Foam formation during digester loading

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ABSTRACT

Foam formation causing reduction in digester capacity utilisation is explained. Foam generation from Daba and Salia bamboo and hardwoods such as Eucalyptus, Casuarina, Subabul and Acacia has been measured. The variation in foam formations have been explained by varying moisture content. The conditions for measurement of relative foam formation from different raw materials has been standardised. A—B extractives in all the raw materials mentioned and in stored Eucalyptus and Salia bamboo have been determined. The effect of chip size and dust on foam formation in bamboo-hardwood mixture has been studied.

Introduction :

Foam generation is a problem commonly encountered in kraft pulping process, mainly during digester loading & brown stock washing. Though, the problem due to foam during digester loading is not critical in pulp mill, it can restrict full capacity utilisation of the digesters & thus plays role in the economy of pulp and paper manufacturing. Leakage and overflow of foam becomes a nuisance sometime and causes safety problem.

Perusal of literature showed that no systematic studies have been carried out to find out the cause of foam generation, neither the quantity of foam generated from different raw materials. The present paper is intended to bring out the factors responsible for foam generation and the relative foaming tendency from bamboo and some commonly used hardwoods. The effect of moisture content and chip size on foam generation have also been defined.

Foam and fatty acids :

Foam is an entrapped air in a tough, tenacious soap film. It is a random collection of air bubbles; 95% of its volume consists of air and 5% of water with a very high surface tension[1] viz 70m N/m. Foam can be formed from a large number of resins and fatty acids[2] such as abietic acid, stearic acid, palmitic acid, lauric acid, oleic acid, linoleic acid and linolenic acid. during the digestion process, the acids are converted[3] to their corresponding sodium salts (Fig. 1). The fats and unsaponifiables present in the chips also contribute to foam generation. The resin is estimated at alcohol-benzene (1 : 2) extractive or ether extractive as % on OD wood[2].

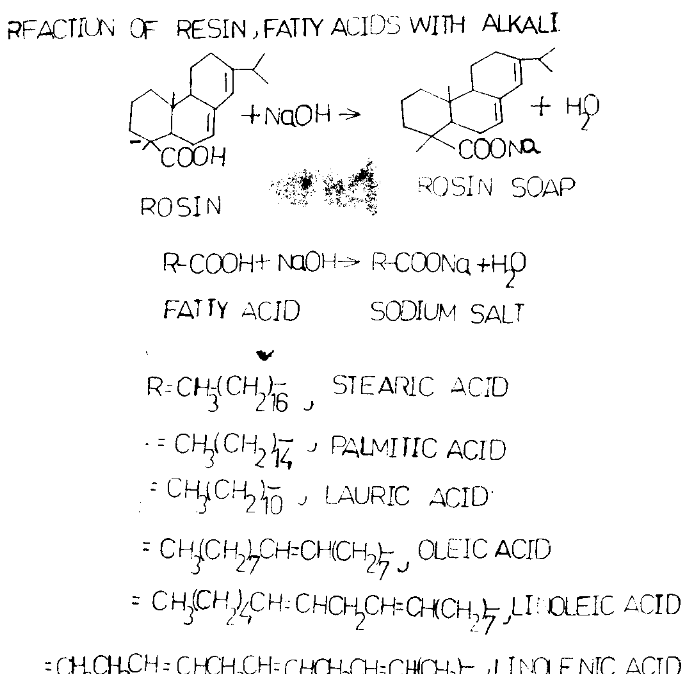

Fig. 1

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The nature of ether extractive of hardwood and softwood differs appreciably. The average composition[2] (based on ether extractive) is :

			Hardwoods	Softwoods
1.	Resin acids	%	0-2	42.0
2.	Fatty acids,	%	19.0	12.0
3.	Fats,	%	55.0	35.0
4.	Unsaponifiables,	%	24.0	11.0

Unlike softwoods, hardwoods have low resin content. Fats and fatty acids together constitute 75% of the ether extractives of hardwoods. As the unsaponifiable compounds do not readily react with alkali, foam formation during bamboo or hardwood utilisation might be due to fats and fatty acids.

