.1) than that in mango without bark (FS factor=11.2).

ANTHRAQUINONE PULPING

On addition of anthraquinone, delignification in pulp is accelerated and the carbohydrates including hemicellulose, are protected against peeling by oxidation of the reducing end groups. Thus the overall yield increases on addition of anthraquinone (5).

Apart from yield, reduction in alkali charge on using anthraquinone has been reported (7); 11-13% less alkali charge. The kappa number is also reduced on addition of anthraquinone (6).

Table-5							
Physical strength properties							
Particulars		Mango with bark			Mango without bark		
		Initial	30°SR	40°SR	Initial	30°SR	40°SR
Bulk,	cc/g	1.58	1.48	1.46	1.85	1.55	1.43
Tear factor		23.5	23.7	28.4	17.0	31.5	35.1
Burst factor		23.9	26.2	24.4	34.5	27.5	27.3
Breaking length,	m	4378	4378	5064	3675	5438	5283
Double fold,	no.	3	3	3	2	6	7
FS factor			11.24			15.1	

Table-6				
Yield with varying doses of AQ (Mango without bark)				
AA as Na_2O (%)	AQ (%)	Screened yield(%)	Rejects (%)	Total yield(%)
17	Blank	51.3	0.67	51.97
17	0.05	51.77	0.32	52.09
17	0.1	54.09	0.62	54.71
17	0.15	53.47	1.84	55.31
17	0.2	54.71	0.65	55.36

Table-9				
Yield with varying doses of AQ (Chakunda with bark)				
AA as Na_2O (%)	AQ (%)	Screened yield(%)	Rejects (%)	Total yield(%)
17	0	48.4	-	48.4
17	0.05	48.6	-	48.6
17	0.1	49.3	-	49.3

Though possibility of increasing the pulp yield with anthraquinone is well known and practised in many mills in abroad, it is yet to be used on regular basis in any mill in India. Some laboratory studies have only been made in India. However, rarely hard wood containing bark has been studied earlier. As mango wood gave exceptionally good properties with yield as high as 51.8%, it was considered worthwile examining whether the yield can be further increased on addition of anthraquinone **(Table-6)** along with that of casuarina with bark **(Table-7)**, subabul with bark **(Table-8)** and chakunda with bark **(Table-9)**.

Table-7					
Yield with varying doses of AA and AQ (Casuarina with bark)					
AA as Na_2O (%)	AQ (%)	Kappa No.	Screened yield (%)	Rejects (%)	Total yield (%)
15	0	23.40	54.78	0.10	54.88
15	0.1	23.50	54.88	0.21	55.09
16	0	22.40	53.90	0.06	53.96
16	0.1	21.09	54.80	0.12	54.92
17	0	19.16	49.95	-	49.95
17	0.05		52.28	0.2	52.48
17	0.1	19.04	53.39	0.01	53.40

Table-8					
Yield with varying doses of AA and AQ (Subabul with bark)					
AA as Na_2O (%)	AQ (%)	Kappa No.	Screened yield (%)	Rejects (%)	Total yield (%)
15	0	32.9	55.0	0.2	55.2
16	0	31.6	53.9	-	53.9
17	0	24.9	51.5	0.1	51.6
17	0.05	-	52.8	0.8	53.6
17	0.1	-	53.2	0.6	53.8

In Table-6, yield values of mango chips without bark at AA of 17% and anthraquinone percentage of 0, 0.05, 0.1, 0.15 and 0.2 are given. At 0.05%, the screened yield is 51.8%, at 0.1%, it is 54.09% which could be increased to 54.7% at 0.2% of anthraquinone. The total yield values for blank is 51.97%, which was increased to 55.36% on addition of 0.2% of anthraquinone. Thus 3.4% of yield gain can be attained with anthraquinone in mango without bark. The rejects in case of 0.15% anthraquinone was only high (1.84%), in other cases, it was 0.3 to 0.6%.

The AA concentrations were varied at 15, 16 and 17% in case of casuarina with bark (Table-7), the anthraquinone percentage having been limited to 0.1%. The kappa number at 15% AA with 0.1% anthraquinone remains same as blank, which is lowered by 1.3 no. at 16% AA and remains unaltered at 17% AA on addition of anthraquinone. Thus the advantage of kappa number reduction in bark-containing casuarina, excepting at 16% AA (by 1.3 no.), is not appreciable. The yield gain is quite significant at 17% AA in particular; the total yield has increased from 54.9% to 55.1% at 15% AA, 54% to 54.9% at 16% AA and 50% to 53.4% at 17% AA with 0.1% of anthraquinone. At 17% AA and 0.05% of anthraquinone, the total yield value was 52.5%, thus yield gain of 2.5% which could be further increased to 3.45% with 0.1% of anthraquinone.

