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USE OF KAPOK PULP TO IMPROVE PROPERTIES OF RECYCLED PAPER

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Abstract

Using recycled paper is one way to reduce environment problems. However, higher cycle numbers of recycling leads to reduction of paper strength; thus, improvement of recycled paper properties is very important. One way to improve strength of recycled paper is to use kapok pulp because kapok is the long fiber and a large number of kapok fibers are found in Thailand. In this study, paper was made by using kapok and recycled pulp to compare with those using softwood pulp-to-recycled pulp ratios at 100:0, 10:90, 20:80, 30:70 and 0:100. As a result, it was found that recycling up to three cycles had a small effect on paper properties. A higher amount of kapok pulp in the mixed pulp between kapok pulp and recycled pulp increased opacity, density and tensile index but decreased brightness, whiteness and porosity of handsheets. On the other hand, the higher amount of softwood pulp led to higher porosity and tear index. So, the combination and amount of pulps used is really dependent on the final paper property required.

Key words: recycled paper, kapok, softwood, paper properties

Introduction

Waste paper recycling now becomes remarkably important due to environmental concerns, increasing paper consumption, government regulations, deforestation, fiber shortage in some countries and so on. However, the challenging part of waste paper recycling is the quality improvement of paper made from these recycled fibers since the pulp quality especially the paper strength is normally decreased after repeated recycling. Generally, the way to improve recycled pulp strength can be done by refining that pulp before making it into sheets of paper. By doing so, recycled pulp is fibrillated and this can increase the surface areas of fibers available for water absorption and bonding. Another way of improving the strength property of paper made from

recycled fibers is to mix the recycled pulp with the virgin pulp. Softwood pulp can be a good candidate for this purpose since paper made from softwood pulp is generally stronger than paper made from hardwood pulp due to the higher fiber length of softwood fiber as compared to hardwood fiber. However, Thailand as one of the tropical countries usually has no softwood pulp and need to import from abroad. So, finding a new fiber source in Thailand to do this task for softwood fiber is incredibly fascinating.

Kapok fiber abundantly found in Thailand might be used as a substitute of the softwood fiber to improve the strength of recycled pulp due to its remarkably high fiber strength. In general, kapok fiber is hollow with a thin fiber wall and large lumen [1, 2]. It has the external diameter of 16.5±2.4 m, the lumen diameter of 14.5±2.4 m and the fiber length of 25±5 mm [3]. For chemical composition, kapok fiber contains 35% cellulose, 21.5% lignin, 22% xylan and 13% acetyl groups on a weight basis [4]. Though kapok fiber has high tensile strength but it is very brittle. As such, kapok fiber is rarely used in textile industry but it is used as stuffing for pillow and mattress instead due to its light weight. Taking the advantages of its hydrophobicity, kapok fiber is also used as stuffing for life jacket as well. Also, the papermaking potential of kapok fibers was investigated by Chaiarrekij et al. [5, 6]. It was found that kapok fiber can be a potential fiber source for papermaking in Thailand. Paper made from kapok pulp has high tensile and burst strengths and due to its moderately hydrophobic surface, kapok paper might be potentially used as a packaging paper.

This research was thus aimed to study the effects of kapok pulp on improving properties of paper made from recycled pulp and then compare them with the results obtained from using softwood pulp instead of kapok pulp. If kapok pulp seems to provide the competitive results, then this might provide a good opportunity to increase the use of recycled paper in Thailand.

Experimental:

Preparation of kapok pulp

Since kapok fibers were so difficult to be dampened, kapok fibers were first soaked in 5% (w/v) sodium hydroxide solution for 2 weeks. Then, they were cut into small pieces around 0.0-1.0 cm long. These kapok fibers were then pulped at 120°C for 2 husing 20% of (w/v) sodium hydroxide based on O.D. (oven dried) fiber weight. Kapok pulp was then washed and refined twice using a disc refiner with the disk gap of 10/1000 inch. Then, the refined kapok pulp was disintegrated at 80°C for 5 min to remove latency [7].

