Technical Assessment of Papermaking Properties of Eucalyptus Grandis and E. Tereticornis of Different Age Groups

SINGH, SV*, BHANDARI S.S.*, BHARATI REKHA*, & GUHA S.R.D.*

ABSTRACT

Comparative proximate chemical analysis, pulping, bleaching and papermaking properties of plantation grown *Eucalyptus grandis* and *E. tereticornis* of different age groups are reported. It has been found that the amount of polyphenols (hot water and methanol extractives) increase with age in both the species and coppise rotation wood contains higher amount of polyphenols than original one. *Eucalyptus grandis* gave pulps of higher yield and higher degree of delignification as compared to *E. tereticornis* at all groups investigated. Within *E. grandis* the pulp yield increased with age upto 14—15 years and then decreased, whereas in case of *E. tereticornis* it decreased with age. Bleaching characteristics of both the species at all age group were similar. Both unbleached pulps of *E. grandis* developed better strength properties than *E. tereticornis*. Within *E. grandis* the wood of 14—15 years age group gave best results. In case of *E. tereticornis* the burst, and tensile index were similar for both age groups whereas tear index increased with age.

INTRODUCTION :

Within the genus Eucalyptus there are wide differences in papermaking properties which are usually assessed in terms of species, age or size of tree and wood quality. In case of plantation grown species effect of age should be considered as an important factor for technical assessment of pulps in papermaking economy, and to rationalise coppice rotation period in relation to pulp quality.

Eucalyptus among other hardwoods has recently acquired considerable importance as a fibre source, well accepted by papermakers for specific qualities of its pulp, viz., good formation, high bulk, high opacity, medium tensile and good tear. Eucalyptus pulps have found their use in all the three types of papers-fine papers, newsprint and packaging materials.

Eucalyptus kraft pulp gives unique combination of strength, bulk and opacity. This combination together with excellent sheet formation caused by the extremely small fibres makes it an ideal raw material for fine papers.

Although wood from the tree of this great genus constitutes the major part of raw material of the Australian pulp and paper industry, the knowledge what is available from literature on Eucalyptus species and their utilization may not be exactly applicable to our situation, because it is well known that the characteristics of plantation grown woods differ from those occurring in their natural habitat and as well as in plantation species locality and age variations also significantly change physical and chemical nature of wood. These facts led us to undertake a detailed examination on papermaking qualities of our plantation grown Eucalyptus species.

A series of investigation has been carried out to evaluate papermaking qualities of *Eucalyptus grandis* and *E. tereticornis* with special reference to the effect of age, chemical composition, density and wood structure (fibre and vessels) on pulping and bleaching characteristics and surface and other physical properties of paper. This paper deals with effect of age on their pulping, bleaching and papermaking characteristics.

RAW MATERIALS AND METHODS :

Four samples of *E. grandis* and two of *E. tereticornis* of different age groups growing in Kerala State

*Cellulose and Paper Branch,
Forest Research Institute and Colleges, Dehradun.

have been taken for studies reported in this investigation, the details of which are given in Table 1. The logs were converted into chips by a 4 knife Waterous chipper. The chip size and moisture content affect the rate of delignification as they affect the rate of transport of chemicals to the site of reactions and of reaction products away from the site by diffusion[1,2]. In the work described in this paper it was considered sufficient to use samples of chips for which the average size and moisture content were constant. The chips size was in between 16mm to 26 mm in length and breadth, the thickness being 2–3mm.

Table—1

DETAILS OF AGE GROUP OF EUCALYPTUS SPECIES

Sl. No.	Age group years	Year of Plantation	Date of collection	Specific Gravity o.d. weight green volume
	E. grandis			
1.	5–6	(1961 plantation felled in 1971) 6 yrs. coppice	11.5.77	0 452
2.	10–11	1966	9.5.77	0.405
3.	14–15	1962	9.5 77	0.395
4.	18–19	1959	9.5.77	0.368
	E. tereticornis			
5.	5–6	1971	9.5.77	0.579
6.	14–15	1963	12.5.77	0.535

PROXIMATE CHEMICAL ANALYSIS :

The chips were disintegrated in a Wiley mill to produce wood meal of 40-60 mesh which was used for experiments on proximate chemical analysis. All proximate chemical analysis were carried out according to TAPPI standards. Solubility in methanol was determined by extracting wood meal with methanol in a Soxhlet extractor. These results are recorded in Table 2.

PULPING :

The evaluation of pulping properties of all the samples of the two species was carried out using kraft process, first under identical conditions to have a comparative assessment of their pulping behaviour and thereafter the cooking chemical charge was varied wherever necessary, to cook them to a pulp of same Kappa number level (21 ± 1) so as to examine their comparative bleaching characteristics for producing bleaching grade kraft pulps for fine papers.

STANDARD COOKING CONDITIONS :

In the first series of experiments all the cooks were carried out under identical conditions in the series digester, consisting of 2.5 lit. vessels rotating in an oil bath keeping the following conditions constant :

Table—2

CHEMICAL COMPOSITION OF EUCALYPTUS GRANDIS AND E-TERETICORNIS OF DIFFERENT AGE GROUPS

Species and age group	% Solubility in			Tappi Klason lignin		Klason lignin (a)	Holocellulose %	alphacellulose %
	Methanol	Hot water	1% NaOH	Acid in– soluble %	Acid soluble %			
E. grandis (5–6 yrs.)	7.0	3.7	11.8	30.0	4 0	24.1	75.5	46.4
E. grandis (10–11 yrs.)	4.4	1.6	11.1	25.1	4.5	25.0	76.9	48.1
E. grandis (14–15 yrs.)	4.6	2.5	11.0	27.2	2.5	24.4	76 8	46 6
E. grandis (18–19 yrs.)	5.7	2.9	10.3	28 5	3.8	25 4	74.8	43.6
E. tereticornis (5–6 yrs.)	6.8	2.4	11.6	32.1	3.3	27.8	75 9	42.4
E. tereticornis (14–15 yrs)	7.8	3.4	10.9	33.5	3.2	28.1	76.1	46.0

* All percentages expressed on oven dry wood meal.
(a) Wood meal pre–extracted with 0.5% NaOH was used.

