

FIBRE FRACTIONATION FOR HIGH POROSITY SACK KRAFT PAPER

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ABSTRACT

High performance sack kraft paper must be both strong, with high Tensile Energy Absorption (TEA), and also be porous. Refining increases pulp strength but simultaneously decreases porosity, limiting the available strength increase. Fibre fractionation can increase porosity by removing some of the fines and short fibres, enabling the pulp to be refined to a higher strength. In this study, two fractionation strategies were demonstrated to produce pulp with significantly higher TEA-porosity performance. The first strategy used a small diameter, smooth-hole screen plate to remove short fibres and fines and create a long fibre pulp that was 70 to 80 percent of the mass of the feed stream. The resulting long fibre pulp had significantly higher porosity after being laboratory refined with a PFI mill to a target TEA. The corresponding short fibre pulp was low consistency, low freeness and low porosity, making it more suitable for less demanding products that require smoothness for printing. The second strategy used a large diameter, smooth-hole screen plate, operating at a low reject ratio to fractionate the longest fibres to produce a super-porous, high-strength pulp. The short fibre pulp consisted of 60% of feed stream and only had a small drop in freeness, consistency and porosity from the feed, but had an increase in smoothness.

INTRODUCTION

The manufacture of high-performance, sack kraft paper is a speciality process ideally suited for Canada's long-fibre softwood resource. This paper is primarily used to produce multi-wall sacks used in the most demanding applications, such as, cement and grain packaging. In these applications, the contents are pumped, carried by air at high speeds into the sack. The paper must be strong enough to withstand the stress due to filling, yet have low enough air resistance to minimise the air pressure within the sack to prevent rupture. In many operations the speed at which the sacks can be filled limits production.

These paper grades are under increasing pressure from competing paper producers and alternative packaging material producers to improve product performance while decreasing product cost. As paper performance has improved, sack manufacturers have moved from 4-ply sacks to 3-ply sacks using 70 gsm paper to 2-ply sacks using 90 gsm paper, dramatically reducing the amount of paper used in sack construction. Paper strength is of primary

importance. The strength performance of actual paper sacks is best predicted by the Tensile Energy Absorption (TEA) of the paper, which is a measure of the paper's work to failure. TEA is defined as the area under the tensile-elongation curve and is therefore a combination of total tensile strength and stretch of the pulp. The TEA of the pulp is developed by a combination of high and low consistency refining. High consistency refining induces micro-compressions and curls the fibres to provide increased stretch [Page85]. Low consistency refining develops the tensile strength of the pulp. Unfortunately, refining to increase strength simultaneously decreases the porosity of the sheet, i.e. increases air-resistance, most likely due to the generation of fines and short fibres [Scott-Kerr96]. Therefore, refining to improve paper strength is limited by the requirement to maintain high porosity.

Fibre fractionation can substantially improve the porosity of the pulp by removing the short fibres and fines that reduce porosity but do not add significantly to sheet strength. The high porosity fraction can then be refined to a higher strength. In a previous study [Roberts98], pressure screens were used to fractionate out the fines and short fibres from a fully-bleached, softwood kraft pulp. The resulting long fibre pulp had a significantly increased freeness, which enabled the pulp to be refined to a higher tensile strength. This resulted in a kraft pulp with improved reinforcing potential that is suitable for reinforcing lightweight mechanical printing paper grades. In this study, a series of pilot fractionation trials and subsequent lab refining are performed to demonstrate how fractionation can improve the strength and porosity of sack kraft paper.

EXPERIMENTAL

A fibre length fractionation study was performed in Paprican's screening pilot plant. Two screening strategies were examined. The first strategy tried to remove just the fines and shortest fibres that significantly decrease the sheet porosity but do not significantly contribute to the sheet's strength. In this strategy, the screen was operated to pass the fines and short fibers through the screen plate and into the accept stream, while most of the pulp mass was retained by the screen plate and passed into the reject stream. This was accomplished by using a small diameter, smooth-hole screen plate, operated at the lowest possible volumetric reject ratio.

The second strategy tried to remove a small amount of the longest fibres to produce a super-high porosity pulp, while degrading the remaining pulp only slightly. In this strategy, the screen passes most of the pulp through the screen plate and retains only a small fraction of the longest fibres in the reject stream. This was accomplished by using a relatively large diameter smooth hole screen plate operating at a low volumetric reject ratio.

