

REINFORCING POTENTIAL OF JUTE PULP WITH *TREMA ORIENTALIS* (NALITA) PULP

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Two morphologically different pulps, a long-fiber jute pulp from a soda-AQ process and a short-fiber *Trema orientalis* pulp from a kraft process, were evaluated and compared for their reinforcing potential. *T. orientalis* pulp needed less beating energy than jute pulp at the same drainage resistance. Addition of jute fiber pulp to the *T. orientalis* pulp increased tear strength. Sheet density of pulp blends was increased with the increase of beating degree of both pulps and the proportion of *T. orientalis* pulp. Tensile index and burst index of blended pulp were increased when the beating degree and proportion of *T. orientalis* pulp increased.

Keywords: Jute pulp; *Trema orientalis* pulp; Beating degree; Pulp blending; Tear index; Tensile index

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INTRODUCTION

Globally, there is a trend towards continually increasing paper machine speeds and a drive for reduced resource consumption (paper of lower grammage). Consequently, a number of paper grades, including newsprint and higher value mechanical paper, such as supercalendered grade A (SCA) and light weight coated (LWC), require the addition of softwood fiber to act as reinforcement pulp (Martin and Richard 2000). The major use of softwood kraft pulps is to reinforce weaker papermaking furnishes. In Bangladesh the main fibrous raw material resources available for papermaking are short-fibred hardwoods and agricultural and industrial wastes. In the search for a potential long-fibre substitute for softwood pulp, most published research suggests jute fiber as an appropriate solution (Akhtarzaman and Shafi 1995; Jahan 2001; Jahan and Farouqui 2000).

Recently we identified a potential fast-growing species for pulping named *Trema orientalis* (Jahan and Mun 2004; Jahan et al. 2007) (local name Nalita). It is a native species, and grows everywhere in Bangladesh. At present, this species is not planted for industrial use. It yields short-length fibers, and consequently produces lower tear strength (Jahan and Mun 2003). *T. orientalis* fibers are not likely to be used on a 100% basis for paper manufacturing in Bangladesh, even in view of the low amount of allocated forestland for pulpwood in the country (FAO 2005). The demand for packaging-grade paper is increasing rapidly in Asia (Anon 2008; FAO 2005). Packaging grade paper needs higher tensile-tear properties. So blending with jute pulp may help to achieve the desired paper properties.

Pulp blending is a common practice in papermaking to achieve desired properties of end products. For instance, reinforcement of soda-AQ kenaf pulp with sunflower stalks

pulp increased strength properties (Khristova et al 1998). Blending of 30-50% kenaf CTMP with loblolly pine kraft pulp produced pulp with acceptable strength for linerboard (Mayers and Bagby 1994). Horn et al. (1992) suggested that kenaf CTMP can be used as a reinforcement pulp instead of expensive semibleached softwood kraft fibre for newsprint. Xu and Zhou (2007) showed that the mixing of hardwood chemical pulp with chemical mechanical pulp improved bulk and light scattering properties and also improved interfiber bonding strength as compared to chemical pulp alone. The addition of abaca pulp to softwood pulp increased tear strength, fracture toughness, and folding endurance for the isotropic sheets, but the tensile strength decreased slightly (Karlsson et al. 2007).

Jute fiber pulps, like softwood pulps, require more refining to reach a given tensile strength. Different tear-tensile strength relationships are obtained, depending on fiber length. However, these differences rapidly decrease with reducing proportions of softwood fiber included in eucalypt/softwood and mixed hardwood/softwood pulp blends (Kibblewhite 1993; Brindley and Kibblewhite 1996; Mansfield and Kibblewhite 2000). For example, for 80:20 eucalypt/softwood blends, refining requirements, tear/tensile strength relationships, and optical properties are similar when the softwood component consists of either the Canadian, or the medium or low radiata pine pulp. The refining process itself has a critical effect on the formation and runnability of the paper machine.

In the first part of this study we compare the refining capability of jute fiber and *T. orientalis* pulp in a PFI mill versus a Valley beating system and determine papermaking properties. In the second part, the effect of addition of jute fiber pulp to *T. orientalis* pulp in three drainage resistance ranges has been studied and fitted in a non-linear equation for creating realistic (i.e. non-linear) models, simulating the behaviour of suspensions and paper properties in pulp blends. Jute pulp was prepared by a soda-AQ process and *Trema orientalis* pulp by a kraft process. The pulp properties are given in Table 1.