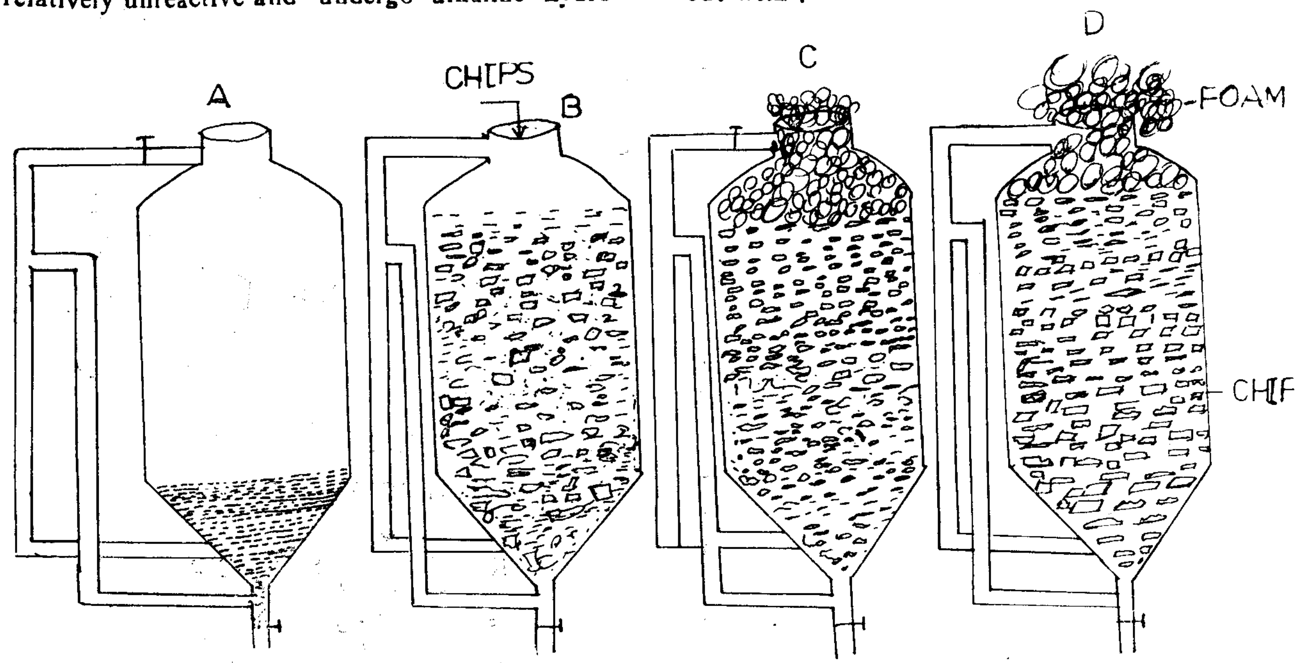
Fatty acids are long straight chain monocarboxylic acids. Fats are esters of fatty acids and alcohols in wood (mostly glycerol). Compared to fatty acids, fats are relatively unreactive and undergo alkaline hydrolysis to corresponding acids and alcohols in presence of alkali.

Foam generation during digester loading :

The foam generation pattern in kraft process during digester loading has been shown in Fig. 2. Initially the digester is fed with white liquor upto its 15% capacity (Fig. 2A), followed by filling up of chips upto the neck (Fig. 2B). When white liquor is further fed and the entire liquor is recirculated for 30-45 minutes, foam generation commences (Fig. 2C). Excess of foam may occassionally be formed (Fig. 2D) which may hinder further chip feeding. Consequently, it will adversely effect the digester capacity utilisation.