The screening trials were carried out using a Bird Centrisorter M200 pressure screen. The screen used a bumped rotor operating at a constant rotational velocity of 1710 RPM. An unbleached, dried, softwood kraft pulp was used in all trials. The feed consistency was approximately 1.2% and the Canadian Standard Freeness was approximately 620 mL. Smooth-hole screen plates were chosen over contour slotted screen plates because they have been shown to fractionate fibres by length more effectively [Olson99]. In these trials, three different smooth-hole screen plates were used, with aperture diameters of 0.8, 1.0 and 1.75 mm. Selected samples of fractionated pulp were chosen then refined in a PFI mill and tested following CPPA standard conditions.

RESULTS

Fractionation trials were performed using all three screen plates, operated over a range of volumetric reject ratios. **Figure 1** shows the Canadian Standard Freeness of the long fibre stream versus the mass flow rate of the accept stream (short fibre stream) as a fraction of the feed stream for each trial condition. For the screen plates with the smallest aperture diameter (0.8 and 1.0 mm), where the strategy is to remove the only the short fibres, this figure indicates how much of the short fibre material has to be removed to achieve a certain freeness value. For the large aperture, smooth-hole screen plate, where the strategy is to remove only the longest fibres, the mass of short fibres represents the mass of lower porosity pulp produced.

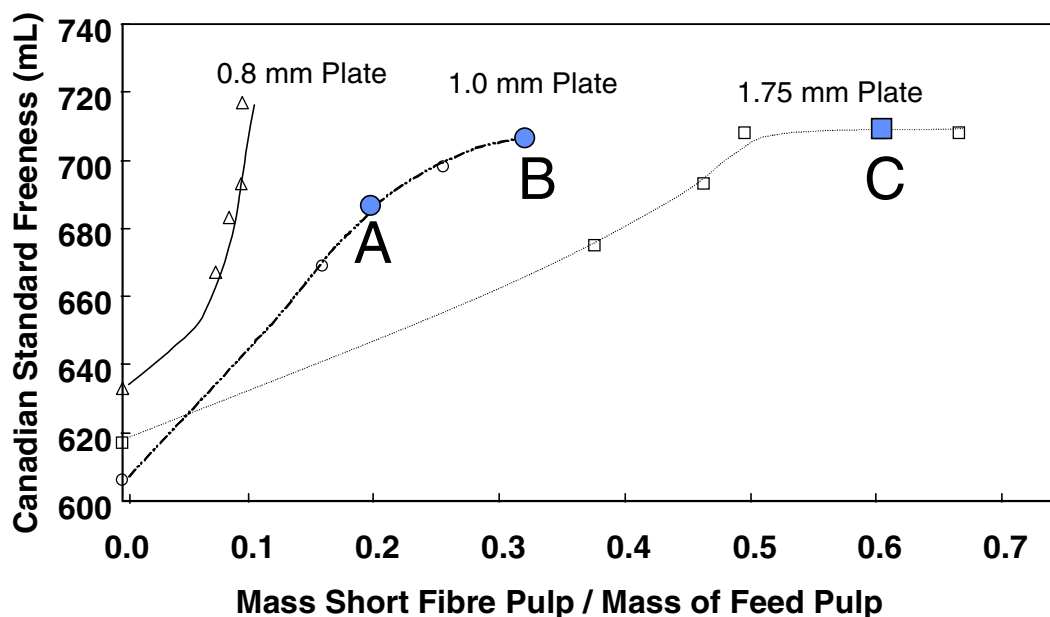


Figure 1. Freeness of the fractionated long fibre stream for the 0.8, 1.0 and 1.74 mm diameter screen plates operated over range of volumetric reject ratios. Three trial conditions with high freeness reject pulp were selected for PFI refining and physical testing and are indicated as A, B and C.