Yield results of subabul with bark are given in Table-8. Kappa number with 17% AA was 24.9 with total yield of 51.6%. With 0.05% of anthraquinone, the yield increased by 2%; with 0.1% of anthraquinone, it was 53.8%.

Chakunda with bark when cooked with 17% of AA and with 0.05 and 0.1% of anthraquinone, increase in yield found was 48.6% amd 49.3% respectively from initial value of 48.4% i.e. 0.9% of increase which is much lower than in other raw materials.

Anthraquinone pulping efficiency thus appears to be variable with the hard wood. The pulp yield without anthraquinone pulping is shown in **Fig.2** and with anthraquinone in **Fig.3.** The increase in pulp yield due to anthraquinone addition in different hard woods studied shown yield of 0.9 to 3.45%. It can be seen that the maximum increase of pulp yield is 3.4% in casuarina with bark and mango without bark.

FINANCIAL GAIN

The financial gain is to be considered from this paper

i. due to use of bark, and

ii. on anthraquinone pulping.

As the cost of hard wood is variable from place to place, it should be calculated separately in each mill.

i) Saving due to bark

Considering cost of hard wood to be Rs. 1,500/ton and debarking cost to be Rs. 300/ton; with 10% of bark content, saving of Rs. 18,000 can be immediately calculated for 100 TPD mill.

Apart from saving, supply can be easier as the whole tree can be loaded directly on to the truck and transported straightway to the paper mill. The supplier may like to reduce the cost further as debarking will not be there.

However, on the processing of bark-containing wood, care has to be taken and thoroughly confirmed from laboratory studies that shives or specks do not cause a problem.

(ii) Saving due to anthraquinone

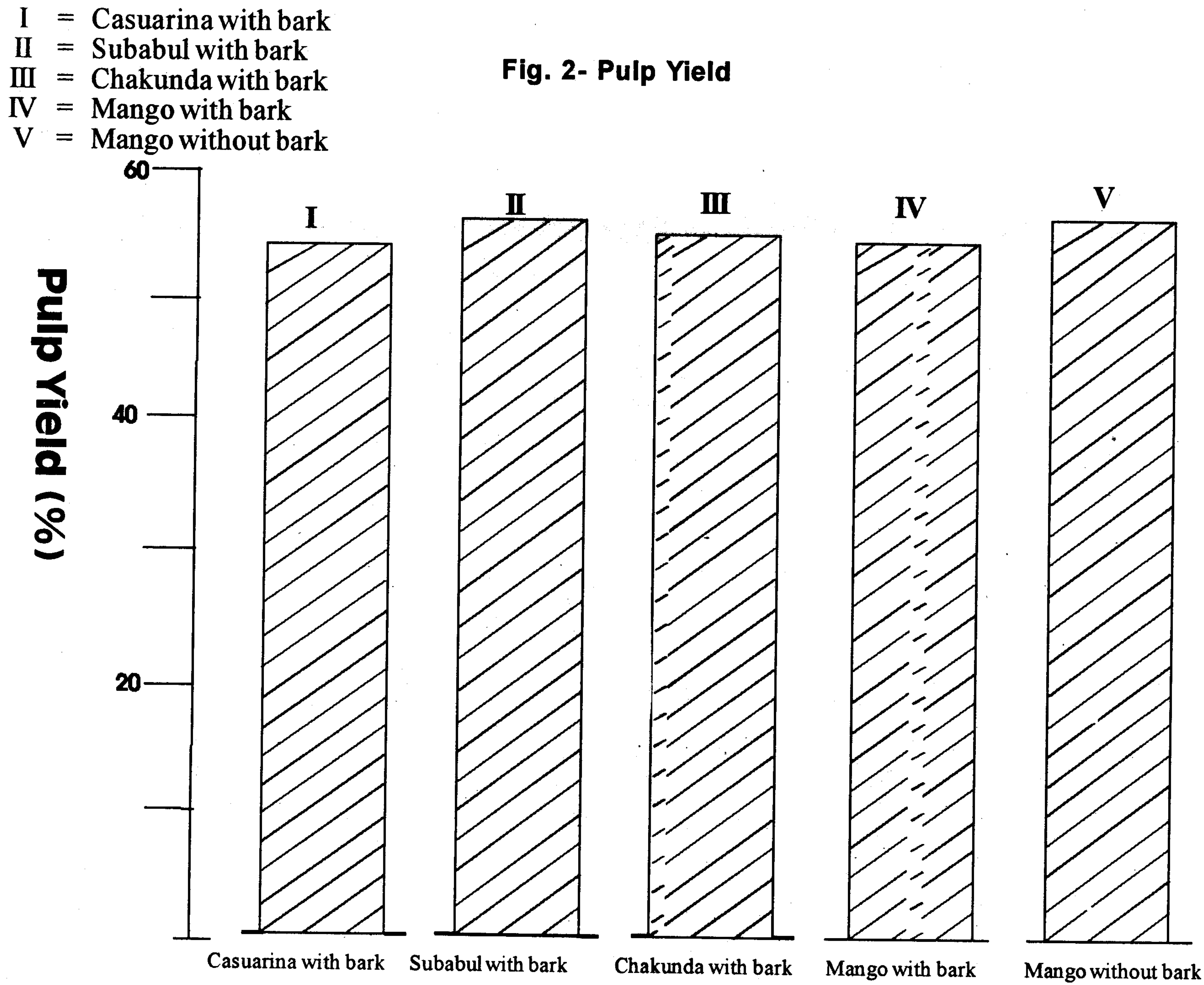
Similarly for an increase of 3.4% of pulp yield due to anthraquinone addition may be calculated which comes out to be saving of Rs. 600/ton of pulp or Rs. 60,000/100 ton or Rs. 2 crores (330 days/year) per year for a mill using 100 TPD pulp.