Experimental :

The source of various samples studied are summarised in Table—1. Experiments have been carried out with :



A-EMPTY DIGESTER
B-DIGESTER WITH CHIPS
C-LIQUOR CIRCULATION PUMP ON
D-CHIP LOADING HINDERED
FIG-2-DIGESTER LOADING

TABLE 1 : NAME & SOURCES OF SAMPLES

Local Name	Botanical Name	Source
Daba bamboo	Bamboosa Arundenacia	Assam
Salia bamboo	Dendrocalamus strictus	Orissa
Eucalyptus	E. Tereticornis	PAPRI Experimental plantation
Subabul	L. Leucocephela	,,
Acacia	A. Auriculiformis	,,
Casuarina	C. Equisitifolia	,,

i. fresh samples

ii. after soaking in water to various moisture levels, and

iii. samples stored in open air for about 1 year.

The raw material samples were chipped in commercial voith and vecoplan chippers.

Foam generation in laboratory :

For foam generation study, a laboratory rotary digester was used. White liquor was collected from the mill (M/s. J.K. Paper Mills) and heated to 80°C before adding in the digester. The amount of white liquor added was calculated on 17% active alkali basis.

White liquor was collected from the bottom drain valve of the digester and it was again added to the chips. Circulation in this manner was carried out for 30 to 45 minutes. After the stipulated period, the liquor was collected (concentrated liquor). The chips were further wa shed twice each time with 2 litres of water. The washings (1 & 2) were also collected.

500 ml of liquor was taken in one litre measuring cylinder and regulated air was passed into it for 1 minute. The foam generated, was measured in volume (ml). Foam was generated in 1st washing and 2nd washing also. Total foam generated was computed and presented in ml as a measure of foam creating tendency of raw material.

The concentrated liquor was analysed for active alkali content. The absorbancy of the liquor was measred at 410 nm in UV-visible spectrophotometer. The extracted chips were washed, powdered and the ether extractives were determined.

Results and discussion :

The moisture content in different samples are shown in Table-2, along with the experimental conditions, the amount of foam formed and the A–B extractives. The moisture content in fresh samples varies between 31-44%. The circulation period is restricted to 30 minutes. As the temperature of freshly prepared white liquor in the plant is 80°C, the same temperature was maintained in laboratory. The amount of active alkali consumed is about 2% in Salia bamboo and about

TABLE 2 : FOAM GENERATION IN DIFFERENT RAW MATERIALS

Particulars		Daba Bamboo	Salia Bamboo	Acacia	Eucalyptus	Subabul	Casuarina
1. Moisture,	(%)	35	39	35	44	31	33
2. Active alkali applied as Na_2O,	(%)	17	17	17	17	17	17
3. Temperature of white liquor.	(°C)	80	80	80	80	80	80
4. Circulation period	(min.)	30	30	30	30	30	30
5. Active alkali consumed	(%)	0.63	2.00	0.68	2.00	0.68	1.71
6. Amount of foam, (per 500 ml liquor)	(ml)	350	310	340	310	290	210
7. A-B extractives, :	(%)						
a. Before circulation		4.85	4.89	3.43	4.94	2.06	4.29
b. After circulation		3.27	2.19	2.39	4.35	1.01	3 09
c, Reduction in extractives		1.58	2.7	1.04	0.59	1.05	1 20

0.65% in other samples excepting Casuarina (1.71%). The amount of foam generated in 500 ml of liquor varied from 210 to 350 ml, the highest being in Daba bamboo and lowest in Casuarina. Acacia chips also showed quite high foaming tendency (340 ml.). The histograms of foam generated for various raw materials are shown in Fig 3.

The percentage of A–B extractives before circulation was in the range of 4 3 to 4 9, excepting in subabul and Acacia. The percentage of A–B extractives in chips after liquor circulation are also mentioned in Table-2. The A-B extractive content apparently governs the amount of foam generated. The slight divergence in some cases may be explained based on variation in properties of wood such as basic density as well as nature and amount of fatty acids. When the basic density is high, the penetration of liquor can not be very effective as in case of Casuarina (900–1100 kg/m³).