From Figure 1, the initial freeness of the feed pulp is approximately 605-630 mL. The variation of the feed pulp freeness is due to multiple passes through the screen, pumps and valves which is unavoidable in pilot experiments. For the smallest diameter screen plate (0.8 mm), the freeness increases to approximately 720 mL after removing approximately 9% of the feed pulps mass. Although the fractionation performance was high, this screen plate had low capacity and was difficult to operate due to considerable reject thickening at low volumetric reject ratios. The 1.0 mm screen plate also reached a high freeness (approximately 710 mL), but required a higher mass of short fibres to be removed. At 20% short fibre removal the freeness reached a value of 685 mL and at a 30% short fibre removal the freeness was approximately 710 mL. At these two trial conditions the screen had stable operation and pulp samples were collected for refining and subsequent physical testing (trial A and B). The 1.75 mm screen plate also reached a freeness of 710 mL, at the point where 60% of the feed pulp passed through the screen plate and 40% was retained as a long fibre product. At this screening condition the long and short fibre pulp streams were sampled for refining and physical testing (trial C).

The consistency, freeness, average fibre length, fines content volumetric and mass flows are summarised in **Table 1** for the three screening conditions chosen (trial A, B and C) for further refining and testing. Fibre length and fines content were determined using a Kajaani FS-200. Fractionating with a small aperture screen plate caused a large drop in accept consistency, freeness and fibre length, and an increase in percent fines. These changes indicate significant fractionation. The larger aperture screen plate has a smaller drop in accept consistency, freeness and fibre length in comparison with the small aperture screen plate. However, the long fibre product in the reject stream has considerably higher freeness and fibre length than the long fibre pulp with the small aperture screen plate. This indicates that most of the pulp passed through the plate and was slightly degraded, while a small amount of the longest fibres were retained in the reject stream.

Trial	A			B			C		
Screen plate hole dia. (mm)	1.0			1.0			1.75		
Stream	Feed	Accept	Reject	Feed	Accept	Reject	Feed	Accept	Reject
Consistency (%)	1.28	0.43	2.56	1.18	0.47	4.02	1.26	0.90	3.37
Freeness (mL)	606	193	685	588	176	699	607	512	707
Length (mm)	1.19	0.69	1.50	1.20	0.70	1.61	1.18	0.95	1.69
Fines (%)	7.2	16.6	4.8	7.6	15.0	4.0	7.4	9.9	3.7
Volume (%)	100	60	40	100	80	20	100	85	15
Mass (%)	100	20	80	100	32	68	100	60	40

Table 1. Analysis of the feed, accept and reject pulp for the three screening conditions chosen for further refining and testing. The reject stream has longer fibres, higher freeness, lower fines content and higher consistency than the accept stream.

The unfractionated pulp, the long fibre pulp from trial A and B, and the long and short fibre pulp from trial C were refined in a PFI mill for 0, 1000, 2000 and 4000 revolutions and standard handsheet tests were performed. **Figure 2** shows how the TEA and porosity of the pulp responded to PFI refining. For the unfractionated pulp, the initial TEA is approximately 1400 mJ/g with a Gurley Air Resistance of approximately 11 s/100mL. As the pulps are refined both the TEA and air resistance increased. The increased air resistance is most likely due to improved inter-fibre bonding and sheet consolidation. However, the increase in air-resistance could also be due to fines material, generated in the refining process, filling the inter-fibre space and closing up the sheet, but this mechanism is expected to be a minor contribution, since the PFI mill does not generate a large amount of fines.

After fractionation, the long fibre products are significantly more porous (lower Gurley air resistance). For example, the air resistance of trial C's long fibre pulp decreased from approx. 12 s/100mL to less than 2 s/mL. There was also a slight initial decrease in the TEA of the long fibre pulps after fractionating. However, the increase in air-resistance during refining was less than that of the unfractionated pulp. This resulted in a significantly higher TEA at a target porosity

