UDC (UDK) 676.022:633.875

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EFFECT OF REFINING ON ORGANOSOLV ACACIA HYBRID PULP FIBRES AND HANDSHEETS PROPERTIES

SUMMARY

This paper examines the influence of pulp freeness in different refining degree of organosolv pulps on various handsheet properties. The aim of this study was to compare the handsheet properties from unrefined and refined organosolv pulp fibres by using PFI Mill. For organosolv pulping, organic solvent of ethanol was used. In this study, 50%, 60% and 70% concentrations of ethanol were used to cook Acacia hybrid wood chips in temperature controlled batch digester for 2.5 hours at 185 °C. During refining process, PFI Mill was used to treat pulp to improve the handsheet properties. Pulp freeness was determined by using Canadian Standard Freeness (CSF) tester. From this study, pulp freeness decreases as PFI revolution increases. As action of refining is done on the pulp, fibrillation is occurred on pulp fibre wall. As the process of refining continues, fibrillation increases. Refining caused the pulp fibres to have more surface area which increases fibre-to-fibre bonding. Besides that, 70% ethanol concentration Acacia hybrid pulp is easier to refine in PFI Mill compared to 50% and 60% ethanol concentration consumed. Therefore, its pulp freeness is lowest among them in different PFI revolutions.

Keywords: Organosolv, PFI Mill, Refining, Freeness, Acacia hybrid

INTRODUCTION

Refining process is the mechanical treatment and modification of pulp fibres so that they can be formed into desired properties of paper. Most unrefined pulp produces paper with poor strength properties. Therefore, it is an important step in papermaking industry for producing high quality paper. There are various refiners for refining process such as Hollander Beater, Disc refiner, Conical refiner, Lampen Mill, Valley beater and PFI Mill. Nowadays, PFI Mill is used throughout the world.

The main target of refining is to improve the bonding ability of pulp fibres. Besides that, refining will shorten the longer fibres become fibre bundle (floc) for a good sheet formation. Refining affects fibres in many ways with fibre development such as fibre shortening, external fibrillation, and internal fibrillation and curling the fibres. As fibres undergo refining process, fibres collapsed and make more flexible, and their bonding surface area is increased.

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Furthermore, Acacia hybrid is a fast growing species with good fibre quality and high basic density which can be found in tropical region. Therefore, Acacia hybrid has a better quality for plywood, fibreboard, pulp and paper industry. Moreover, Acacia hybrid has a good range of pulping qualities. According to Pinso and Nasi (1992), *A. auriculiformis* has higher pulpwood productivity (234-305 kg/m^3) than *A. mangium* (179-268 kg/m^3). Acacia hybrid wood fibres which have been chemically pulped, but not additionally treated with mechanical action, produce a weak, bulky sheet. Therefore, refining is the application of mechanical treatment to pulp slurries to develop paper strength properties. The aim of this study was to compare the handsheet properties between unrefined pulp fibres and refined pulp fibres organosolv pulping with treated in PFI Mill.

MATERIAL AND METHODS

In this study, Acacia hybrid wood was used as raw material. It was harvested from Sabah Development Authority (SAFODA) forestry plantation in Kota Kinabalu, Sabah.

After debarking, Acacia hybrid wood was cut, chipped and screened into desired uniform size of 2 cm X 2 cm X 0.5 cm. Acacia Hybrid wood was reduced in size so that cooking chemicals can easily penetrate the wood chips to separate lignin from the cellulose.

For preparing organosolv pulp, ethanol was used as the organic solvent, 1M of sodium hydroxide as catalyst and water were used to delignify the wood chips in a digester. In this study, 50%, 60% and 70% concentrations of ethanol were used. A total of 1 kg oven-dried Acacia hybrid wood chips were weighed and fed into a 15-litre rotating temperature controlled batch digester with 10:1 ratio of liquor to wood for each cooking. Each cooking temperature was 185 °C. The total duration of each cooking was about 2.5 hours.