Preparation of softwood pulp

Commercial softwood pulp was soaked in water overnight. Then, it was beaten using a valley beater until pulp freeness reached the value of 350±50 ml.

Preparation of recycle pulp and handsheet making

Commercial A4 paper sheets from the same brand were cut into small pieces and soaked in 5% (w/v) sodium hydroxide solution overnight. Then, these paper sheets were re-pulped at 50 ºC for 90 min at the speed of 500 rpm. The pulp was then divided into three portions. The first portion was mixed with kapok pulp with the ratios of kapok pulp: recycled pulp of 0:100, 10:90, 20:80 and 30:70. The second portion was mixed with the softwood pulp of 0:100, 10:90, 20:80 and 30:7. The remaining recycled pulp was then made into handsheets and dried at 90 ºC for 6 min.

All these handsheets made from only recycled pulp was then repulped again following the same path as described earlier up to 3 cycles. For each cycle, paper was made from the mixed pulps using the ratio mentioned earlier. Finally, all these handsheets were tested for paper properties like brightness, opacity, density, porosity tensile and tear strengths and so on. The results were then compared as to examine the effects of numbers of recycling cycles. The effects of kapok and softwood pulps on paper properties were also compared.

Results and discussion

Brightness

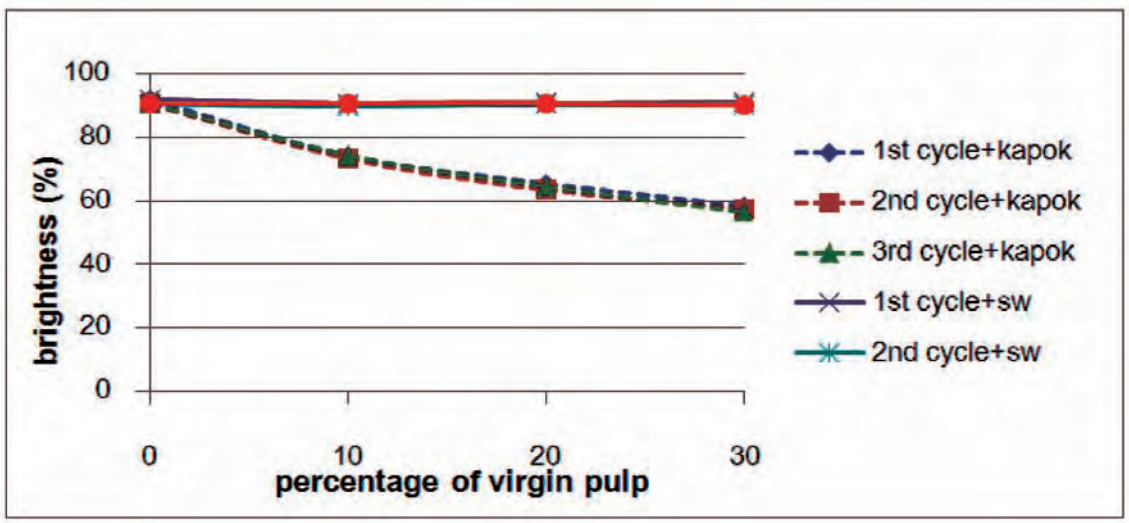

Figure 1 The Effects of Recycling Cycles, Kapok Pulp and Softwood (SW) Pulp on Brightness

(Note: Kapok and SW pulps have brightness values of 19.15% and 84.31%, respectively)

As shown in Figure 1, the handsheets made from 100% recycled paper were the brightest and their brightness values were very close to those made from 100% softwood pulp (84.31% brightness) while those made from 100% kapok pulp had the lowest brightness (19.15% brightness). Also, the effect of recycling on brightness was so small as compared to the effects of pulp types. Clearly, the effect of kapok pulp on brightness is more pronounced than softwood pulp. Brightness was decreased more by adding kapok pulp as compared to those of the softwood pulp at the same ratio. This might be because kapok fibers are so yellowish. So, adding a higher amount of kapok can lead to lower brightness eventually.