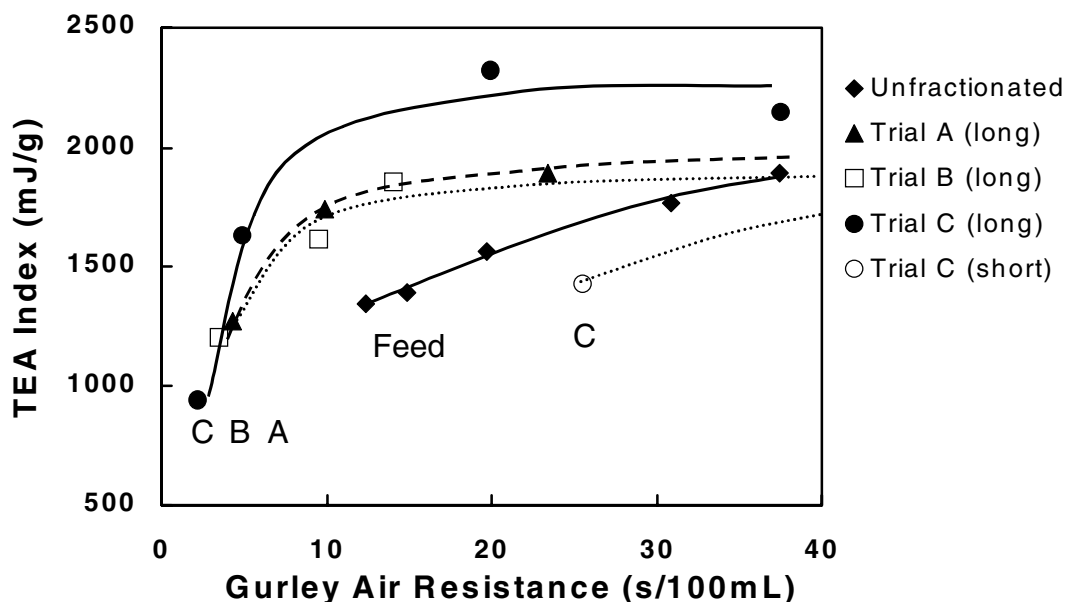


Figure 2. The TEA and porosity response to PFI refining of the fractionated and unfractionated pulps. Pulps with air resistance beyond 40 s/100 mL were not plotted. Fractionation significantly decreases the air resistance of the long fibre stream. This decrease is maintained during refining and results in a high TEA, low air resistance pulp.

As more short fibres and fines are removed from the pulp the TEA-porosity performance improves. The long fibre product from the large aperture fractionation trial (trial C) had the best performance because it had the highest percentage of long fibres and the lowest percentage of short fibres.

The TEA increase from PFI refining is due almost entirely from the increase in tensile strength. **Figure 3** shows a similar relationship between Breaking Length and porosity as the relationship between TEA and porosity. Whereas from **Figure 4**, the stretch of the fractionated and refined pulps remained relatively constant, with only a slight increase during refining.

The short fibre product from trial C had a similar strength response to refining as the feed pulp, except that the initial air resistance was higher. This short fibre pulp may be more suitable for paper products where smoothness and printability are more important than porosity. The Sheffield Roughness of the fractionated and PFI refined pulps were also determined and plotted in **Figure 5**. This figure shows that the short fibre fraction was considerably smoother (lower roughness) than the long fibre fractions at the same tensile strength.

The porosity improvements available through fractionation of long and short fibres are substantial. The difference between handsheets is evident in the two micrographs of the long fibre and short fibre pulps from trial C shown in **Figure 6**. The handsheet made with short fibres is noticeably more closed, i.e. less porous, than the handsheet made with long fibres on the right.