The cooked wood chips were washed with water for three times to remove the remaining chemicals and black liquor before being disintegrated for one minute in a stock divider. After pulp disintegration, the pulp was passed through a laboratory pulp screener to remove rejects such as non-defiberised wood chips and knots. The pulp was diluted to a consistency of not more than 1% for pulp screening process. After screening process, pulps were undergone the refining process using PFI Mill according to TAPPI T 248 sp-00. In order to evaluate effect of refining condition to hardwood Acacia hybrid, pulp was refined in different PFI revolutions. The pulp consistency for refining was 10% at 4 different degrees; 0, 6000, 10 000, and 12 000 revolutions. Pulp freeness was done using the Canadian Standard Freeness (CSF) tester according to TAPPI T 227 om-99. Handsheets of 80 g/m^2 O.D. grammage were produced in a semi-automated sheet former in accordance with TAPPI T 205 sp-02 standard. Folding endurance, bursting strength, tearing resistance and tensile properties of handsheets were determined according to TAPPI Standard of T 423 om-98, T 403 om-02, T 414 om-04 and T 494 om-01, respectively.

Comparison of handsheets properties between unrefined pulp fibres and refined pulp fibres organosolv pulp were tabulated and analysed.

RESULTS AND DISCUSSION

In this study, pulp was refined at 4 different PFI revolutions; 0 rev., 6 000 rev., 10 000 rev. and 12 000 rev. As the refining process was done on the pulp fibres, the pulp freeness decreased which was shown in Figure 1.

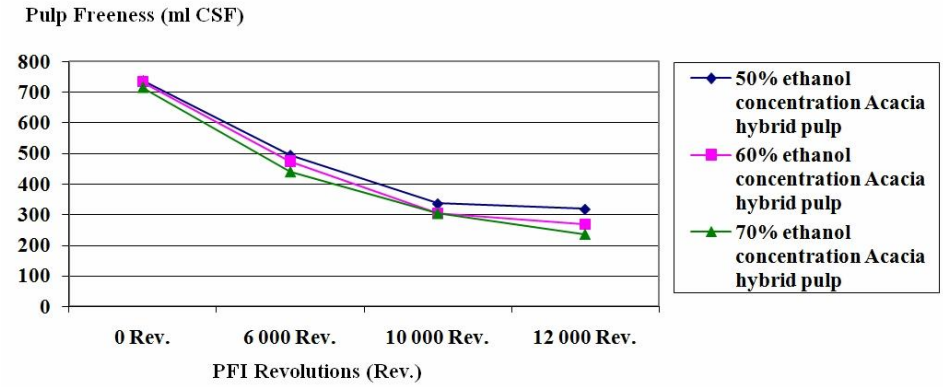

Figure 1. Comparison of pulp freeness (ml CSF) between different ethanol concentrations for Acacia hybrid at different PFI revolutions

For 50% ethanol concentration of Acacia hybrid pulp, pulp freeness decreased 33% from 737 ml CSF at 0 rev. to 494 ml CSF at 6 000 rev. 32% continuously decreased from 494 ml CSF at 6 000 rev. to 336 ml CSF at 10 000 rev. There was a small decline about 5% from 336 ml CSF at 10 000 rev. to 318 ml CSF at 12 000 rev. Figure 2 shown 50% ethanol concentration pulp fibres were refined at different PFI revolutions.

Meanwhile, for 60% ethanol concentration of Acacia hybrid, pulp freeness decreased from 733 ml CSF at 0 rev. to 474 ml CSF at 6 000 rev., 305 ml CSF at 10 000 rev. and 269 ml CSF at 12 000 rev. 60% ethanol concentration pulp fibres were refined at different PFI revolutions shown in Figure 3.

The same decreasing trend can be seen for 70% ethanol concentration where the pulp freeness decreased from 715 ml CSF at 0 rev. to 439 ml CSF at 6 000 rev., 303 ml CSF at 10 000 rev., and dropped to 235 ml CSF at 12 000 rev. Fibre fibrillation was happened on 70% ethanol pulp fibres wall as refining was done which shown in Figure 4.

It was observed from Figure 1, freeness of Acacia hybrid pulp with 50%, 60% and 70% concentration ethanol were showed the same trend of decline pulp freeness after refined by PFI Mill which showed the relationship between refining revolution and pulp freeness. Fibrillation on the pulp fibre wall occurred when refining process was done. As the process of refining continues, fibrillation increases which showed clearly in Figure 2 until Figure 4.