The results of foam generation in stored raw materials are shown in Table–3. It is obvious that because of long storage, the moisture content is 12-14% in the two samples of Eucalyptus and Salia bamboo

TABLE 3 : FOAM GENERATION IN STORED RAW MATERIALS

Particulars		Salia bamboo	Eucalyptus
1. Moisture,	(%)	14	12
2. Active alkali applied as Na_2O,	(%)	17	17
3. Temperature of white liquor	(°C)	80	80
4 Circulation period,	(min.)	30	30
5. Active alkali consumed,	(%)	2.68	2.68
6. Amount of foam, (per 500 ml liquor)	(ml.)	295	170
7. A–B Extractives :			
a. Before circulation		2.88	3.82
b. After circulation		0.7	3 38
c. Reduction in extractives	(%)	2.18	0.44
8. Reduction in A-B extractives, (on original extractive)	(%)	75.7	11.5

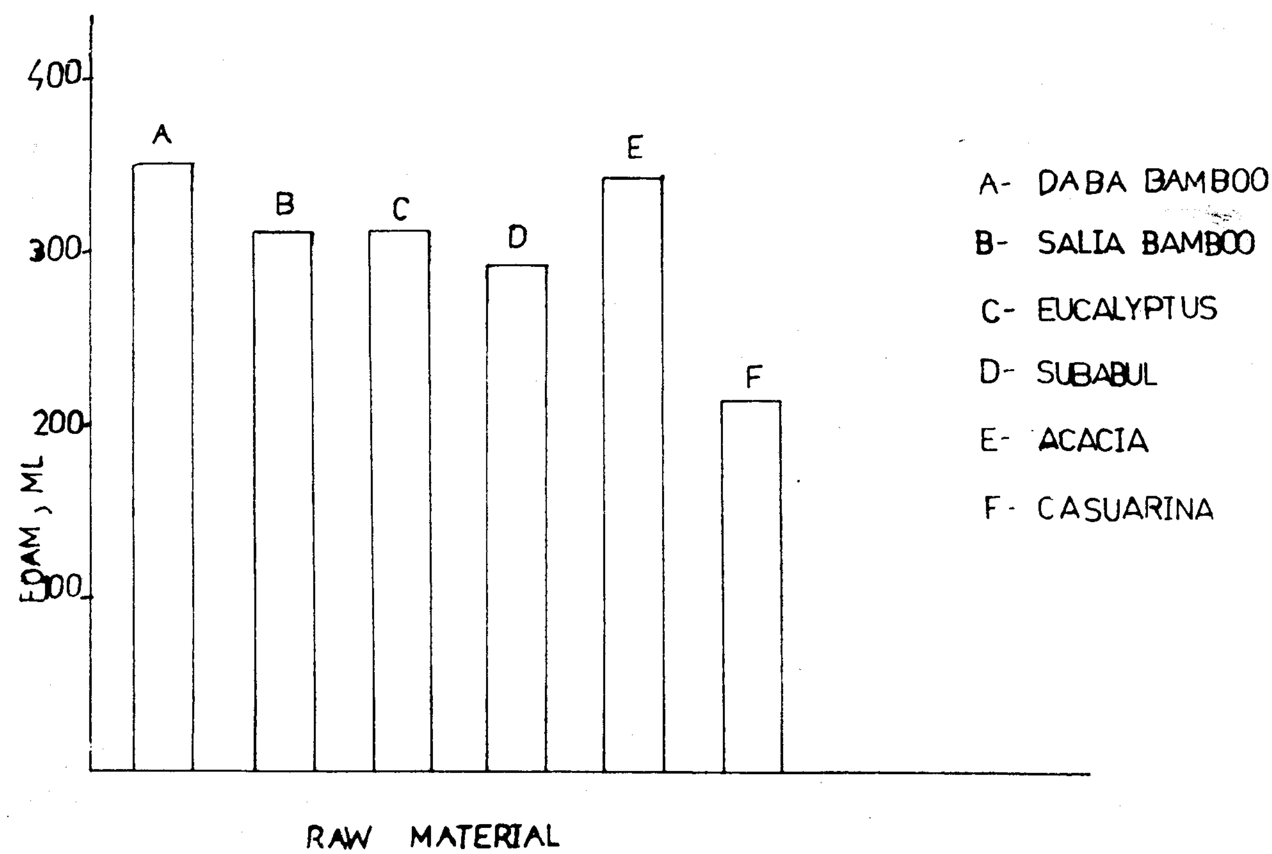
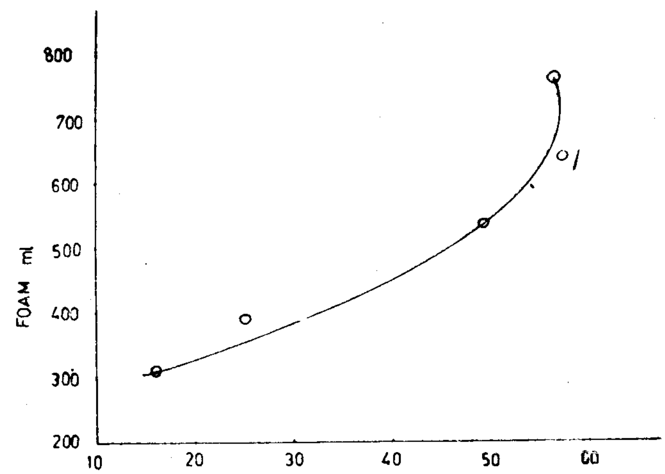