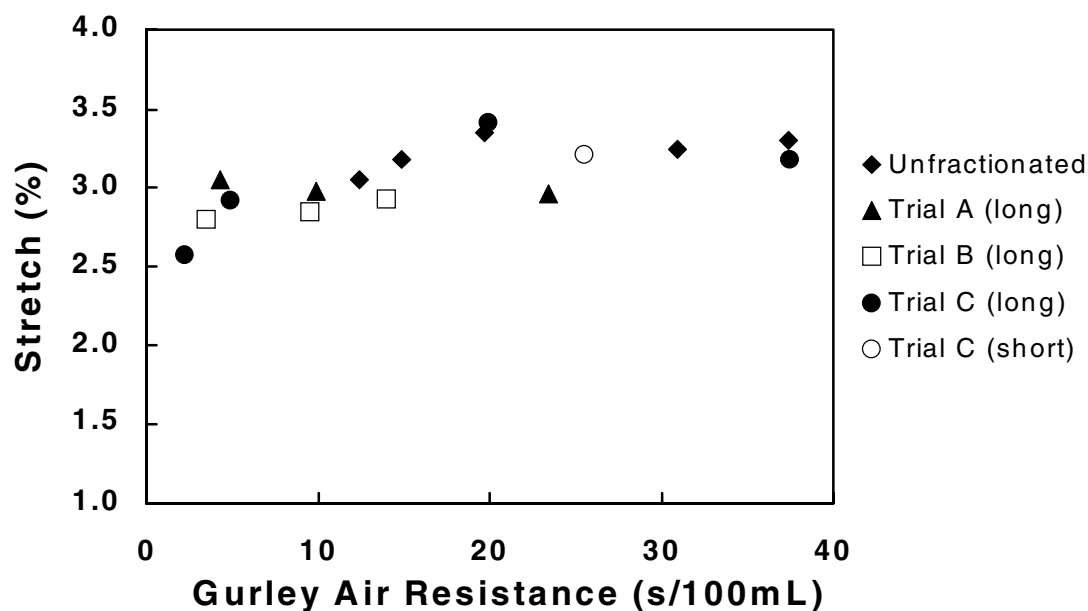


Figure 3. The tensile strength and porosity response to PFI refining of the fractionated and unfractionated pulp. The TEA increase is due to an increase in tensile strength.

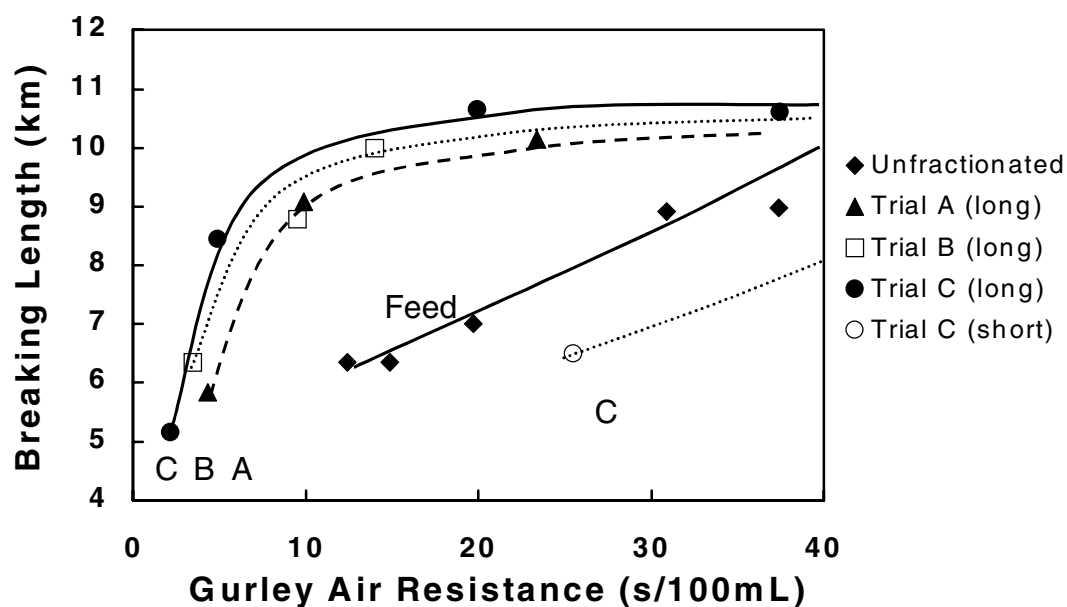


Figure 4. The stretch and porosity response to PFI refining of the fractionated and unfractionated pulp. The increase in stretch is small for all samples.