Whiteness

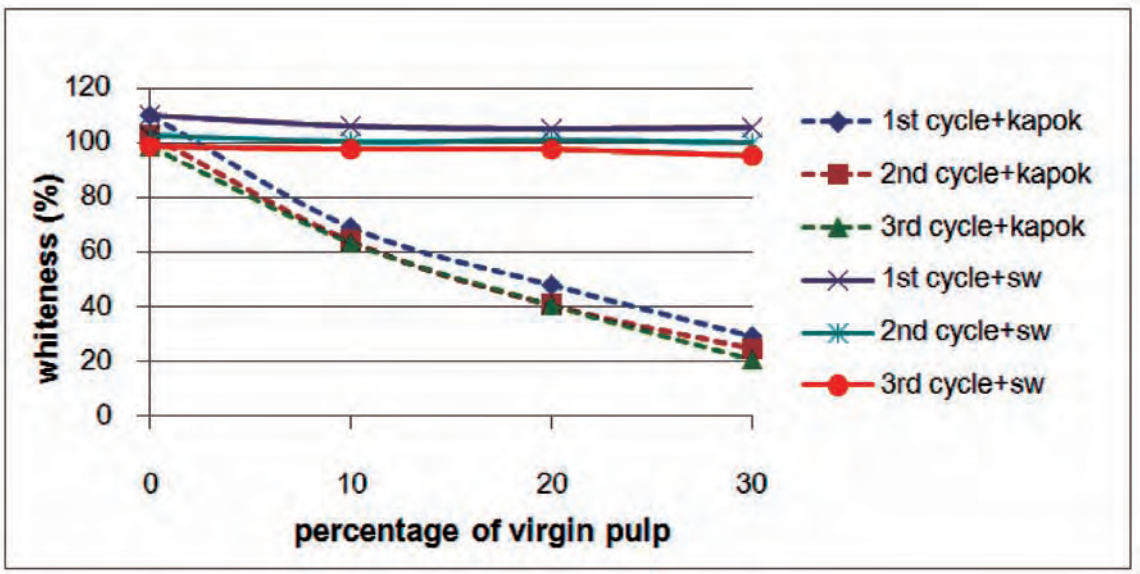

Figure 2 The Effects of Recycling Cycles, Kapok Pulp and Softwood (SW) Pulp on Whiteness

(Note: Kapok and SW pulps have whiteness values of 72.62% and 83.44%, respectively)

Figure 2 illustrates the effects of recycling, kapok pulp and softwood pulp on whiteness. It was apparent that the results obtained from whiteness followed the same trend as in the case of brightness with the same explanation.

Opacity

Opacity of handsheets made from 100% recycled pulp was highest and it was higher than those made from kapok and softwood pulps which were 69.19% and 82.05%, respectively (Figure 3). The effect of numbers of recycling on opacity was small as compared to the effects of pulp type and percentage. Unlikely, increasing amount of kapok pulp in the pulp mixture provided the

handsheets with higher opacity while the opposite results were obtained from the softwood pulp. Opacity could be lower when longer fibers like softwood and kapok pulps were added into the pulp mixture since the surface areas for light scattering were smaller. This could be clearly seen for the case of softwood pulp. However, when the kapok pulp was added, the yellowness of the pulp seemed to overcome the effects of its length and this led to lower opacity instead.