Fig. 3

studied. The high active alkali consumed in stored raw materials is due to degradation of carbohydrates caused by biological infestation[4]. The amount of foam generated in both the stored samples are less than the fresh samples. The volume of foam in stored Eucalyptus is only 120 ml instead of 310 ml in the fresh samples. The A-B extractives for Salia bamboo and Eucalyptus are 2.9 and 3 8% respectively The percentage reduction in alcohol-benzene extractives in Salia and Eucalyptus are 76% and 11% respectively. The resin and fatty acid content of paper making raw materials decreases during open storage[5] In fact, this is one of the simplest ways of reducing the formation of chloro-organic compounds in the effluent[6]. As the moisture as well as A-B extractives here are low, the volume of foam generated is also not as high as in fresh samples.

The foam creating tendency of Daba bamboo with varying moisture content has been studied to find out the effect of moisture content in the chips on the mechanism of foam generation The moisture content in the sample was varied either by drying or by soaking in water for various intervals. The moisture content was varied from 16–57%, the initial value being 25%. The amount of foam generated is proportional to the content in the chips (Fig 4). The amount of foam at 16% moisture is 310 ml, while at 56-57%, it is 650-770 ml. If the chips are soaked for more than 6 hours, there is no further increase in the volume of foam; rather it decreases. When it is soaked for 24 hours in water, the moisture content is 57% but the amount of foam is 650 ml only. When the chips are soaked for long periods (7, 6 hrs), the penetration of liquor is facilitated, thus the volume of foam generated increases. Moreover the fats and unsaponifiable compounds are likely to be hydrolysed resulting in formation of fatty acids.



Foaming Tendency Of Daba Bamboo

FIG NO-4

TABLE 4 : FOAM CREATING TENDENCY OF DABA BAMBOO (ASSAM)

Particulars		Dried for 24 hours	As such	Soaked in water for 4 hours	Soaked in water for 6 hours	Soaked in water for 24 hours
1. Moisture,	(%)	16	25	49	56	57
2. Active alkali applied as Na_2O,	(%)	17	17	17	17	17
3. Circulation period,	(min.)	30	30	30	30	30
4. Temperature of white liquor	(°C)	80	80	80	80	80
5. Active alkali consumed,	(%)	0.68	2 71	4.18	4.18	4 09
6. Amount of foam (per 500 ml liquor),	(ml)	310	390	540	770	650
7. Bubble size,		small	small	small (quick dispersed)	big (quick dispersed)	big (quick dispersed)
8. A—B extractives,	(%)	4 85	4 85	4.85	4.85	4.85
9. After circulation (on wood)		3.81	1.86	1.32	2.16	2 83
10. Reduction in A-B extractives, (on original extractive)	(%)	21.4	61.6	72 8	55 5	41.7