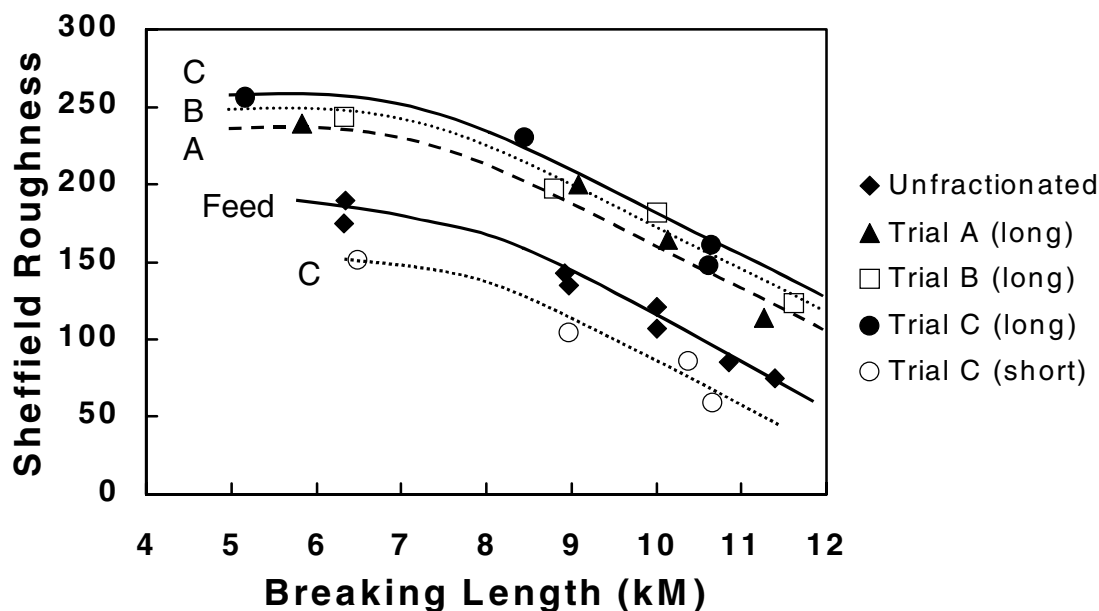


Figure 5. *The Sheffield Roughness and tensile strength response to PFI refining of the fractionated and unfractionated pulp. The long fibre stream is rougher, while the short fibre stream is smoother and more suitable for products that require good printability.*

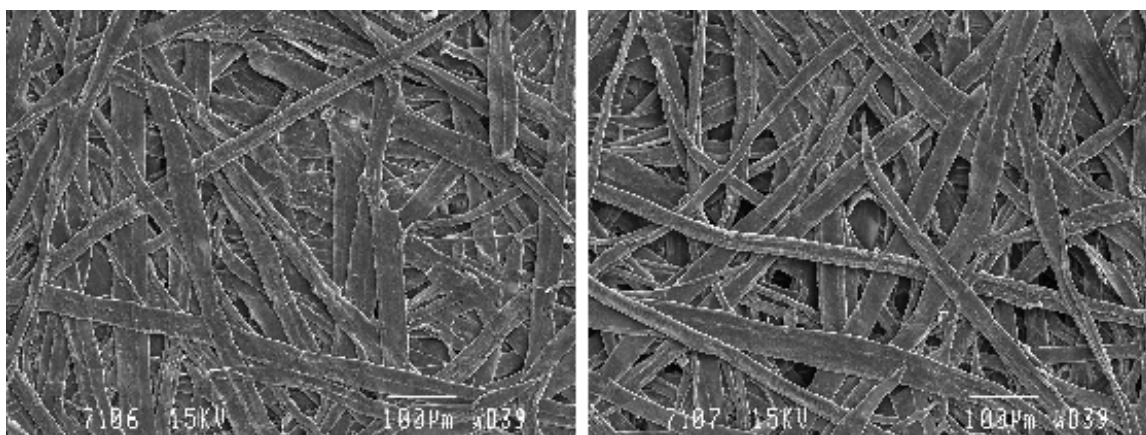


Figure 6. *Photo-micrographs of the unrefined short (left) and long (right) fibre pulps from trial C.*

On fast papermachines, the minimum allowable pulp freeness may limit the amount of refining that can be applied to the pulp, and in turn limit the strength increase. The freeness drop during refining may be particularly important for the short fibre product, which has the additional freeness decrease from fractionating. The response of tensile strength and freeness to PFI refining is shown in **Figure 7**. As expected the tensile-freeness response to refining is similar to the tensile-porosity response. The long fibre products have a significantly higher breaking length at a target freeness. This result is similar to that reported by Roberts et al 1998 [Roberts98].