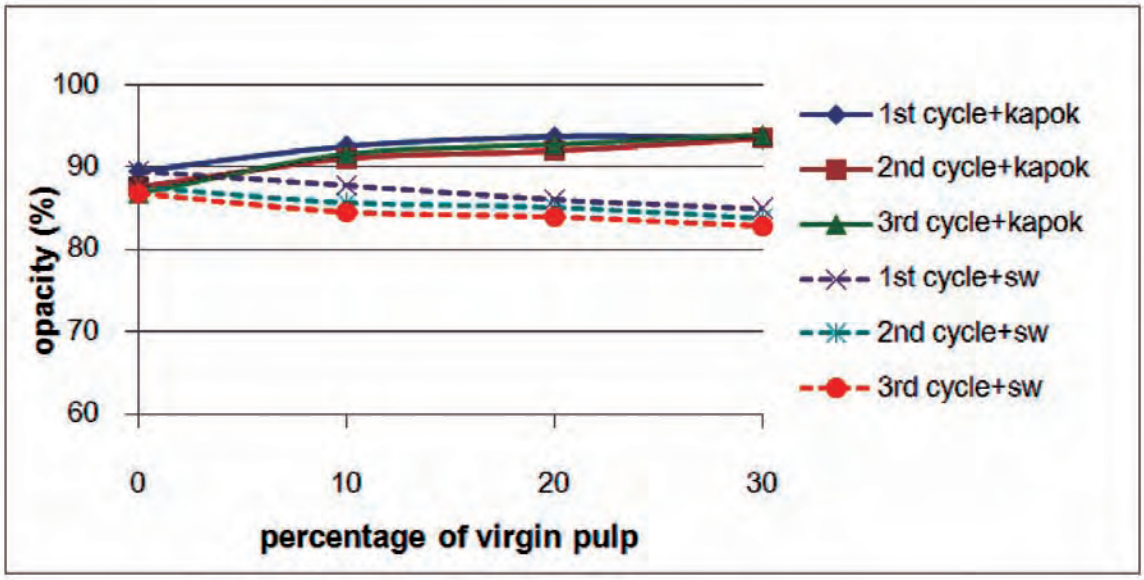

Figure 3 The Effects of Recycling Cycles, Kapok Pulp and Softwood (SW) Pulp on Opacity

(Note: Kapok and SW pulps have opacity values of 69.19% and 82.05%, respectively)

Density

Paper made from 100% softwood pulp had highest density (0.627 g/m^3) while that from 100% kapok pulp had lowest density (0.525 g/m^3). Although both pulps contained long fiber which should contribute to higher density due to more contact areas for inter-fiber bonding, kapok fibers were then entangled and provided a poor paper formation. This might be the reason for the low density of 100% kapok handsheets (Figure 4). It was also found that the effect of recycling cycles on density was quite small as compared to the effects of pulp type and the amount of pulp added. The more kapok or softwood pulp was added, the denser handsheets became. This might be because the better fiber bonding was obtained by adding long fibers into the short fibers of 100% recycled pulp.

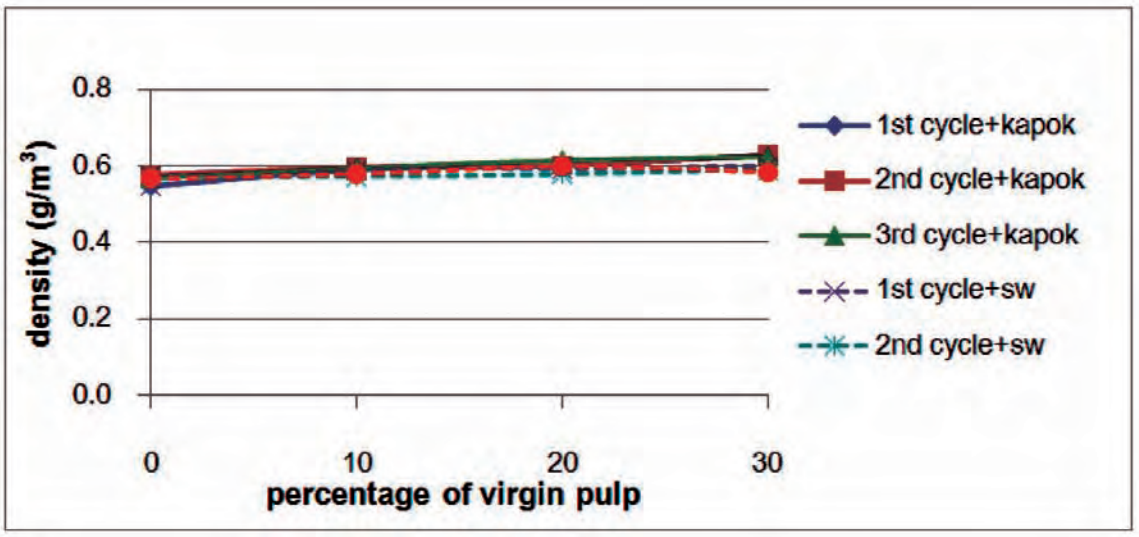

Figure 4 The Effects of Recycling Cycles, Kapok Pulp and Softwood (SW) Pulp on Density