ENVIRONMENTAL PRESERVATION

(i) Due to bark

Along with the financial saving, use of bark can help environmental preservation as the number of trees required to be felled for a mill, will be reduced. For casuarina presuming 1 tree to be 30 kg; for 10 tons 350 trees can be saved per day in a 100 TPD mill, which will annually become 12,000 number (365 days/year).

Fig. 2- Pulp Yield



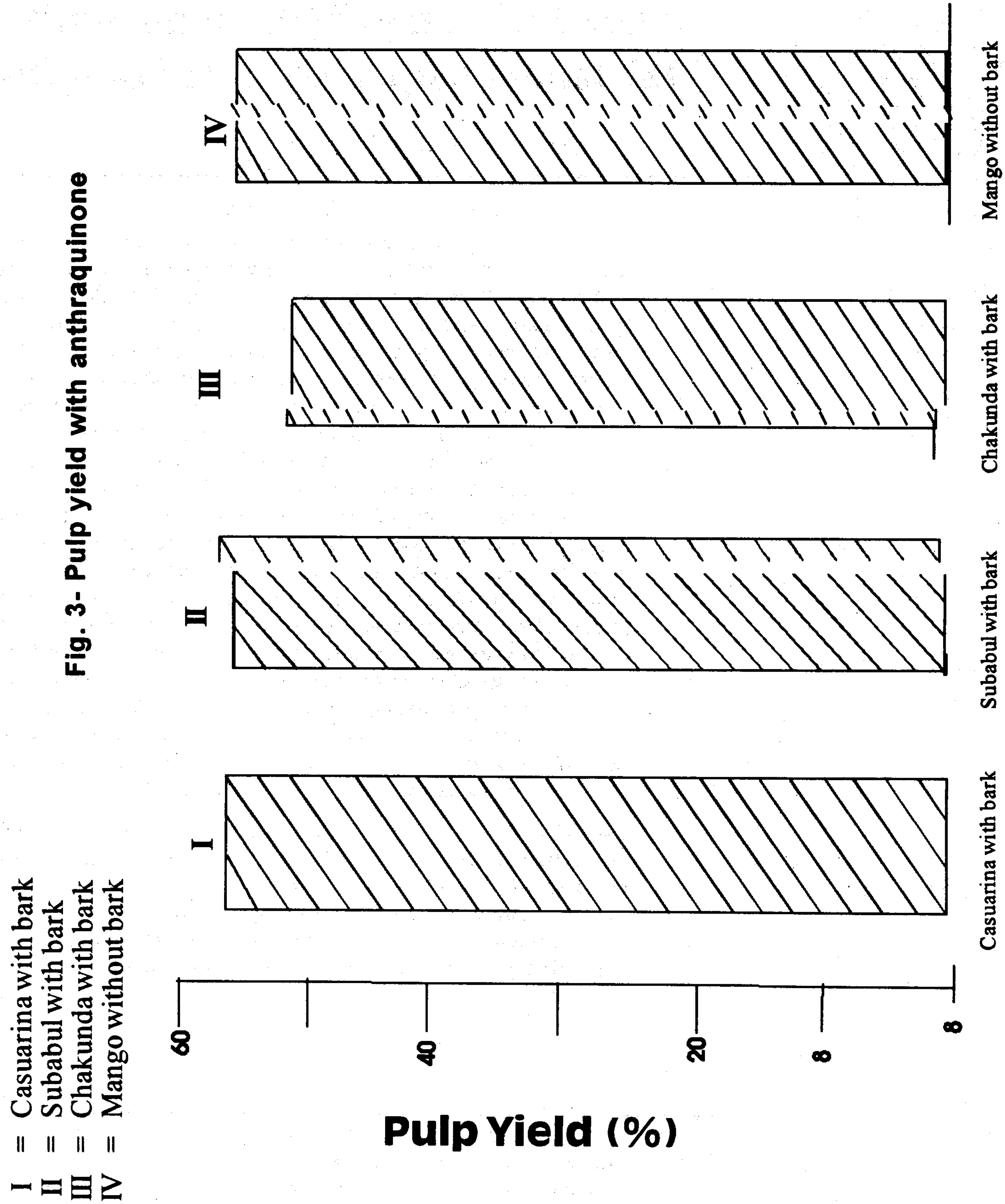


Fig. 3- Pulp yield with anthraquinone

(ii) Due to anthraquinone

With 3.4% increase in pulp yield for casuarina, this also amounts to 10,000 trees to be saved per year in a 100 TPD pulp using mill.

(i) and (ii) will save 22,000 number of trees/ year can be saved only in 1 mill.

(iii) Mango is already in use in Indian mills but the percentage may be 3-5%. It is firstly not available and no mango plantation is done for paper industries. Mango can provide not only its wood but fruits and its leaves as fodder. It may be worthwhile finding out possibility of large scale plantation of mango, so that the food problem can also be solved in the country to some extent.

Environmental preservation is thus has a bearing on wood and pulp yield in a tree, the former being quantified as per acre or hectare. Higher the wood yield per hectare or higher the unbleached and bleached pulp yield percentage, it is good for pulp and paper mills and also for the national cause on environmental preservation. Proper selection of tree (1) and modern plantation technologies including tissue culture and specially the clonal technology (1) is already being practised in many mills with claim of increasing wood yield/hectare from 40 tons to 120 tons in India and in few cases nearing to 200 tons in abroad. We have recently suggested through silvicultural application that the wood yield can be increased manyfold, the manure being again composted sludge from the paper mill (2). The composting was accomplished through a new process called FSVS (2). Extensive use