Chip charge	—	400 g. oven-dry-
Active alkali charge	—	15% as Na_2O
Sulphidity	—	25%
Chip to liquor ratio	—	1 : 3.5
(including chip moisture)	—	
Time to reach 100°C	—	15min.
Time from 100 to 170°C	—	105min.
Time at 170°C	—	60min.

OTHER COOKING CONDITIONS :

E. grandis samples of various age groups excluding 14-15 years age and both the samples of *E. tereticornis*, were cooked with 16% and 17% active alkali charge respectively to obtain pulps of same Kappa number (21±1) keeping all other conditions constant as mentioned above.

RANDOMISATION OF COOKS :

The cooking of all the 6 sample of the two Eucalyptus species of different age groups designated as 1 to 6 in Table 3 was carried out in triplicate in each case and the pulps representing the same samples were mixed together to form a composite for further processing after checking their yields and rejects in each cook.

Table–3

SAMPLES DISTRIBUTION BETWEEN DIGESTERS

Digester No.	Cooks 1	2	3
1	1	6	2
2	2	5	4
3	3	4	6
4	4	3	1
5	5	2	3
6	6	1	5

Altogether 18 bombs were filled of the three cooks required in one set of experiment. Samples and cooks were randomised so that the variation between cooks has little effect on final evaluation. The randomisation example is given in Table 3. The digester number in Table 3 refer to serial numbers of table for species and age group identification. This systematic randomisation was done to reduce any variation between the cooks to repress the effect of increasing cooking time from digester 1 to 6 due to the lag in removal of the digesters. The condition for this randomisation is that the digesters are always removed in ascending order.

After the cooking schedule was completed, the vessels from the series digester were removed and quenched in water. After 5 minutes of quenching they were removed, opened and emptied on terylene cloth to remove black liquor. The pulp was washed and disintegrated for five minutes in a disintegrator fitted with an impeller (at 3000 r.p.m.). The disintegrated pulp was washed thoroughly free of black liquor on a buscher funnel fitted with a terylene cloth. The washed pulp was stored at +5°C in polyethene bags for further analysis.

PULP ANALYSIS :

The pulps of three cooks representing the same sample were combined before screening. The yield of the composite pulp was also determined and compared with the yield of individual cooks. It was found that there was practically no variation in the two. The composite pulp was screened on a flat screen with 0.35mm slots and percentage of screened rejects was determined by weighing after drying at 105±3°C in an oven for 6hrs. The yield of screened pulp was determined by weighing the wet pulp lot and taking two repersentative samples of 50g. from the lot to be dried in an oven at 105±3°C for 6 hours.

The dried samples were weighed and the yield was determined by simple calculations of percentage moisture in 50g. of the representative samples and conversion to the total weight of wet lot of pulp.

Kappa number and lignin content of screened pulps were determined according to APPITA standard (p 201mm-[63]) and TAPPI standard (T 13mm[54]) respectively. The results of cooking experiments and pulp analysis of composite samples are given in Table 4.

BLEACHING :

The bleaching of all the pulps (Kappa number 21±1) was done under identical conditions using CEH sequence The chlorine demand of the pulp was determined on small scale experiments as follows :

CHLORINATION :

The chlorine demand for chlorination stage was calculated by carrying out mini scale chlorination with 20 g. oven-dry unbleached pulp samples at different levels of chlorine application (percentage was varied from 0.22 to 0.28 times of Kappa number). The series of experiments carried out for mini scale and large scale chlorination are given in Table 5.

Table—4

Kraft Pulping on Eucalyptus Grandis And E-Tereticornis of Different Age Groups*

Species & Age group	Pulp yield %	Screen rejects %	Kappa No. %	Klason lignin %	Pulp yield %	Screen rejects %	Kappa No. %
	Active alkali—15% as Na_2O				Active alkali—16% as Na_2O		
E. grandis (5–6 yrs.)	50.2	0.33	29.0	3.1	48.7	0.27	21.2
E. grandis (10–11 yrs.)	55.6	0.12	28.0	1.5	53.1	0.15	20.5
E. grandis (14–15 yrs.)	55.3	0.10	21.7	1.7	—	—	—
E. grandis	54.4	0.34	25.2	1.6	52.4	0.00	20.4
					Active alkali 17% as Na_2O		
E. tereticornis (5–6 yrs.)	47.3	0.60	41.0	4.1	44.1	0.15	21.7
E. tereticornis (14–15 yrs.)	45.2	0.17	40.0	4.8	42,5	0.07	21.6

Constant conditions : Chip charge 400 g o.d., Chip to liquor ration 1:3.5, Sulphidity 25%; time to *100°C 15 min; time from 100 to 170°C 105 min; time at 170°C 60 min.

Table — 5

Plan of Bleaching Experiments at Chlorination Stage

	MINI SCALE I	II	III	IV	V	LARGE SCALE
Pulp g.	20	20	20	20	20	200
Time min.	60	60	60	60	60	60
Temp. °C.	30	30	30	30	30	30
Consistency %	3	3	3	3	3	3
Cl_2 Charge %	4.4	4 8	5.2	5.6	6.0	5 6

The residual chlorine was determined and plotted against the amounts of chlorine applied. An inflection was observed after certain amount of application of chlorine. The point of inflection is taken as chlorine demand of pulp. After determining the chlorine demand large scale chlorination of pulps (200 g.) was carried under the constant conditions mentioned in last column of Table 5.