(Note: Kapok and SW pulps have density values of 0.525 g/m^3 and 0.627 g/m^3, respectively)

Porosity and air resistance

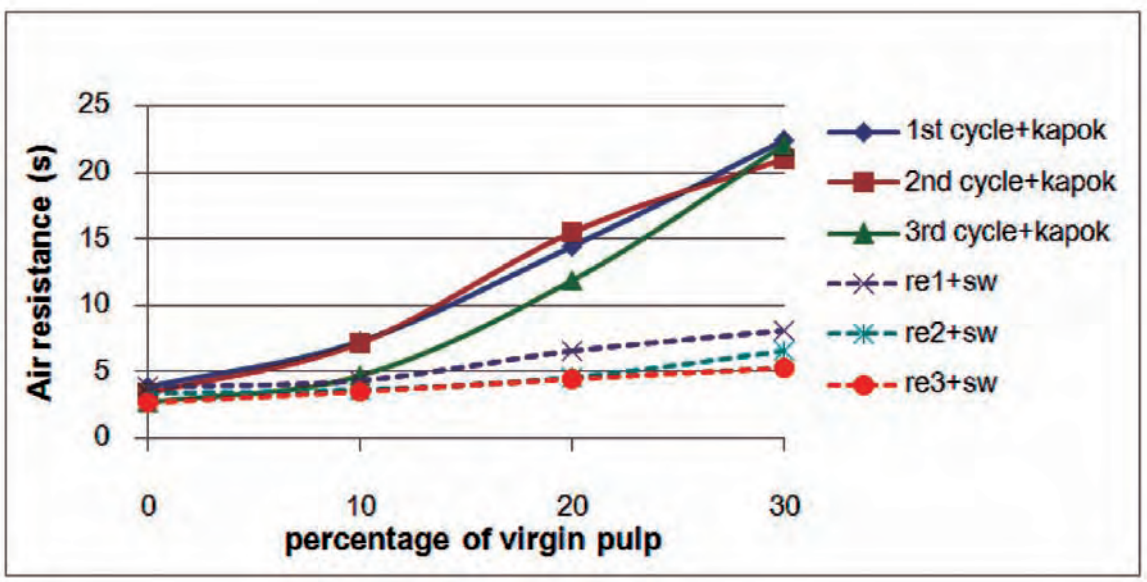

Figure 5 The Effects of Recycling Cycles, Kapok Pulp and Softwood (SW) Pulp on Air resistance

(Note: Kapok and SW pulps have air resistance values of 38.2 s and 24.4 s, respectively)

Porosity of handsheets was determined by measuring the air resistance of handsheets. Porous paper has less air resistance and the time allowing air to pass through is quite short. As can be seen from Figure 5, it was clear that recycled fibers offered paper with lowest air resistance time or highest porosity because of the poor fiber bonding. Kapok pulp provided handsheets with highest air resistance time or lowest porosity as compared to softwood pulp because of its longer fiber length. Recycling paper up to 3 cycles did not impose a strong impact on porosity while pulp type and percentage did. Since kapok pulp itself had the highest air resistance time or lowest porosity, the paper containing kapok fibers had much lower porosity than that containing softwood pulp at the same ratio.