The tear and tensile strength of all the pulps were measured and plotted in **Figure 8**. In general, fibre fractionation did not significantly alter the tear-tensile relationship of the pulp. However,

there may be a slight increase in tear-index at a constant breaking-length for the long fibre pulp fractionated with the large aperture screen plate, but the increase is small.

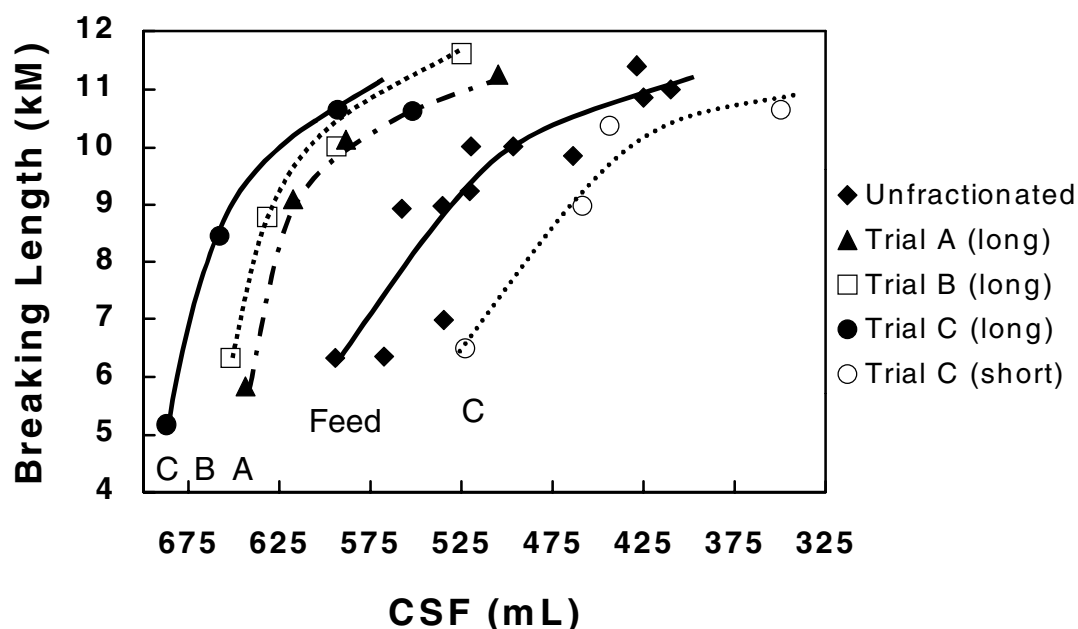


Figure 7. The tensile strength and Freeness response to PFI refining of the fractionated and unfractionated pulp.