EXPERIMENTAL

Materials

The *T. orientalis* used in this study was collected from the BCSIR Experimental Field, Dhaka at the age of 3 years old. Three trees were selected for this experiment. 2 ft from the top and bottom of these trees was discarded and the remaining portion was debarked and chipped to 0.2 x 1 x 2 cm size. Jute fiber was collected from Jute Mill in Narayangong. The jute fiber was very clean and free from scaling. These were chopped to 2-3 cm in length.

Pulping

Pulping was carried out in a 20 liter capacity batch cylindrical digester heated by means of electrical resistance. A motor was used to rotate the digester. *T. orientalis*, and jute fiber pulping was carried out by kraft and soda-AQ processes, respectively. The soda-AQ process had been found to produce better pulp from jute than the kraft process (Jahan 2001). The normal charge was 2 kg of o.d. Nalita or 1.5 kg jute fiber. In the soda-

anthraquinone (AQ) pulping, active alkali and AQ charges were 16 % as NaOH and 0.05% on o.d. raw materials. Pulping was continued to 1 h at 170 °C, with a jute-to-liquor ratio of 1:5. In the kraft process the active alkali charge was 18 % as Na₂O on o.d. raw materials, and the sulphidity was 25 %. Pulping was continued to 2 h at 170 °C, with a *T. orientalis* to liquor ratio of 1:4. After digestion the pulp was washed until free from residual chemicals and screened by flat vibratory screener (Yasuda, Japan). The pulp yield was determined gravimetrically as percentages of oven-dry raw materials. Results are given in Table 1.

Table 1. Pulp Properties of Jute and *Trema orientalis* Pulp

	Pulp yield %	Kappa number	Fibre length, mm	Fibre diameter µm	Pentosan, %
Jute fibre	68.8	11.7	2.5	19	18.8
<i>T. orientalis</i>	50.5	22.2	1.1	23	10.7

Table 2. Physical Properties of Jute and *Trema orientalis* Pulp Blends

Jute:Nalita(X _j)	Jute °SR(X _{jsr})	Nalita °SR(X _{nsr})	°SR	Tear mNm ² /g	Tensile Nm/g	Burst kPa.m ² /g	Density, g/cc
100:0	16	18	16	12.7	10.5	1.2	0.274
75:25	16	18	16	10.8	11.6	1.2	0.364
50:50	16	18	16	9.7	15.5	1.5	0.384
25:75	16	18	16	7.9	25.0	1.8	0.413
0:100	16	18	18	7.1	26.3	1.9	0.447
100:0	45	18	45	12.3	42.0	3.4	0.468
75:25	45	18	30	10.9	32.9	2.9	0.456
50:50	45	18	28	9.3	32.0	2.5	0.451
25:75	45	18	21	8.0	31.5	2.2	0.448
0:100	45	18	18	7.1	26.3	1.9	0.447
100:0	16	40	16	12.7	10.5	1.2	0.274
75:25	16	40	18	12.9	23.7	2.4	0.380
50:50	16	40	22	12.1	44.0	3.5	0.440
25:75	16	40	25	9.6	54.7	3.8	0.478
0:100	16	40	40	7.0	75.2	5.6	0.567
100:0	45	40	45	12.3	42.0	3.4	0.468
75:25	45	40	36	10.1	46.8	3.6	0.480
50:50	45	40	36	9.0	54.7	4.4	0.492
25:75	45	40	37	8.1	66.8	5.0	0.512
0:100	45	40	40	7.0	75.2	5.6	0.567
100:0	16	54	16	12.7	10.5	1.2	0.274
75:25	16	54	19	12.5	31.2	2.9	0.374
50:50	16	54	24	9.2	53.9	3.9	0.450
25:75	16	54	36	7.6	65.9	4.3	0.531
0:100	16	54	54	6.9	74.0	5.2	0.583
100:0	45	54	45	12.3	42.0	3.4	0.468
75:25	45	54	48	9.7	53.3	3.6	0.444
50:50	45	54	49	8.3	58.9	3.8	0.483
25:75	45	54	52	7.2	63.6	4.1	0.524
0:100	45	54	54	6.9	74.0	5.2	0.583

Beating

To compare the development of strength properties in two beating devices, *T. orientalis* and jute fiber pulps were beaten separately in a PFI mill for different numbers of revolutions and in a Valley beater for different intervals of time. The beating gap between bar and bedplate was 0.2 mm for the PFI mill. After beating, handsheets of about 60g/m² were made in a Rapid Kothen Sheet Making Machine according to German Standard Methods DIN 106. The physical properties of handsheets were determined by the TAPPI method T 220 sp-96.