EXTRACTION :

The extraction of all the chlorine treated pulps under the conditions mentioned in last column of Table 5 was carried out under identical conditions arbitrarily chosen as follows :

Caustic soda	—	2%
Consistency	—	8%
Temperature	—	70±1°C
Time	=	2 hours

HYPOCHLORITE STAGE :

The hypochlorite stage was given to the pulps having undergone C and E stage under the following constant conditions :

Calcium hypochlorite (available chlorine)	—	2 %
Consistency	—	8 %
Temperature	—	40±1°C
Time	—	2 hours
pH	—	10.0

All the percentages expressed above are on ovendry pulp.

BLEACHED PULP ANALYSIS :

The yield of pulp was determined as described for unbleached pulp. The brightness was determined according to SCAN method using Elrepho Tester. The results are recorded in Table 6.

Table — 6

Brightness and Yield of Bleached Pulps of Eucalyptus Grandis and E. Tereticornis

Species and age group	Total chlorine applied at C and H stages %	Kappa No.	Brightness	Yield %
E. grandis (5–6 yrs.)	7.6	21 2	79.1	48.6
E. grandis (10–11 yrs.)	7.6	20.5	76.1	50 0
E. grandis (14–15 yrs.)	7.6	21.7	75.3	49.6
E grandis (18–19 yrs.)	7.6	20.4	77.2	49.4
E. tereticornis (5–6 yrs.)	7.6	21.7	76 7	40.1
E. tereticornis (14–15 yrs.)	7 6	21.6	75.7	38.3

PULP EVALUATION :

BEATING :

The various pulps were beaten in PFI mill to different degrees of freeness according to ISO Standard (DP 5264) by charging 30 0 g. o.d. pulp at 10% cosistency, 17.7 N/Cm beating pressure and 6.0m/sec relative speed.

SHEETMAKING :

Hand sheet of 60±2 gsm were prepared on standard British paper sheet making machine. They were pressed and are dried using standard procedures.

TESTING :

Physical testing of handsheets for tensile index, burst index, tear index, stretch and bulk etc. was done after conditioning the sheets at 65±2%RH and 27±1°C These were performed according to ISO Standard (DP 5269).

RESULTS AND DISCUSSIONS

EXTRACTIVES AND SOLUBILITIES :

The determination of various types of soluble components as rep esented in conventional proximate analysis does not seem to be logical in all cases. For example, ether and alcohol benzene solubility may not be of much use in case of hardwoods, whereas these gives indications of the amount of waxy and resinous matter in case of softwoods, particularly pines. Instead, in case of hardwoods methanol solubles should be examined as hardwoods contain appreciable amount of polyphenols which are of importance from over all paper making point of view and are soluble in methanol. Polyphenols provide additional nuclear positions for condensation reaction of lignin during pulping and thus create problems in viscosity of black liquor during recovery process. Hot water solubles also correspond to some extent to the amount of polyphenols present in hardwoods, whereas cold water solubility is of not much significance. The values of methanol and hot water solubles in case of *Eucalyptus* species of varying age groups were determined and the results are recorded in Table 2.

A perusal of the data in Table 2 on methanol and hot water solubles indicates that there is an increasing trend of these components with age in case of both *E. grandis* and *E.tereticornis.* It will also be seen from these data that the amounts of both methanol and hot water solubles of 5-6 years age coppice wood (regenerated after 10 years of first felling) are much more than those of any other non-coppice wood of higher age groups (upto 18 Yrs.) investigated. This means that the wood of coppice growth even at young age contains higher amount of polyphenols than non-coppice wood. However, this information on amount of polyphenols has its limitations because of the fact that the nature of polyphenols is more important than their quantity in wood.

It has been observed that pulping and bleaching characteristics of these species of varying age groups were not influenced to any degree on account of varying amount of polyphenols. The data on the solubilities in methanol and hot water further indicate that the *E. tereticornis* contains more amount of polyphenols as compared to *E. grandis.*

1% caustic soda solubility is of importance in assessing the soundness of wood in respect of its decay. The values determined for ***E. grandis*** and ***E. tereticornis*** are recorded in Table 2. It will be seen from these values that all the samples have almost same amount of solubles. The values are quite normal and allowed further processing on pulping and bleaching characteristics of the raw materials.

LIGNIN CONTENT :

Klason lignin determination is an indicative of apparent lignin content in wood. It has been reported in literature and observed by the authors also that the apparent lignin content of some species of hardwoods particularly Eucalyptus are abnormally high when the standard method of determination is employed. This is caused by the presence of considerable amount of "Kinos" in these woods. These kinos are precipitated during the lignin determination by 72% sulphuric acid treatment so that the Klason lignin obtained is heavily contaminated with kinos and the values are misleading. Therefore one should be very wary in examining the values of Klason lignin in case of *Eucalyptus* species and other hardwoods as well. Another important point while looking at Klason lignin content is to bear in mind that value under examination corresponds only to the acid insoluble portion of lignin (AIL) in wood meal. There is a part of lignin which goes in to solution as acid soluble lignin (ASL) during treatment with 72% sulphuric acid. Determination of ASL should be followed as a part of Klason lignin determination experiment because the value of ASL is of considerable interest. Firstly the total lignin content of wood meal can only be known by adding the amount of ASL to that of AIL. Secondly it has been reported that ASL is mainly derived from cell wall and AIL from middle lammella[3]. This fact is of great value in providing preliminary information on limitation of high degree of pulping in combination with the bleachability of pulp. A pulp of higher ASL will be difficult to bleach as compared to the pulp of lower ASL. But at the same time one has to restrict the degree of cooking so as not to degrade the pulp significantly for want of removing cell wall lignin which influences the bleachibility.

