Varietal response of jute fibres with varying meshiness to alkali treatment: Part II—Properties of alkali-treated jute fibres

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Different varieties of jute fibres each with different levels of meshiness index have been treated under three different conditions of NaOH solution, namely 9% conc./2°C temp. (9/2), 18% conc./30°C temp. (18/30), and 18% conc./10°C temp. (18/10). Loss in weight and amount of shrinkage and their relationship with the change in tenacity and breaking extension of fibres have been studied. It is observed that the concentration and temperature of NaOH solution along with the degree of opening have considerable effect on the properties of fibres. Out of the three conditions, 18/10 is found to be more effective in developing desirable characteristics of breaking extension and tenacity with sufficient crimps for better spinning performance and better blend compatibility with other natural and man-made fibres.

Keywords: Alkali treatment, Hemicellulose, Jute reeds, Lignin, Meshiness index

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1 Introduction

Crimp generation as a consequence of structural changes on alkali treatment has been observed as an effective means to counteract with inherent deficiency of stiffness in the jute fibres. In our earlier study, it has been established that out of the three treatment conditions (18/30, 18/10 and 9/2), 18/10 is comparatively more attractive condition for the development of crimp characteristics. W-4 and Desi varieties have shown better crimp behaviour than TD-3 and Mesta in terms of decrimping extension, decrimping stress, specific crimp energy and crimp stability. But if the full potential of the alkali treatment is to be ascertained, it would be quite pertinent to deliberate on the other changes in the physical properties of fibres, as a result of this process of high technical importance. The literature available on the tensile strength of alkali-treated jute provides a conflicting picture. Sarkar reported an increase in strength of fibres on treatment with 1% NaOH solutions. Mukherjee et al. observed an increase in the breaking load on treatment with 1% NaOH in cold and a reduction at 18%. But Samipati et al. came out with the contradictory result that the fibres treated with 10% caustic soda solution experience some deterioration in tensile strength but with 18% hardly any loss in the strength. Fibre extension and flexibility have been reported to increase as a result of alkalinization. In the present work, the effect of alkali treatment conditions on properties of different varieties of jute under various meshiness conditions has been studied. This study is an effort to have an insight in the modification of jute fibre characteristics on alkali treatment.

2 Materials and Methods

The properties of raw materials used in the study have been reported earlier. Thirty-six samples were prepared under different combinations of concentration and temperature of alkali bath. Shrinkage, weight loss and fibre fineness have been determined as reported earlier.
2.1 Determination of Tensile Properties of Fibres

Instron tensile tester with 20 mm gauge length, 5 mm/min cross-head speed and 100 gf full-scale load was used to obtain the load-elongation curves. Curves obtained through tensile loading on Instron were of the nature as shown in Fig. 1. A typical load-elongation curve ONB of a jute filament treated with caustic soda solution has been shown. The linear part NB of the curve ONB was extrapolated to cut the axis OX at Q. Therefore, OQ is the measure of the decrimping extension and OW & OV are the breaking load and breaking elongation values respectively. Fifty fibres were tested and the average values of breaking load and breaking extension were calculated. Fibre extension was calculated by subtracting the decrimping extension from extension-at-break.

3 Results and Discussion

3.1 Weight Loss

Table 1 shows that 18/30 gives the maximum weight loss in all varieties and in all states of fibres while 9/2 gives the minimum. From these results, it can be argued that the weight loss depends on strength of alkali used and temperature. The reasons for this behaviour can be attributed to higher swelling effect at higher concentration and higher breakage of bonds between the constituents at higher temperature and concentration.

In case of less meshiness, the fibres are more in free state and hence, no restriction in swelling takes place. Again due to combing, some surface damage may occur and roughen the surface. Side by side, more exposure of fibre surface to alkali may also have an effect on the weight loss.

It can be observed from Table 1 that Corchorous capsularis variety like W-4 shows maximum weight loss. This behaviour indicates that there must be more amount of amorphous region and probably less lignin. It is well known that lignin inhibits swelling and even a small reduction in lignin content can enhance softness of feel and provide ease with which hemicelluloses can be removed. Desi variety also has more or less the same weight loss as that of W-4. But TD-3 and Mesta have significantly less weight loss than W-4.

3.2 Length Contraction

Table 1 shows that there is more contraction at 18/30 and 18/10 as compared to that at 9/2; further the contraction at 18/10 is more than that at 18/30. Sarkar et al. have shown that the crystalline/non-crystalline ratio of cellulose decreases on strong alkaline treatment. Roy et al. also observed that at 18% texturizing concentration considerably high swelling of cell wall occurs along with stress relaxation. Under such excessive swelling condition and hence with much weakening of secondary forces in case of 18/10, the tie molecules will release the internal stresses mostly by disorientation, while in 18/30, they have another option for doing so through segmental motion under higher thermal vibration. Thus, the chain disorientation is expected to be more in 18/10 than in 18/30, and hence more length contraction in 18/10.

Alkali’s known effect of removing meshiness has probably been the reason for the marginal difference in length contraction among the samples of varying degree of combing but meshiness adversely affects crimp formation as reflected in decrimping extension. It has been found that W-4 and Desi varieties undergo shrinkage more than TD-3 and Mesta. Analyzing the whole thing, it can be stated that the varieties giving more weight loss shrink more.