Blending

The beaten (Valley beater) and unbeaten unbleached *T. orientalis* and jute fiber pulps were mixed in different proportions from 0 to 100 percent at intervals of 25 %, followed by disintegration for 30,000 revolutions in a standard laboratory British disintegrator. Handsheets were prepared and papermaking properties were determined as above. The results of the handsheet testing are given in Table 2.

RESULTS AND DISCUSSION

Beating

Beating of chemical pulp is an essential step in improving the bonding ability of fibres, causing a variety of simultaneous changes in fibres, such as internal fibrillation, external fibrillation, fibre shortening or cutting, and fines formation (Page 1989; Ebeling 1980). The pulps were beaten in the PFI mill and Valley beater, and strength properties were determined. The PFI mill is used to beat pulp fibre to increase fibre flexibility and improve papermaking properties, but Valley beating causes fibrillation, generating fibres of lower length, and producing fines. The results are given in Figs. 1-5.

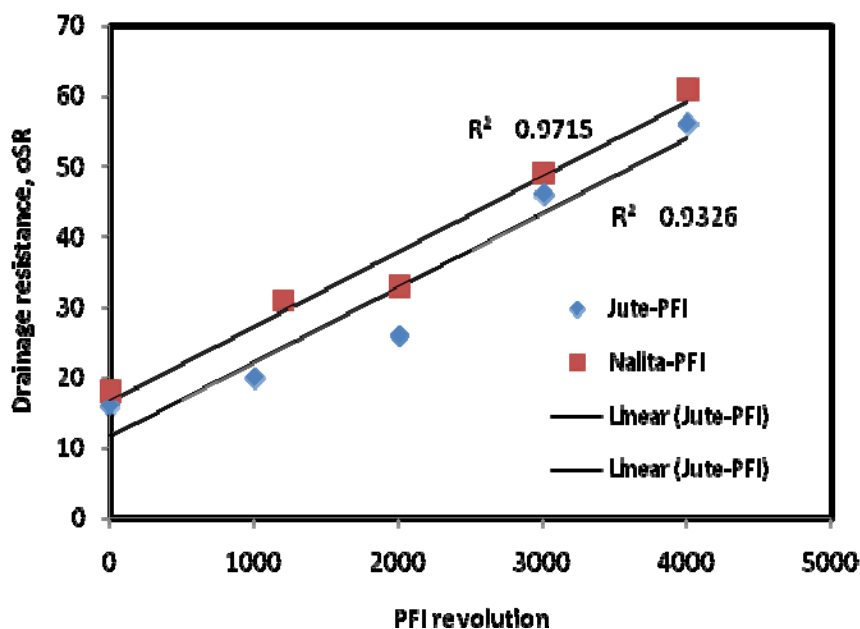


Fig. 1. Beatability of jute and *Trema orientalis* pulp

Figure 1 shows that for a given drainage resistance, *T. orientalis* pulp required less refining energy than that of jute fibre pulp. Both pulps showed linear relationships between drainage resistance and refining level. The tensile and burst index of both pulps rapidly developed (drainage resistance °SR 10 to 30) until they leveled off at moderate levels of drainage resistance (Figs. 3-4). Valley beating showed better development in tensile and burst index than that of PFI mill. But tear index showed completely reversed results; pulp refined with the PFI mill showed better tear index in both pulps.