Tensile index

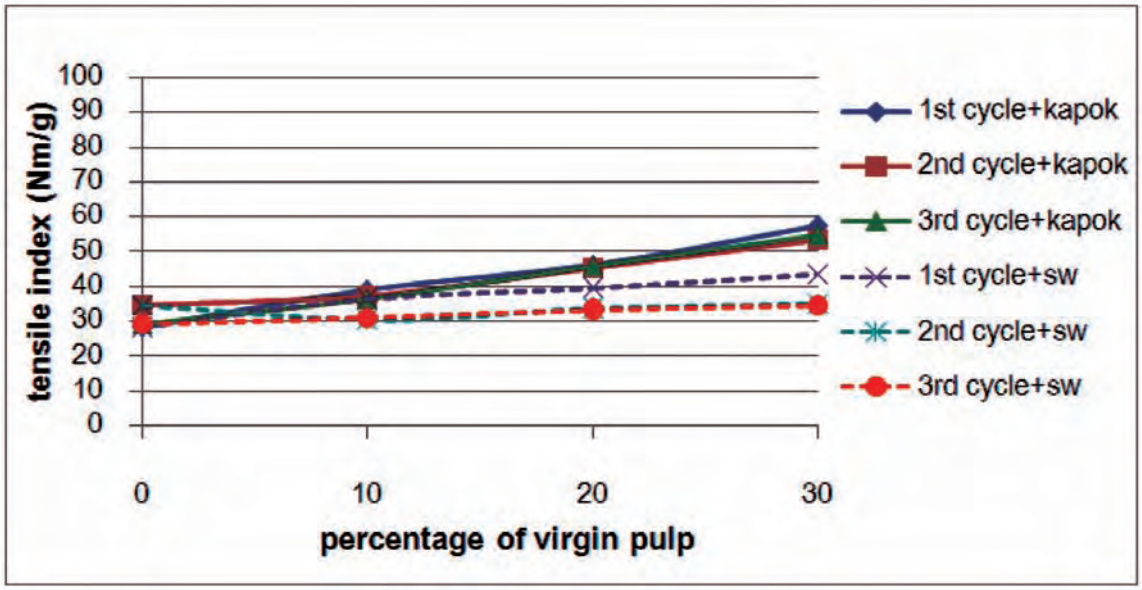

Figure 6 The Effects of Recycling Cycles, Kapok Pulp and Softwood (SW) Pulp on Tensile Index
(Note: Kapok and SW pulps have tensile index values of 86.35 Nm/g and 51/85 Nm/g. respectively)

Tensile index is defined as tensile strength divided by grammage. The results from Figure 6 indicate that paper made from 100% kapok pulp was strongest as depicted by its highest tensile index (86.35 Nm/g) due to its outstanding fiber strength. Paper made from 100% recycled pulp was weakest as expected since fibers were destroyed during the recycling process. Also, the numbers of recycling cycles had a small impact on tensile index. Both kapok and softwood pulps seemed

to improve the tensile strength of recycle paper but the effects of kapok pulp is more pronounced than softwood pulp in terms of increasing tensile strength of papers.

Tear index

The effects of number of recycling cycles and pulp type on tear index are shown in Figure 7. Tear index was defined as tear resistance divided by grammage. It was clear that number of recycling did not produce effect on tear index. Paper made from only softwood fibers had a highest tear index while the tear index of paper made from 100% kapok pulp was close to those from recycled pulp. The lowest tear index was found when 100% recycled fibers was used to make the paper. Adding the kapok fibers in the recycled pulp did not provide any benefit in terms of tear index improvement; however, tear index was slightly improved when softwood pulp was added to the recycled pulp.