It has been reported by Kawamura and Bland[4] that in order to obtain pure Klason lignin it is necessary to extract wood meal with 0.5% sodium hydroxide, but partial dissolution of the lignin during the treatment is unavoidable. The experiments carried out for determination of Klason lignin by Tappi standard procedure on alcohal - benzene pre extracted and also on 0.5% sodium hydroxide pre-extracted wood meals gave the values as recorded in Table 2.

It will be seen from these data that in case of *E. grandis* and *E. tereticornis* the values obtained with alcohol - benzene pre-extracted wood meal are higher than those found using 0.5% NaOH pre - extracted wood meal. These observations are in conformity with those of Kawamura and Bland[4]. Therefore, the Klason lignin determined by standard procedure in case of *Eucalyptus* species is contaminated lignin and the values could be misleading. Modified method of pre-extraction with 0.5% sodium hydroxide yields more meaningful results on Klason lignin values in *Eucalyptus* species which contain considerable amount of polyphenols. The data also show that the Klason lignin content of *E. grandis* is less than *E tereticornis*.

CARBOHYDRATE CONTENT :

Cross aud Bevan cellulose determination does not convey much except that it provides the most preliminary assessment of fibrous component of the raw materials. Instead, values of holocellulose and alpha celluloses give better information regarding the entire carbohydrate fractions of raw materials. And also these determinations in conjuctions with lignin content are of basic requirement to analyse the pulp quality in respect of its composition and yield on the Ross diagram-one of the analytical guide and tool for studying changes in pulp composition during a cooking cycle. By knowing the values of alpha cellulose, holocellulose and lignin one can draw a contour under which will lie all the compositions of pulp, a raw materials can produce and one can arrest the pulping according to the need of pulp composition desired for a particular type of product. Also on the Ross diagram one can judge whether delignification is prevalent or corbohydrate dissolution.

The values of holocellulose and alpha cellulose determined for *E. grandis* and *E. tereticornis* of different age groups are recorded in Table 2. It will be seen from these data that both the species contain almost similar amounts of carbohydrate fraction at all age groups investigated in this study.

PULPING AND BLEACHING CHARACTERISTICS

A perusal of data in Table 4 shows that in general *E. grandis* could be pulped to much higher yield (about

10% more) and higher degree of delignification as compared to *E tereticornis* under identical conditions. Among *E. grandis* of various age groups investigated in this report the wood of 14-15 years age could be pulped to a Kappa number 21±1 with 15% active alkali, whereas other age groups required 16% active alkali to be pulped to this Kappa number level. *E. grandis* gives pulp of higher yield than *E. tereticornis* at all age groups levels studied in this investigation. Within *E. grandis* the pulp yield increased with age upto 14-15 years and thereafter it declined at higher age group. In case of *E. tereticornis* the yield decreased with age. *E. tereticornis* required 2% more chemicals for cooking to a Kappa number level of 21±1 as compared to *E grandis* of 14-15 years age.

The bleaching characteristics of pulps (Kappa number 21±1) of both the species were almost similar. The data in Table 6 show that in general the pulps from all the age groups of both the species investigated could be bleached to over 75 brightness using CEH sequence and applying 7.6% total chlorine including that at hypochlorite stage. The pulp from *E. grandis* of 5-6 years age group gave higher brightness values (79.1) perhaps because of being young and coppice crops.

These results on pulping and bleaching characteristic show that *E grandis* of 14-15 years age gives highest pulp yield of unbleached pulp (55 3%) as well as of bleached pulp (49.4%). In case of *E. tereticornis* the pulp yield was slightly better at younger age (5-6 years), the unbleached and bleached pulp yields being 44% and 40%, respectively.

PAPER PROPERTIES :

The papermaking potential of a pulp is defined as the range and extent of properties that are attainable using a given pulp. In conventional pulp testing reports, the results obtained are frequently presented as a function of beating with the introduction of interpolations to certain levels of freeness of °SR. However, in many cases it may be worth-while to evaluate each pulp property as a function of some other pulp property. This is based on the principle that pulp evaluation should always be based upon those properties which are or which may be regarded as properties of importance for the product to manufacture. Both these treatments have been given to analyse the data recorded in this study. Pairs of properties examined include (a) bulk as a function of tensile (b) tear as a function tensile and (c) tear as a function of burst. The results on changes in tear, burst, tensile and bulk with freeness are represented in Figs. 1-4 and interdependence of these are represented in Figs. 5-7. (Eg and Et represented *E. grandis* and *E. tereticornis* respectively).

FREENESS OF PULP AND STRENGTH PROPERTIES :

It has been found that improvement in burst index and tensile index with decreasing freeness, in case of *E tereticornis* is identical for both the age groups. This shows that for the range of age groups between 5-15 years, there is no difference in the behaviour of unbleached kraft pulps (Kappa number 40.0) of *E. tereticornis* as far as improvement in bursting and tensile strength with beating is concerned. But the improvement behaviour of tear index was found to be different in the two age groups studied. The wood of age group of 5-6 years give lower values than 14-15 years age group wood. This shows that age has significant influence of behaviour of these pulps during beating for tearing strength development. In case of *E. grandis* on an average, the age group 14-15 years gave the best results, in the development of all the three properties-burst, tear and tensile. In case of tear index the values for all the age groups studied lied in between the ranges attained by 5-6 years age group on the lowest side and by 14-15 years age groups on the highest side. However, the burst and tensile indexes of young coppice wood (5-6 yrs.) approached the level attained by pulp of 14-15 years age group wood.