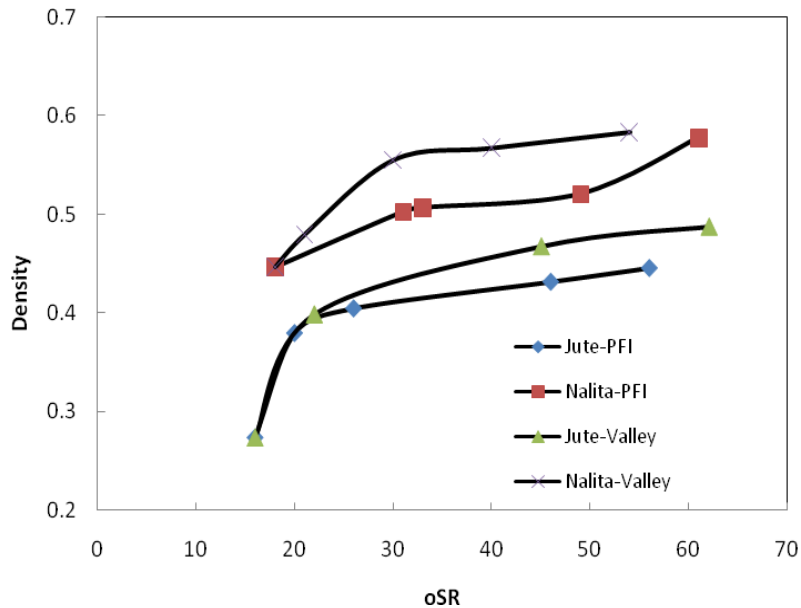


Fig. 2. Drainage resistance verses density of jute and *T. orientalis* pulp

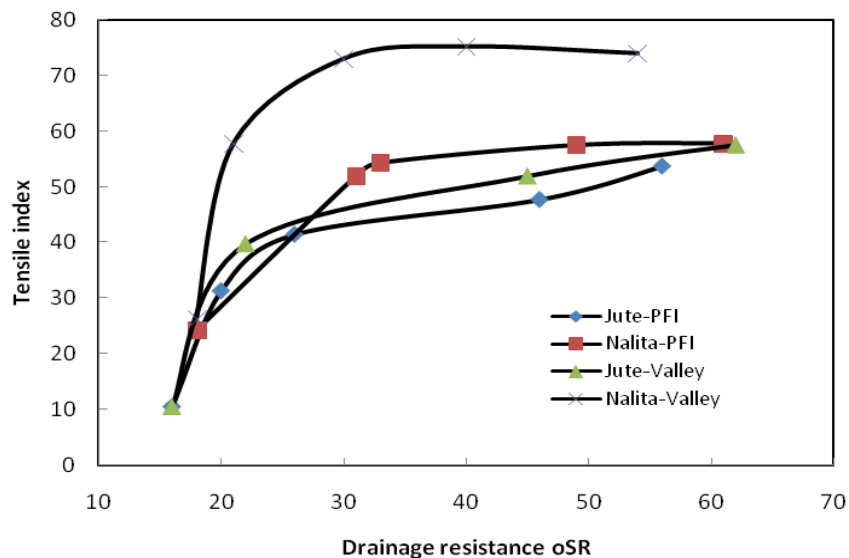


Fig. 3. Drainage resistance verses tensile index of jute and *T. orientalis* pulp