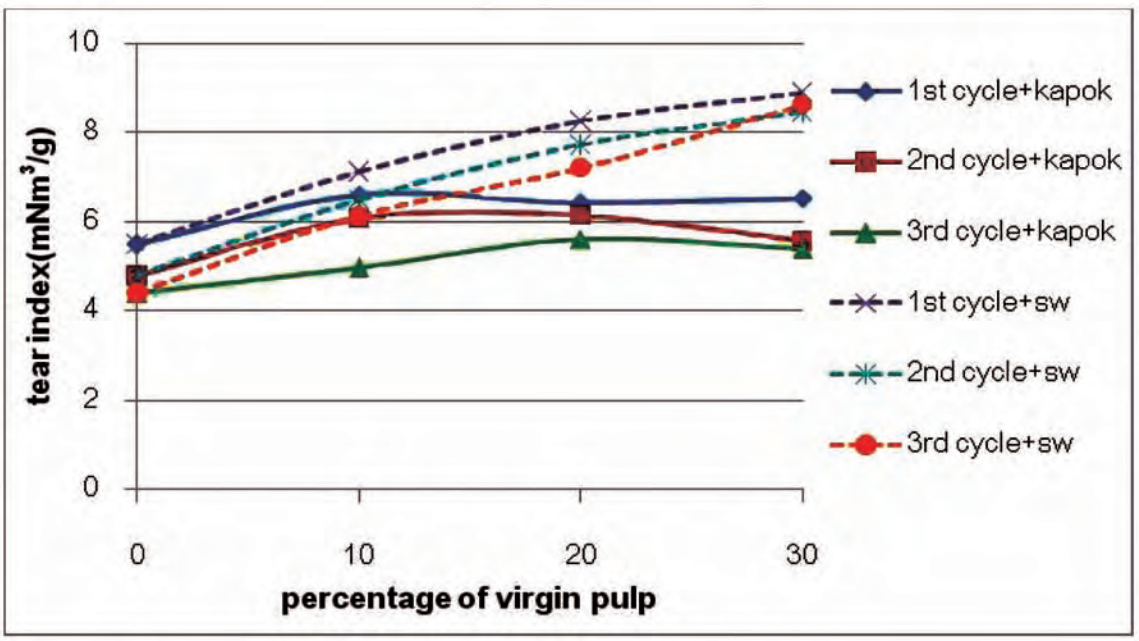

Figure 7 The Effects of Recycling Cycles, Kapok Pulp and Softwood (SW) Pulp on Tear Index

Note: Kapok and SW pulps have tear index values of 6.622 mN m/g and 53.037 mN m/g, respectively)

Conclusion

Recycling seemed to have a small impact on paper properties. However, only up to three cycles of recycling were evaluated in this study. If the numbers of recycling

cycles increases, their effects might be possibly detected. Increasing the percentage of kapok pulp used with the recycled pulp brought about higher opacity, density and tensile index but lower porosity, brightness and whiteness of the handsheets. Using a higher amount of softwood pulp led to higher tear index only. So, using the kapok pulp or softwood pulp or both with a proper amount of pulp is definitely dependent on the final paper properties required.

Acknowledgement

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References

1) Xiao, H., Yu, W.-D., and Shi, M.-W. (2005). "Structure and performances of the kapok fiber," *Journal of Textile Research* 26(4), 4-6.
2) Lim, T.-T., and Huang, X. (2007). "Evaluation of kapok (*Ceiba pentandra (L.)* Gaertn.) as a natural hollow hydrophobic-oleophilic fibrous sorbent for oil spill cleanup," *Chemosphere* 66, 955-963.
3) Huang, X. F., and Lim, T. T. (2006). "The performance and mechanism of hydrophobic–oleophilic kapok filter for oil/water separation," *Desalination* 190(1-3), 295-307.
4) Hori, K., Flavier, M. E., Kuga, S., Lam, T. B. T., and Liyama, K. (2000). "Excellent oil absorbent kapok [*Ceiba pentandra (L.) Gaertn.*] fiber: Fiber structure, chemical characteristics, and application," *J. Wood Sci*. 46(5), 401-404.
5) Chaiarrekij, S., Wongsaisuwan, U., and Watchanakit, S. (2008). "Papermaking from Kapok fiber," *Thai Petty Patent, 4279*, June 13, 2008.
6) Chaiarrekij, S., Apirakchaiskul, A., Suvarnakich, K., and Kiatkamjornwong, S. (2012). "Kapok I: Characteristics of Kapok Fiber as a Potential Pulp Source for Papermaking," *BioResources* 7(1), 475-488.