of bark, acceptance of mango as a suitable hard wood for paper manufacturing and its plantation in forest land, anthraquinone pulping are the three conceptions here which are imperative to be evoked along with clonal technology, silvicultural application and composting of fibrous sludge for the national cause of environmental preservation.

CONCLUSIONS AND RECOMMENDATIONS

Hard woods with bark of casuarina, subabul, chakunda and mango are acceptable for paper manufacturing by kraft cooking. In India, the trees being 4-6 years old and as generally kraft process is adopted, all attempts should be made to use hard woods with bark. This is specially exigent to meet the national cause of environmental preservation and reducing the production cost of paper. However, in case of older trees, it should be throughly evaluated before using in the mill.

Mango wood has many superior properties over other hard woods, namely pulp yield of 51.9%, kappa number of unbleached pulp to be 17.2, low chlorine consumption for bleaching (5.7%), bleached pulp yield of 44.8%, brightness of 82.8% El and exceptionally good P.C. No. of 4.6. On anthraquinone pulping, pulp yield can be increased to 55.4% with acceptable strength properties. Thus mango wood should not be considered as low grade hard wood in any way which is the conception in Indian mills now. Mango wood storing period should not, however, be long as it deteriorates very fast compared to other hard woods.

Anthraquinone pulping is very selective and depends upon type of hard wood and AA concentrations used. The maximum increase in pulp yield with the 4 raw materials studied are; 3.4% in casuarina with bark and mango without bark, 2% in subabul with bark, 0.9% in chakunda with bark.

Use of hard wood with bark, large scale plantation of mango for paper manufacturing, for fruits, for fodder and biomass and anthraquinone pulping can help environmental preservation.

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