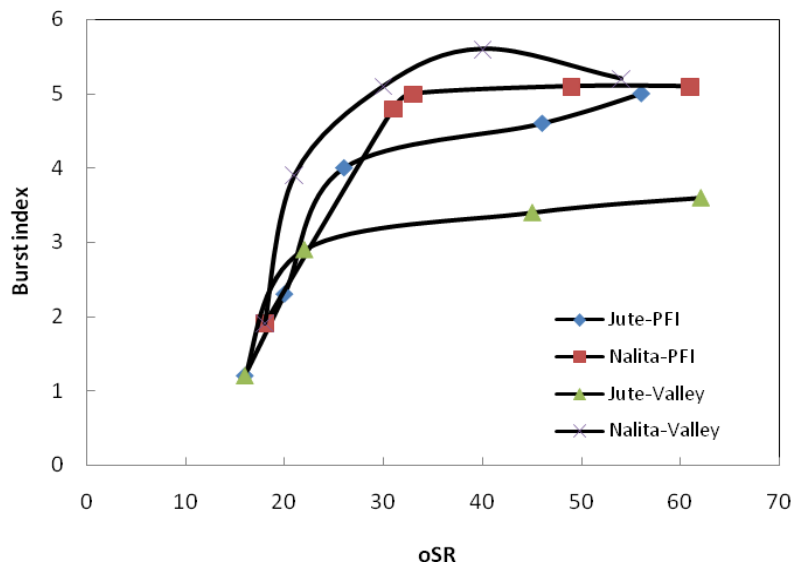


Fig. 4. Drainage resistance versus burst index of jute and *T. orientalis* pulp

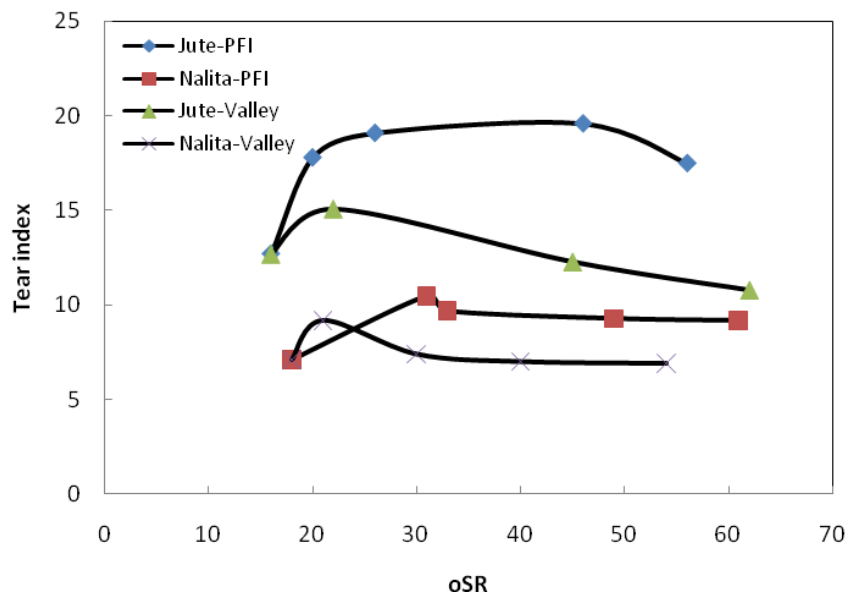


Fig 5. Drainage resistance versus tear index of jute and *T. orientalis* pulp

Jute pulp showed quite high tear index. PFI mill beaten jute pulp had a tear index of 19 $\text{mN}\cdot\text{m}^2/\text{g}$ at drainage resistance 25, which is similar to softwood pulp (Karlsson et al. 2007).

Blending

The effects of adding jute pulp to a *T. orientalis* pulp were evaluated with handsheets. It is important from the Bangladeshi perspective to understand how pulp properties change when jute pulp is mixed with hardwood pulp, especially for packaging and kraft liner paper. Strength properties of handsheet samples under a variety of conditions given by the mixture and central composite design were evaluated. A detailed regression analysis was conducted, and regression models were developed relating the physical properties to

furnish composition and refining levels. Using these regression models, we were able to predict the effect of jute addition and degree of refining on paper properties, allowing us to optimize these variables. The addition of jute pulp to *T. orientalis* pulp drastically influenced the paper properties. Addition of unrefined *T. orientalis* pulp to unrefined jute pulp improved tensile and burst index, while tear index decreased (Table 2). This was expected, since the *T. orientalis* fibre showed higher tensile strength properties in the unrefined state than the corresponding jute pulp.

Drainage resistance ($^{\circ}$ SR)

As seen in Table 2, the Schopper-Riegler degrees ($^{\circ}$ SR) dropped gradually as the proportion of jute pulp increased. The $^{\circ}$ SR value showed a linear relationship to jute pulp addition when both pulps were refined. Addition of refined *Trema orientalis* pulp to the jute pulp yielded a significant increase in tensile, burst, and density also. This was expected, since the original *T. orientalis* pulp showed higher bonding strength properties.

Density

Handsheet density is a good indicator of the conformability of individual fibres in the fibrous network and thus a fair reflection of the fibre's bonding potential. As expected, the densities of sheets were decreased with the increase of jute pulp proportion in the pulp blends, because of the longer fibers in the jute pulp. The densities of sheets increased with addition of *T. orientalis* pulp in both the unbeaten and beaten condition. *T. orientalis* contains a high amount of hemicelluloses (Casey 1980) (Table 1), which contributed to improved density. As expected, the beating degree of both pulps had a significant effect on sheet density (Eq. 1), which would be expected to increase bonding-dependent strength properties. The changes are due to the increased flexibility of beaten pulps, which allows the fibres to come into close contact, hence, more fibres per unit volume, as also observed by Koran (1994).