In case of the development behaviour of strength properties during beating of soft cook unbleached pulps of same Kappa number 21±1, it has been found that for *E. tereticornis* the beating behaviour and development of strength properties differed significantly than that of hard cook pulps of high Kappa number (40.0). The pulp from higher age group wood (14-15 yrs.) had lower strength properties as compared to those attained by pulp from young wood (5-6 yrs.). The values attained by younger wood pulp at lower Kappa Number approached to the values of strength properties attained by best pulps of *E. grandis* (14-15 yrs.). This difference may be attributed to the change in lignin/carbohydrate composition of the two unbleached pulps. In case of *E. grandis* the behaviour of pulps of Kappa number 21±1 was similar to that observed with pulps of varying Kappa number (21 to 29). This is due to the fact that the difference in Kappa No. of these two types of pulps was not very high as it was in case of *E tereticornis.* The best strength properties (burst, tear and tensile) were attained by pulps of 14-15 years age group wood and the rest of the age groups showed almost similar behaviour in development of these strength properties.

The beating characteristics of bleached pulps prepared from unbleached pulps of same Kappa No. (21±1) showed that on bleaching the burst index development pattern of young wood has fallen in line with pulp of higher age group wood (14-15 yrs.) and so is the case with tensile index In case of tear index the values for young wood (5-6 yrs.) pulp has fallen below those of higher age group (14-15 yrs.) wood pulp. This sh ws that bleaching has influenced and altered the behaviour of development of these properties of pulp in these two cases of *E. tereticornis* and in case bleached kraft pulps tear index increased with age. In case of *E. grandis* two ranges of strength properties were isolated. For burst index, the lowest range boundary was formed by 5-6 years and 18-19 years age group pulps and the pulps from 10-11 years age group wood reached the highest line attained by 14-15 years age group wood pulp. In case of tensile index also, the lowest line was formed by 5-6 years age group wood pulp and the highest was attained by 14-15 years age group wood pulp, the values for others lie in between these two. In case of tear index also best values were obtainable with 14-15 age group wood pulp.

The pulps from both species of the age groups investigated behaved in a similar fashion as far as change in bulk of paper sheets with freeness is concerned.

INTER-RELATIONSHIP BETWEEN PAIR OF PROPERTIES :

The inter-relationship between various pairs of physical properties of pulps recorded in tables are represented in Fig. 5-7.

In case of unbleached pulps prepared under identical conditions, the relationship between burst-tear and tensile-tear revealed that for *E. tereticornis* the values lied in different enclosure and were lower than *E. grandis,* whereas in case of unbleached pulps of same Kappa No., the values were higher and occupied the place in the same enclosure as formed by *E. grandis.* The data on bleached pulp properties relationship (in case of burst-tear and tensile-tear) show similar results. In case of *E. tereticornis* both the age groups have found their values in the same enclosure as formed by *E grandis* the younger wood (5-6 yrs) being on the lowest line and higher age group wood in between. In case of bulk tensile relationship all the pulps evaluated has a common strength line relationship.

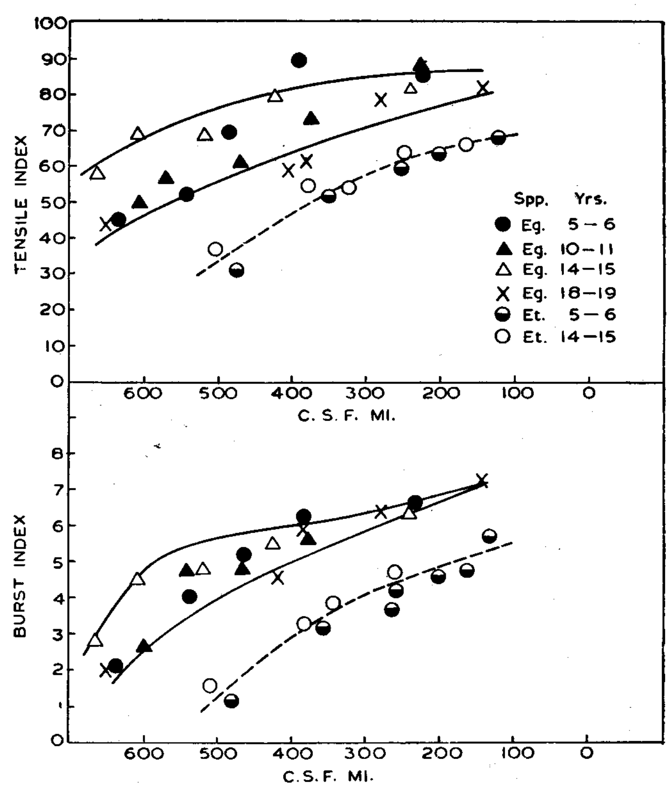

Fig. 1 STRENGTH PROPERTIES Vs FREENESS (PULPS KAPPA No. 21-40)

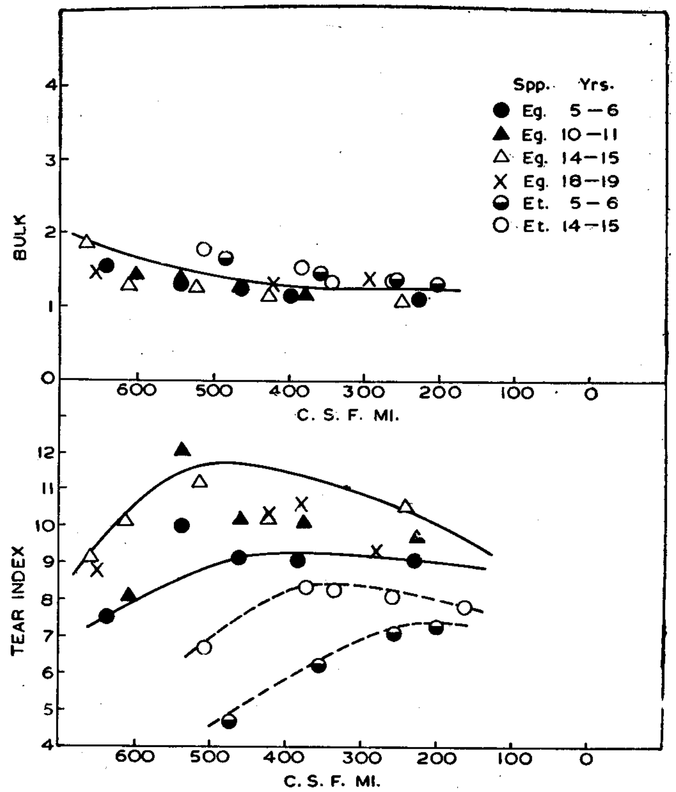

Fig. 2 STRENGTH PROPERTIES Vs FREENESS (PULPS KAPPA No. 21-40)