3.3 Denier Change

The results in Table 1 show that although a marked reduction in denier has occurred at 9/2 but it is lower than that at 18/10, which, in turn, is lower than 18/30. It is also evident that combing contributes towards reduction in meshiness, but the degree of combing would not influence the alkali treatment results to a significant extent. The role of meshiness cannot be neglected at all because it will affect the crimp development to a considerable extent. It can be said that as the combing goes finer, the denier loss in single fibres tends to increase although it remains marginal.

Maximum denier change (reduction) has occurred in W-4 grade followed by Desi and TD-3 and the
Juice and degree of combing the juice fibres subjected to
the fibres remain cemented as conjugate ones. It was
also observed by Samajpati concentration and temperature of NaOH solution (Table
density of juice fibres is found to decrease in general, it becomes increas-
ingly finer with the increase in
lowest in Mesta. With the alkali treatment, the linear
density of juice fibres is found to decrease in general, suggesting that the fibres have become finer. Grade of
juice and degree of combing the juice fibres subjected to
are the factors deciding the fineness of juice fibres and
it becomes increasingly finer with the increase in concentration and temperature of NaOH solution (Table 1). It is known that juice fibres are multicellular and full of fissures and pores. Apart from branching, the fibres remain cemented as conjugate ones. It was also observed by Samajpati et al.\textsuperscript{11} that quite a
number of fibres considered single during the fibre fineness test under magnification of $\times2$ were not single fibres. Under magnification of $\times232$, these pseudo-single entities exhibited distinct holes, void islands and tuning fork shaped structures.

These types of discontinuities or dislocations in fibre geometry are not observed in alkali-treated juice fibres. Hence, it seems that alkali treatment might have brought about splitting of pseudo-single juice fibres as well as healed some of the pores and fissures. It can also be stated that mesh structure of
The higher strength at 18% concentration in comparison to that at 9% has been observed because at higher concentration (18% at 10°C and 30°C), more loosening of structure (because of extensive swelling) helps in making the internal morphological structure of fibre more flexible, and more easier will be the distribution of stresses throughout the fibre matrix. The similar behaviour has been observed by Samajpati et al.11, stating that due to considerable cell wall thickening, void percentage (lumen) in the cell is decreased. Decrease in the weak points within the fibre matrix at 18% has also been mentioned. Increase in density of fibres after alkali treatment as reported by Chakravarty19 can also be considered as a contributing factor for the explanation of higher tenacity at 18% than at 9% concentration. But lower tenacity at 18/30 than at 18/10 can be ascribed to excessive softening of inter-fibrillar matrix, affecting adversely the stress transfer between the fibrils.11

Reduced meshiness contributes favourably towards the alkali treatment. Effect of fibre parameter can appreciably be evaluated not in terms of absolute values of tenacity but in terms of tenacity drop. As is clear from Table 1, the raw fibre tenacity is different for different varieties and it is evident that W-4 has undergone maximum tenacity drop at all conditions, while TD-3 and Mesta show drop in tenacity in smaller extent. But Desi shows very low tenacity drop.

3.5 Fibre Extension

Fibre extension is the index of inherent extensibility. As shown in Table 1, at 18/10 more swelling shrinkage causes more fibre extension than at 18/30, which, in turn, is greater than that at 9/2.

As regards meshiness, the spatial constraints may hinder some swelling action. So, meshiness tries to reduce fibre elongation but not significantly because alkali itself reduces meshiness.

W-4 has developed more fibre extension at 18/10. Similarly, Desi has reported the same value. But at 9/2, the extension is the least in all varieties.

3.6 Breaking Extension

Both the components of breaking extension (decrimping and fibre extension) have the maximum value at 18/10 followed by 18/30 and ultimately reduced to minimum at 9/2. Hence, the combined effect will also respond accordingly (Table 1). With the increase in meshiness breaking extension reduces. W-4 and Desi varieties have higher breaking extension.
4 Conclusions

4.1 Weight loss in jute is governed by the combination of strength of alkali solution and temperature. The minimum weight loss at 9/2 and maximum at 18/30 in all varieties reveal the degree of severity of conditions during alkalinization.

4.2 Length contraction, the result of stress relaxation and loss of orientation, is maximum at 18/10 and lowest at 9/2. The segmental vibrations due to higher temperature at 30°C also helps in stress relaxation along with disorientation that restricts the shrinkage at a level lower than 18/10.

4.3 Denier loss in jute on alkali treatment indicates the loss of meshiness. Maximum denier loss at 18/30 and minimum at 9/2 are the reflection of combined effect of weight loss, length shrinkage and splitting of so-called pseudo-single jute fibres.

4.4 Minimum tenacity drop and maximum breaking extension at 18/10 establish its acceptability as most suited alkali treatment condition. It can also be concluded that although weight loss and length contraction are high at 18/30 and 18/10, the tenacity drop is less as compared to that at 9/2. This fact has been attributed to the more uniform load sharing due to increase in flexibility of the structure in addition to the decrease in voids and weak points.

4.5 Alkali treatment brings about decrease in the rigidity of fibres. The reduction in stiffness is maximum at 18/10, followed by 18/30 and 9/2. The contributing factors for this reduction are alkali induced swelling, partial removal of hemicelluloses, change in proportion of crystallinity, loss in molecular orientation and softening of interfibrillar matrix.

References