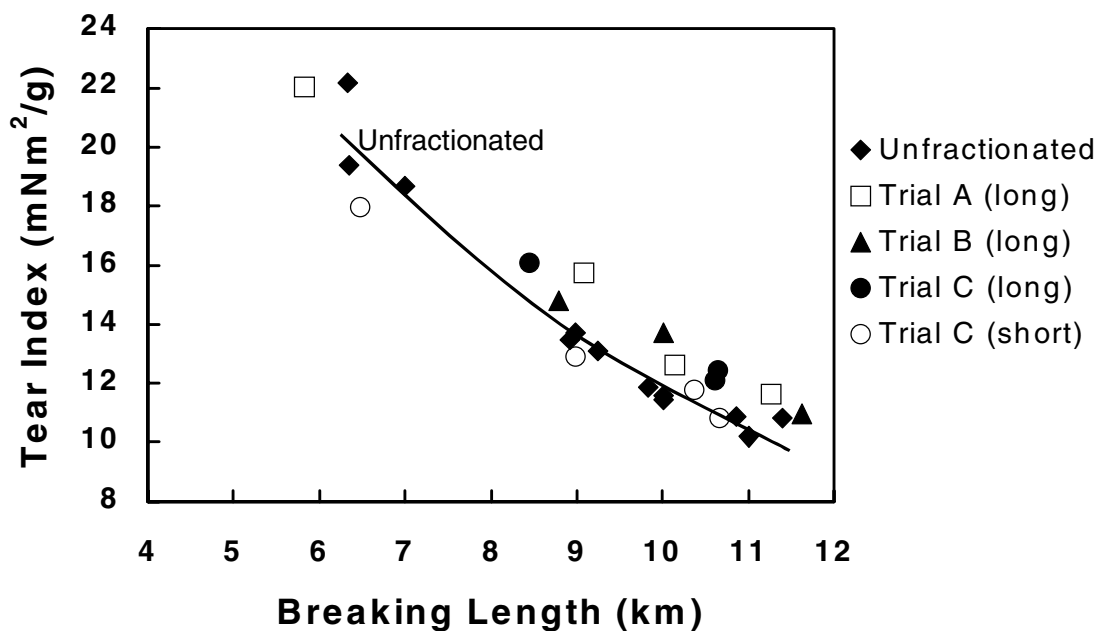


Figure 8. The tear-tensile relationship for all PFI refined pulps. The long fibre pulps had only a small increase in tear strength at a given tensile strength.

DISCUSSION

Fibre fractionation can enable the production of long-fibre, strong, high porosity, high value pulp; however, fibre fractionation simultaneously produces a short fibre fraction that has substantially different properties. Simultaneously producing two different products imposes several process, production scheduling and marketing challenges.

Implementing fractionation into the process is ideal if the mill is producing multiple grades on multiple production lines. This allows long and short fibres to be shunted between lines depending on the products being made. It is more difficult on a single line. Each fraction will have to be stored while the other fraction is running. The capacity of the storage tank will most likely be large and may have to be constructed, which makes implementation more expensive. Thickening equipment may also be required if there is a large consistency drop across the fractionating screen.

Although the long fibre fraction can be easily sold as high performance sack kraft it is not obvious what products can be made from the short fibre fraction. Most likely this fraction will be used to produce bags or other products where smoothness and printability are more important than porosity. Therefore, fractionation requires marketing products with a range of properties. Ideally, both long and short fibre pulps will have superior properties for each customer's demands, whether it is high-porosity or high-smoothness.

A more selective split between long and short fibres is achievable by using a screening system instead of the single screen used in these pilot plant experiments [Allison98]. Of course, a screening system is more expensive to build and operate than a single screen. More extreme mass splits within the screen are also possible, for example, the mass reject rate of the screen or screening system could be 5% or 95% depending on the strategy to be implemented. For the strategy of removing as few fines and short fibres as possible (small aperture screen plate), this would result in a smaller increase in tensile-porosity performance than what was demonstrated here, but would reduce the mass of short fibre to deal with. For the strategy of removing a small amount of the longest, highest quality fibres (large aperture screen plate at a low reject ratio), this would provide even higher tensile-porosity performance in the long fibre stream, although less of it, while degrading the short fibre stream less.

Two experimental compromises were made due to the limitations of pilot scale tests. First, it was hypothesised that fractionation after high consistency refining may further improve the TEA-Porosity relationship of the long fibre fraction since the fines generated during refining can then be removed. However, it was impractical for us to laboratory refine enough pulp required for pilot scale fractionation trials. Second, dried and baled pulp was used instead of never dried kraft pulp because handling, storing and shipping dried and baled pulp is more practical and convenient than never dried pulp. Both issues should be explored during future pilot or mill scale studies.

CONCLUSIONS

Efficient fractionation of kraft pulp is industrially practical with pressure screens equipped with smooth-hole screen plates. As well, the flexibility of the screens operation allows the fractionation to be customised depending on the application. Two fractionation strategies were

demonstrated to produce pulp with significantly higher TEA-porosity performance than unfractionated pulp. The first strategy used a small aperture screen plate to remove only short fibres and fines, creating a long fibre pulp in the reject stream that is 70 to 80 percent of the mass of the feed. The resulting long fibre pulp had significantly higher porosity after being refined to a target TEA than the unfractionated pulp, making it ideally suited for paper sacks that are required to be strong and fast filling. The short fibre product was low consistency, low freeness and low porosity, making it more suitable for products that are required to be smooth for printing. The second strategy used a large aperture screen plate, operating at a low reject ratio to fractionate a small amount of the longest fibres to produce a super-porous, high strength pulp. The short fibre stream consisted of 60% of feed stream and had only a small drop in freeness, consistency and porosity. The fractionated pulp has similar tear-tensile response to PFI refining as the unfractionated pulp.

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