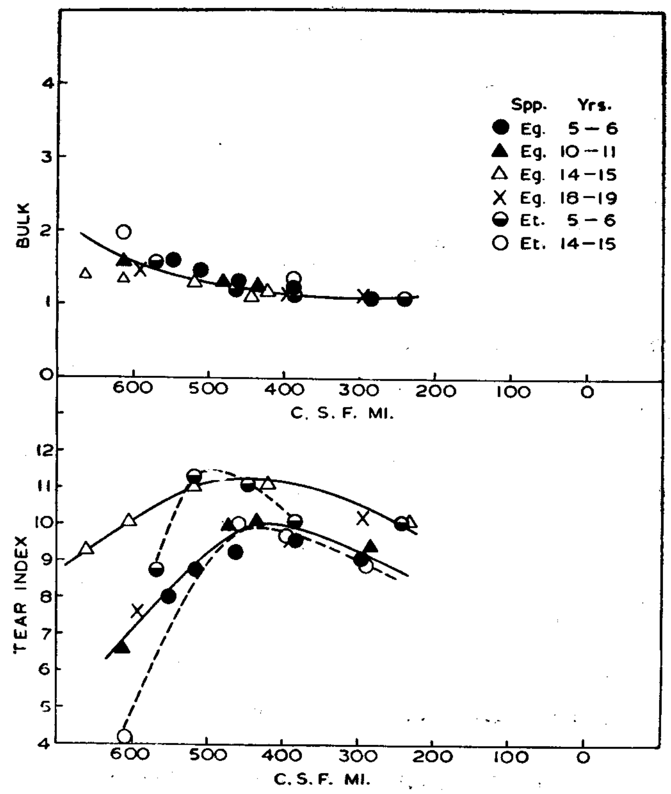

Fig. 4 STRENGTH PROPERTIES Vs FREENESS (PULPS KAPPA No. 21±1)

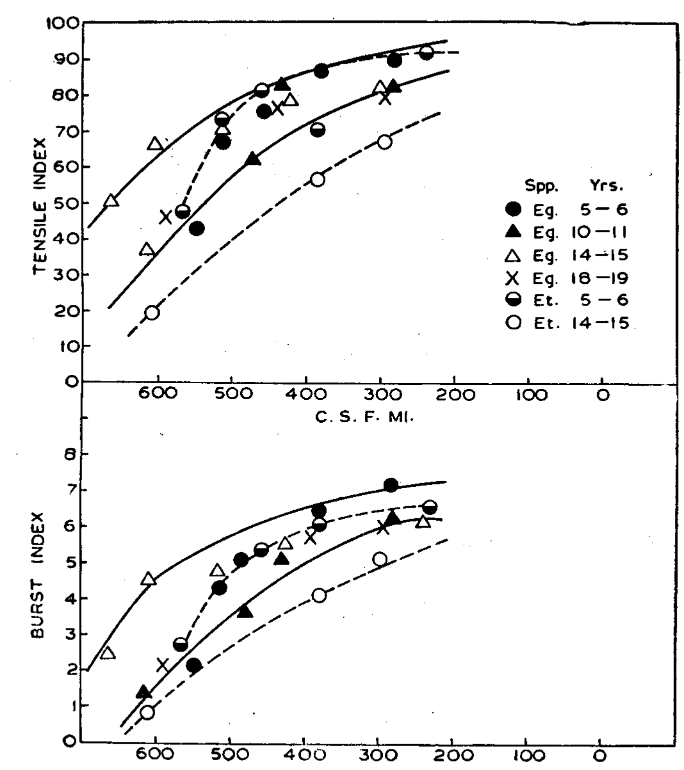

Fig. 3 STRENGTH PROPERTIES Vs FREENESS (PULPS KAPPA No. 21 ±1)

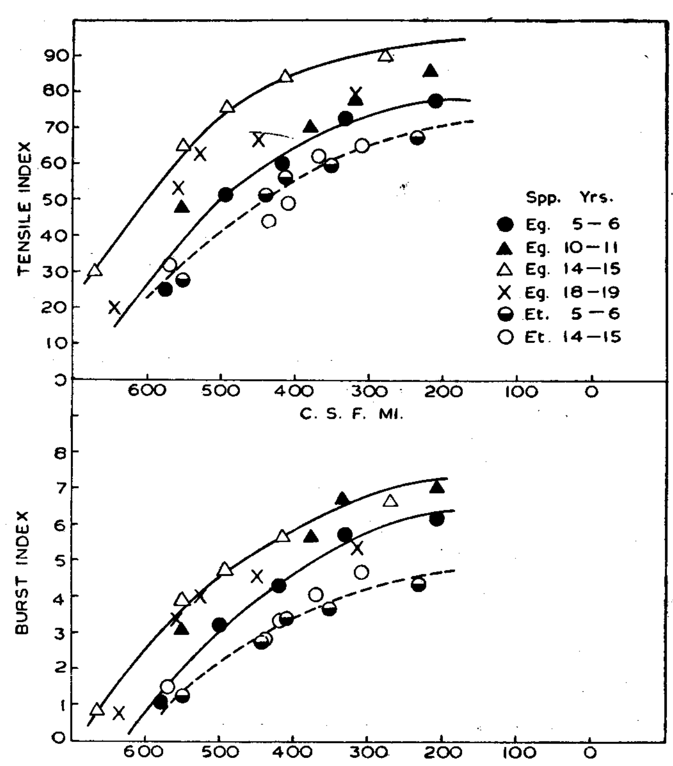

Fig. 5 STRENGTH PROPERTIES Vs FREENESS (BLEACHED PULPS)