The sizes of bubbles formed in foam are found to increase at higher moisture content in the chips. This is due to the extensive evolution or air bubbles from the chip bodies as the diffusion of alkali progresses. The percentage reduction in alcohol-benzene extractive values increases with moisture content value in the chips. This is obviously due to the easiness in the extraction of resin and fatty acids. The percentage reduction in alcohol-benzene extractives is as high as 72% when the material is soaked in water for 4 hours. It is reported that wood stored in water increases the foam forming tendency[7] The present result indicates that the raw material should not be soaked in water for long period before chipping operation.

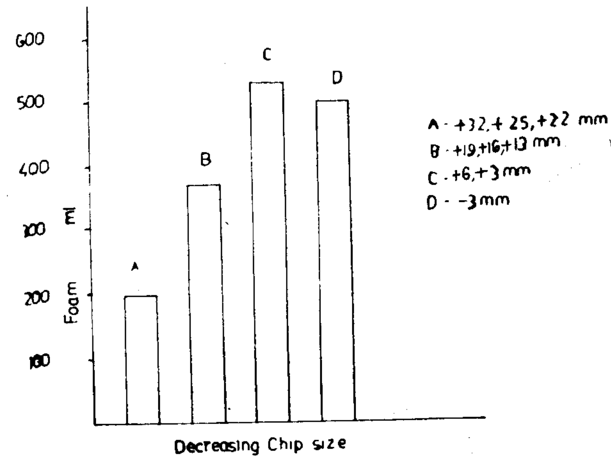
As the diffusion and penetration phenomena play important role in foam generation, chips of varying sizes have also been studied. As the majority of the mills employ bamboo-hardwood furnish, the following study on foam generation vis-a-vis chip size may be quite useful.

Availability of chip surface area varies according to the chip size Smaller chips will have more surface area per unit weight than bigger chips and consequently, liquor penetration will be faster. This also results in removal of more extractives.

Mixed chips (Bamboo : Hardwood = 80 : 20) have been segregated into the following four groups :

Mesh size (mm)	Group
+ 32 to + 22	Big fraction
+ 19 to + 13	Middle fraction
+ 6 to + 3	Small fraction
— 3	Dust portion

On extraction with white liquor, the foam formation is found to increase with decreasing chip size (Fig 5). The results are recorded in Table–5. The liquor from dust fraction develops more than 2.5 times foam than that from big fraction. The bubble size of foam also decreases with increase in chip size. The



CHIP SIZE VS FOAM

FIG NO-5

TABLE 5 : CHIP SIZE VIS–A–VIS FOAM CREATING TENDENCY OF BAMBOO–HARDWOOD MIXTURE

Particulars		+32 to +22 (mm)			+19 to +13 (mm)			+6, +3 (mm)			−3 (mm)		
1. Active alkali (as Na_2O),	(%)	17	17	17	17	17	17	17	17	17	17	17	17
2. Temperature of white liquor	(°C)	80	80	80	80	80	80	80	80	80	80	80	80
3. Circulation period,	(mins.)	45	45	45	45	45	45	45	45	45	45	45	45
4. Active alkali consumed,	(%)	1.55	3.3	2.51	2.83	4.12	4.1	5 41	4.93	4.93	6.05	5.7	5.73
5. Amount of foam (per 500ml liquor)	(ml)	170	180	250	420	360	330	600	650	350	420	460	600
6. Bubble size		Big	Big	Big	Med.	Med.	Med.	Small	Small	Small	Smallest	Smallest	Smallest

big fraction develops foam with big bubbles which are unstable.