$$\begin{aligned} \text{Density} = & 0.454 - 0.031 X_j + 0.01 X_{jsr} + 0.051 X_{nsr} + 0.027 X_j X_{jsr} - 0.02 X_j X_{nsr} \\ & + 0.014 X_{jsr} X_{nsr} - 0.004 X_j^2 - 0.013 X_{nsr}^2 \end{aligned} \quad (1)$$

$R^2 = 0.890$, Adjusted $R^2 = 0.848$

Tensile index

Examining the regression equation obtained for tensile index (2), it is apparent that the determining factors were *T. orientalis* concentrations and its refining levels. The tensile strength of a paper is dependent of the degree of bonding in the sheet and strength on the single fiber. At a constant fiber length, tensile strength increases with increasing density, and at a given density, tensile strength increases with increasing fiber length (Seth 1990). Tensile index of pulp blend was increased when the proportion of *T. orientalis* pulp increased in the unbeaten state (Table 2, Eq. 2, Fig. 6). The largest effect of tensile index of pulp blend was observed in the case of the beating degree of *T. orientalis* pulp (Eq. 2).

$$\begin{aligned} \text{Tensile} = & 35.487 - 5.783 X_j - 4.896 X_{jsr} + 25.0 X_{nsr} + 5.56 X_j X_{jsr} - 6.203 X_j X_{nsr} \\ & + 9.099 X_{jsr} X_{nsr} - 1.87 X_j^2 + 8.068 X_{nsr}^2 \end{aligned} \quad (2)$$

$R^2 = 0.894$, Adjusted $R^2 = 0.854$

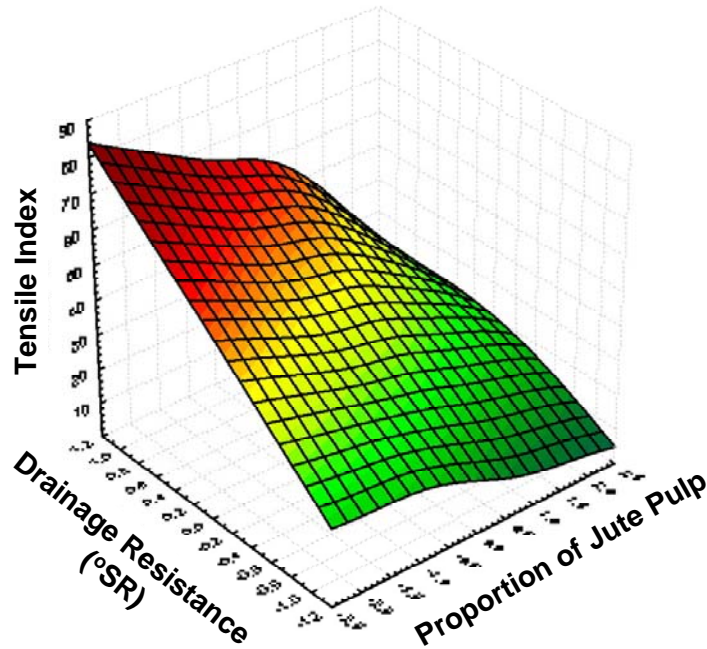


Fig. 6. Surface plot of tensile index against proportion of jute pulp and drainage resistance of *T. orientalis* pulp

Burst index

Burst index also saw an improvement with increasing *T. orientalis* pulp content in pulp blends and its beating degree, yielding a value of 4.4 kPa m²/g when the pulp blend ratio was 50:50 in the refined state. These data suggest that bonding-dependent strength is directly related with the hemicelluloses content of pulp (Casey 1980) (Table 1). Tschirner et al. (2003) observed that the addition of Soda AQ wheat fibre to the hardwood/softwood mixture significant increased in tensile, burst, and density. Horn et al. (1992) observed that the burst strength of the recycled newsprint blends increased with increasing addition of kenaf CTMP.

$$\begin{aligned} \text{Burst} = & 3.035 - 0.295 X_j - 0.396 X_{jsr} + 1.755 X_{nsr} + 0.360 X_j X_{jsr} - 0.430 X_j X_{nsr} \\ & + 0.679 X_{jsr} X_{nsr} - 0.033 X_j^2 - 0.718 X_{nsr}^2 \end{aligned} \quad (3)$$