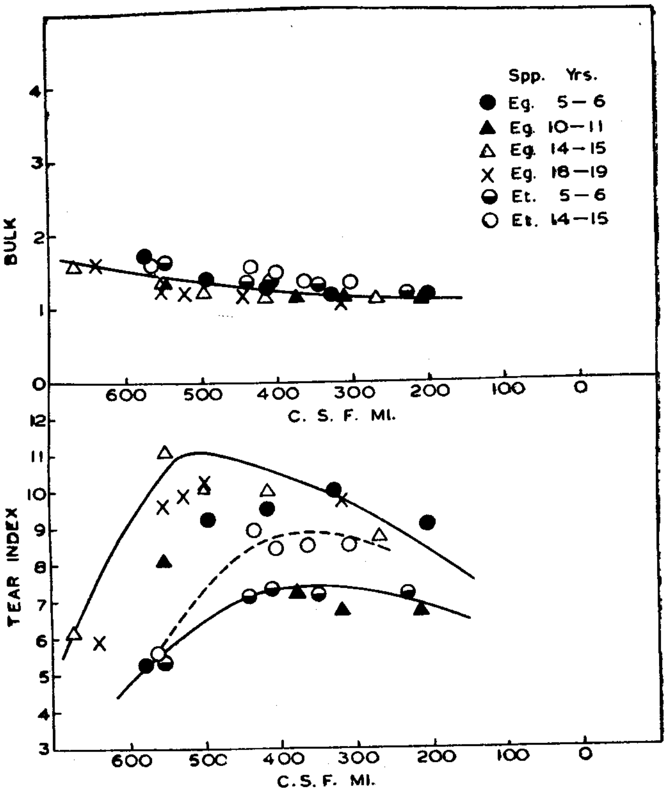

Fig. 6 STRENGTH PROPERTIES Vs FREENESS (BLEACHED PULPS)

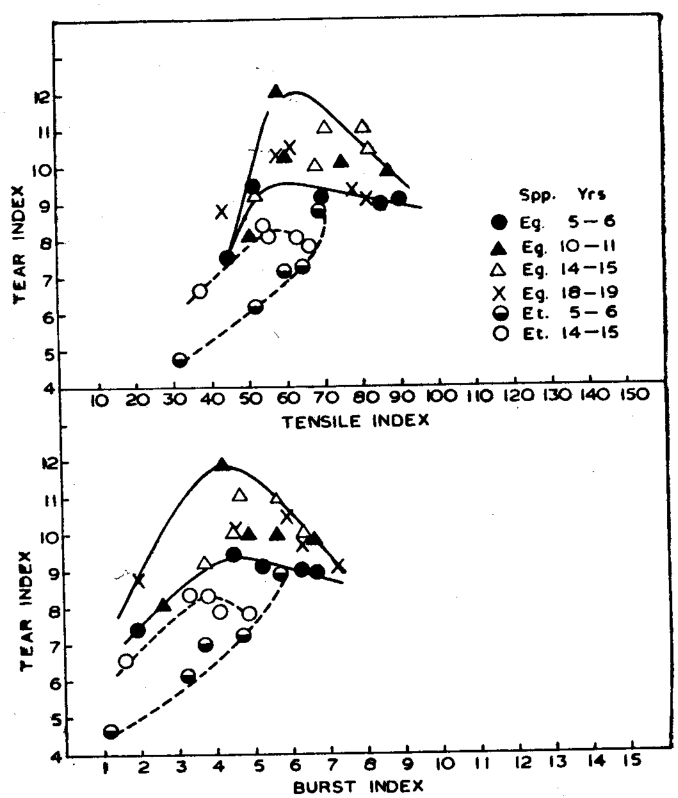

Fig. 7 INTERRELATIONSHIP OF STRENGTH PROPERTIES. (PULPS KAPPA No. 21-40)

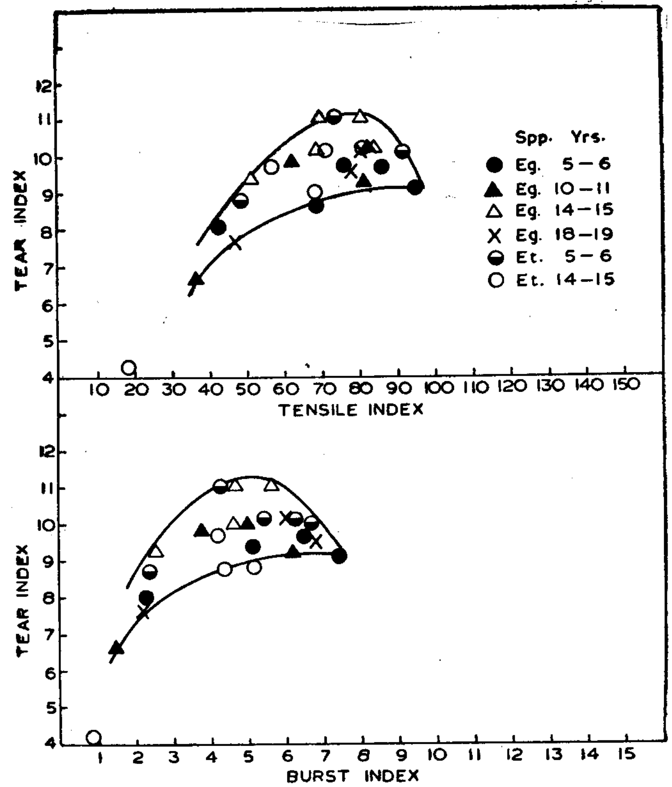

Fig. 8 INTERRELATIONSHIP OF STRENGTH PROPERTIES. (PULPS KAPPA No. 21±1)