The active alkali consumption increases with decrease in chip size. It can be explained in terms of nature of carbohydrate and A–B extractive values. The low molecular weight content which can readily react with alkali, is quite high in the finer fractions due to mechanical damage during chipping. Because of higher surface area available in finer fractions for alkali to react, the A—B extractives can be extracted more easily than in the bigger fraction. Ultimately the foam formation increases with decrease in chip size and specially with the dust fraction.

It was observed that the white liquor darkens as more of wood components dissolve. The change in colour of white liquor may be due to dissolution of tanins, pigments and extractives from chips. The absorption characteristics of circulated liquor at 410 nm have shown that the dust extracted liquor has highest absorbancy. The absorbancy of liquor increases with decrease in chip size (Table–6). The colour appears to be a good indicator of foaming tendency and can be developed as a control parameter in the pulp mill.

TABLE 6 : CHIPS SIZE VIS-A-VIS LIGHT ABSORBANCE PERCENTAGE OF CIRCULATED LIQUOR

Chip Size, mm	Absorbance, % at 410 nm
1. +22, +25, +32	6.7
2· +13, +16, +19	12.5
3. + 3, + 6	20.0
4. — 3	69.0

When dust is added to chips in varying percentage; the foam volume increases gradually (Table–7). Normally the chips contain dusts from 0.5 to 1.0%. Daba bamboo chips generate only 350 ml foam (Table–2) but when 10% dust is added, 510 ml of foam is produced (Table—7). The active alkali consumption also increases with increase in dust content. These results clearly establish that dust content of chips play a key role in foam formation.

when dust is soaked in water for 30 minutes and 1 hour, the moisture content value is found to be 50 and 55% respectively; the initial value being 16.5%, (Table—8). This shows that water penetration is

TABLE 7 : FOAM CREATING TENDENCY OF CHIPS WITH VARYING PERCENTAGE OF SAW DUST

Particulars	Chips+10% dust	Chips+20% dust	Chips+30% dust	Chips+40% dust
1. Moisture, (%)	24	24	24	24
2. Active alkali applied as Na_2O, (%)	17	17	17	17
3. Temperature of white liquor, (°C)	80	80	80	80
4 Circulation period, (mins)	45	45	45	45
5. Active alkali consumed, (%)	4.12	4.9	4.9	5.7
6. Amount of foam (per 500 ml liquor) (ml)	510	600	600	660
7. Bubble size	Small	Smaller	Smallest	Smallest
8. Absorbance % at 410 nm (circulated liquor)	45.6	45.6	49.5	53.8

faster in the dust fraction than in chips. Increase in moisture content in case of dust showed no effect on foam volume produced (Table—8). This clearly indicates that when surface area is not a limiting factor for liquor penetration, moisture plays a minor role in foam forming tendency of chips.

TABLE 8 : FOAM CREATING TENDENCY OF SAW DUST

	Particulars		Saw dust as such	Saw dust soaked in water for 1/2 hr.	Saw dust soaked in water for 1 hr.
1.	Moisture,	(%)	16.5	50	55
2	Active alkali applied as Na_2O	(%)	17	17	17
3.	Temperature of white liquor	(°C)	80	80	80
4.	Circulation period	(mins.)	45	45	45
5.	Active alkali consumed	(%)	6.64	5.03	5 03
6.	Amount of foam, (per 500 ml liquor)	(ml)	590	570	590
7.	Bubble size,		Small	small	small

Conclusion :

The foam formation depends essentially on type of raw material, its A–B extractive value, moisture content and size of chips. Daba bamboo and Acacia generate more of foam than Eucalyptus, Subabul and Salia bamboo. Storage of bamboo and wood decreases foam formation.

Increase in moisture content in chips gives higher volume of foam Chips soaked for longer period generates more of foam Decrease in chip size increases the foam formation. Finer fractions of chips causes more of foam, especially the dust. Consequently keeping the dust content in chips to minimum level is essential to avoid foam problems. The intensity of colour of the liquor under recirculation appears to be a good indicator of its foaming tendency.

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