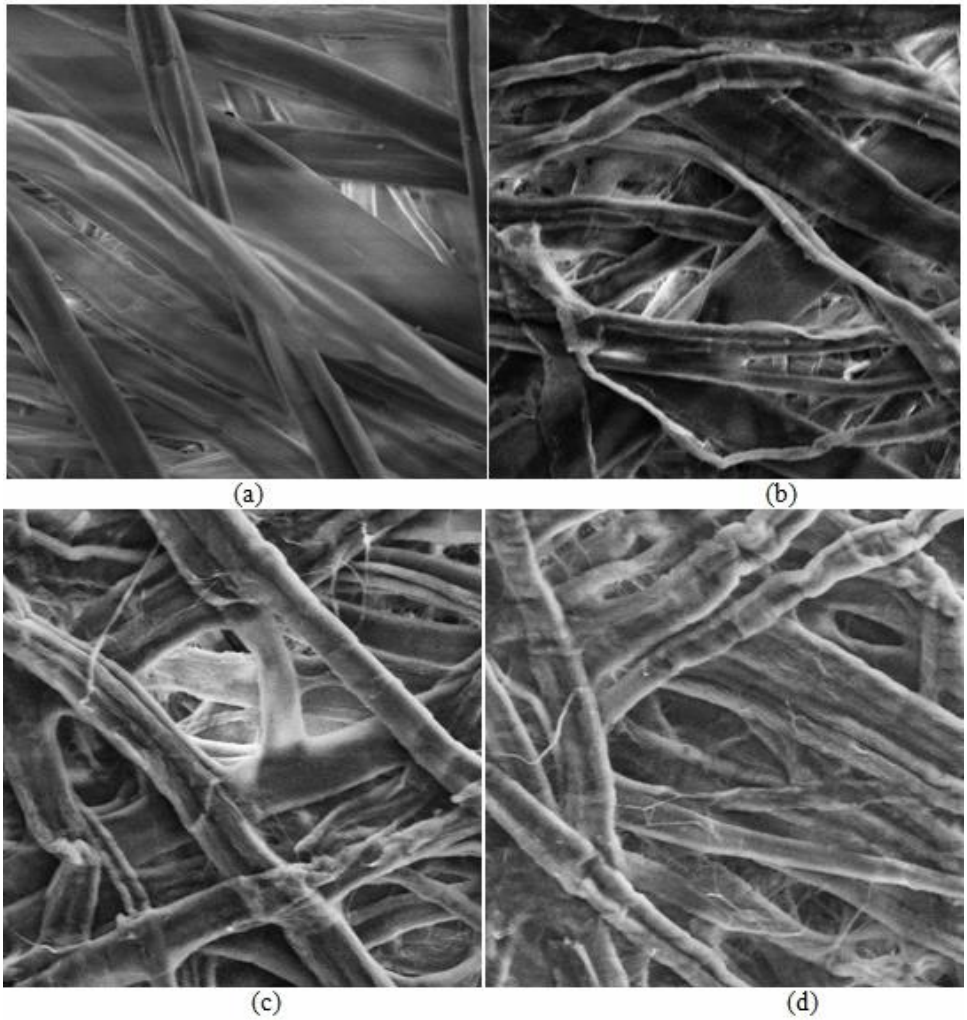

Figure 2. Interaction between moisture contents and different storage temperatures (ºC) on fennel seed germination, LSD(0.05)=5.6363

The more refining revolutions, the more decreased pulp freeness number is. From the obtained result was showed pulp freeness number is reduced if the refiner has higher PFI revolution. This means that the water drops down to the measuring cylinder less and lesser after increasing PFI revolution (Hai, 2008).

Through observing Figure 2 until Figure 4, refining process changes the physical look of the pulp fibres and creates fines. Pulp fibres which are refined at 6 000 rev. and 10 000 rev. in PFI Mill have fines content lower than pulp fibres which are refined at 12 000 rev. during refining process. At higher refining revolution, the more fines are created during external fibrillation action is done.