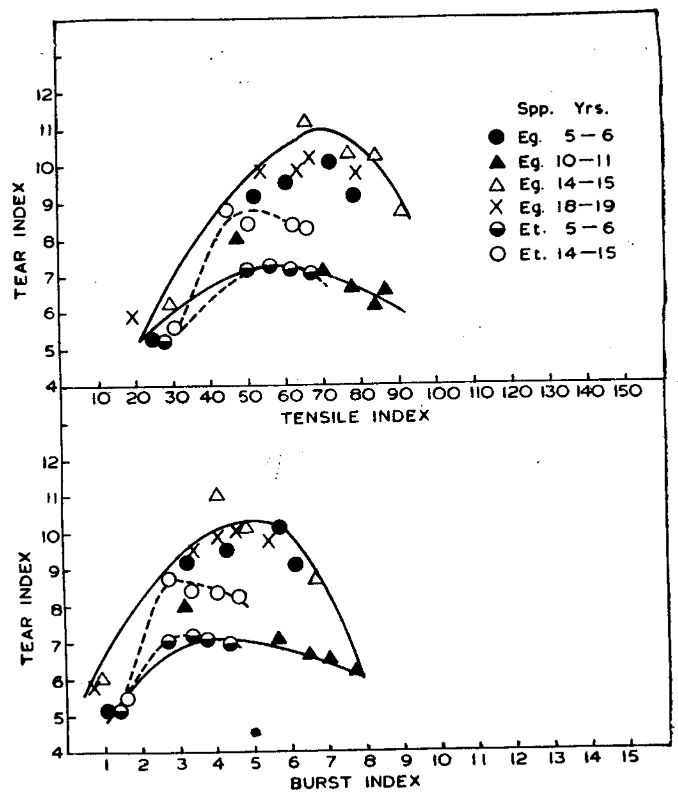

Fig. 9 INTERRELATIONSHIP OF STRENGTH PROPERTIES. (BLEACHED PULPS)

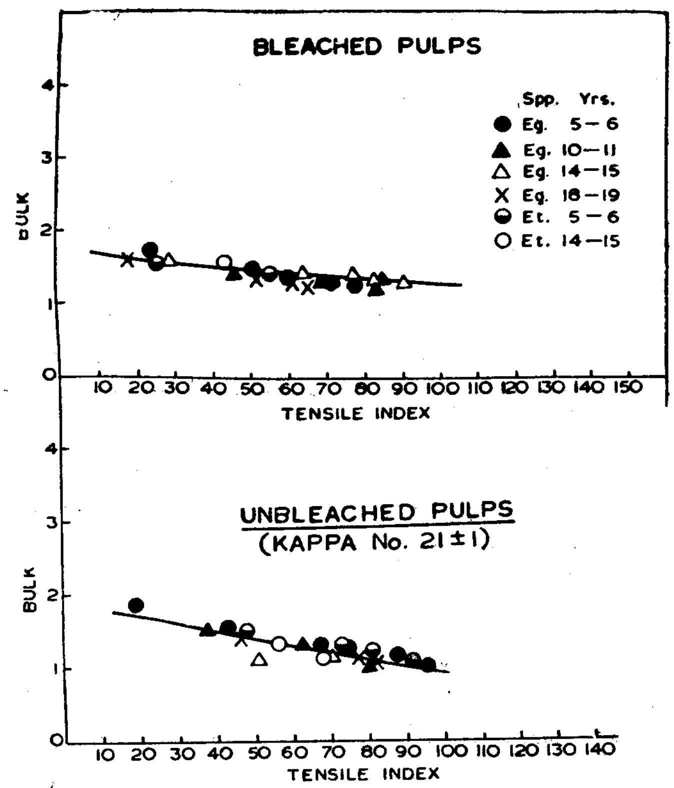

Fig. 10 BULK-TENSILE RELATIONSHIP

CONCLUSIONS :

In case of unbleached pulps obtained by cooking under identical conditions, the properties of *E. tereticornis* were lower than *E. grandis*. Within *E. tereticornis* burst and tensile index were similar for the age group range of 5-15 years, whereas tear index increased with age.

Within E. grandis, on an overall assessment, the best results were obtained with 14-15 years age group wood. Beyond this the properties decreased, in general. There was an area within which lied the properties attained by wood pulps from various age groups range (5-19 yrs.) investigated.

The soft cook unbleached pulps (Kappa No. 21±1) behaved somewhat differently than hard cook unbleached pulps of (Kappa no. 40.0), in case of *E. tereticornis*. The pulps from younger wood had better strength properties and attained the values obtained with best pulps of *E. grandis* (14-15 yrs.) as far as tensile and tear are concerned. In case of burst index the values were in between the two ranges attained be *E. grandis*.

In case of bleached pulps prepared from unbleached pulps of same Kappa no. (21±1), the values of burst and tensile index were lower in case of *E. tereticornis* as compared to *E grandis* of all age groups (5-19 yrs.). The tear index of *E. tereticornis* pulp from lower age group wood (5-6 yrs.) touched the lowest range attained by *E. grandis*, whereas the tear index of higher age group wood (14-15 yrs.) approached the values somewhat in between the two ranges attained by *E. grandis*. Within *E tereticornis* the burst and tensile index were similar for both the age groups, whereas tear index increased with age.

Bulk tensile relationship in case of both the species at all age groups studied are similar for unbleached and bleached pulps.