$R^2 = 0.855$, Adjusted $R^2 = 0.800$

Tear index

The tear index increased with the increase of jute pulp and decreased with the beating degree of jute pulp. This effect is attributed to the long average fibre length (fibre length 0.25 mm) of jute fibre. Tearing resistance is to a great extent dependent on fibre length. Seth (1990) and Seth and Page (1988) have reported an increase in tear index with increasing fibre length. For sheets of high degree of bonding, however, the fibre length is of less importance (Lee et al. 1991). The regression equation (4) shows tear index tends to decreased rapidly with *T. orientalis* pulp refining (Fig. 7). Addition of unrefined jute pulp to the refined *T. orientalis* pulp increased tear index. At 50 % unrefined jute pulp addition to moderate refined *T. orientalis* pulp, tear index increased 12 mN.m²/g, where

tensile index was 44 N.m/g, which was further increased to 55 N.m/g with decreasing tear index to 9 mN.m²/g when jute pulp was refined. Nevertheless, a significant negative impact on tear strength could be observed at high refining levels (Table 2). Karlsson et al. (2007) observed that addition of abaca pulp to softwood pulp increased tear index.

$$\begin{aligned} \text{Tear} = & 9.506 + 1.305 X_j - 0.654 X_{\text{jsr}} + 0.399 X_{\text{nsr}} - 0.163 X_j X_{\text{jsr}} + 0.060 X_j X_{\text{nsr}} \\ & + 0.341 X_{\text{jsr}} X_{\text{nsr}} + 0.200 X_j^2 - 1.183 X_{\text{nsr}}^2 \end{aligned} \quad (4)$$

$R^2 = 0.8845$, Adjusted $R^2 = 0.839$

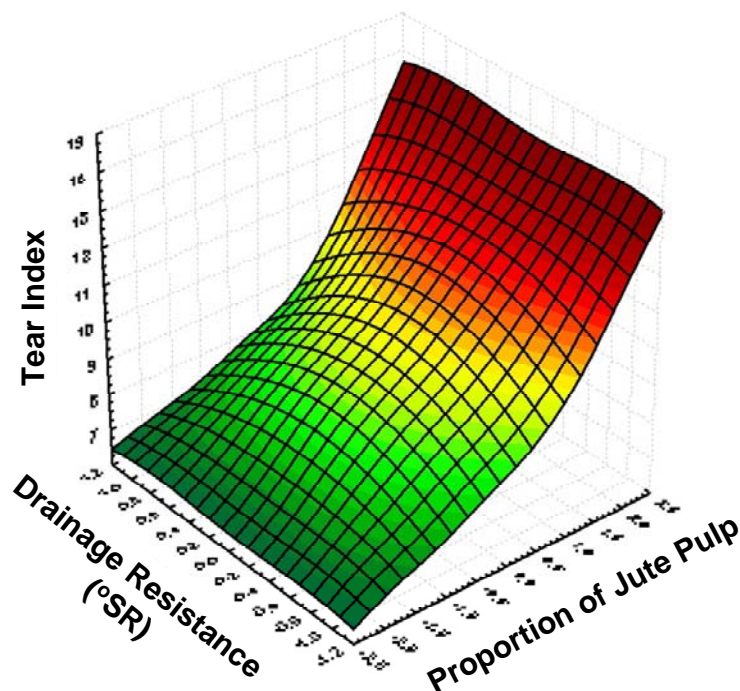


Fig. 7. Surface plot of tear index against proportion of jute pulp and drainage resistance of *T. orientalis* pulp

CONCLUSIONS

Trema orientalis pulp is easier to beat than Jute pulp. Valley beaten pulp showed higher tensile index and burst index than that of PFI mill beaten pulp, while PFI mill beaten pulp showed higher tear index than that of Valley beaten pulp. Statistical models capable of predicting the influence of addition of soda AQ jute pulp to *Trema orientalis* pulp on paper properties were developed. This study also confirmed that additive principles of pulp mixture did not follow the properties of components in the mixture to predict blended pulp properties; some degree of non-linearity could be observed. The addition of jute soda-AQ pulp to a *T. orientalis* kraft pulp increased tear strength considerably. The refining degree and proportion of *T. orientalis* pulp in pulp blends increased sheet density, and consequently increased tensile index and burst index.

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