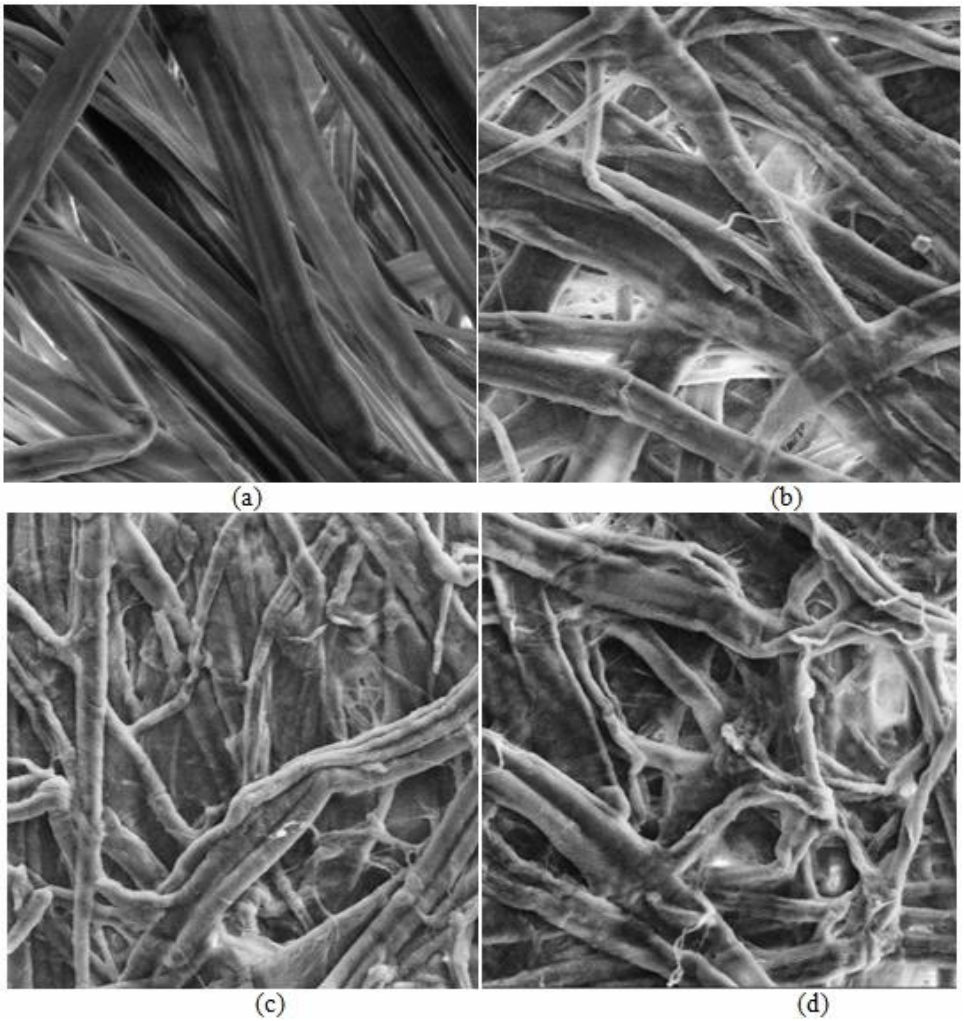

Figure 3. 60% ethanol concentration pulp fibres structure at different PFI revolutions: (a) 0 rev., (b) 6 000 rev., (c) 10 000 rev. and (d) 12 000 rev. (Magnification: 1 000 X)

Biasca (1989) indicated that refining process creates more fines and increases the strength of the fibre-fibre bonds. Furthermore, Walsh (2006) found out that action of refining on pulp fibres caused the fibre surface to break open and create more surface area as refining continues. Therefore, fibrillation process happened on pulp fibre wall as refining is done on the pulp. Besides that, refining process causes the pulp fibres to reduce voids in pulp fibres due to collapsed fibres (Liew, 2002).

Moreover, 70% ethanol concentration of Acacia hybrid pulp has the lowest freeness value among the three refined organosolv pulps which was showed clearly in Figure 1. As concentration of ethanol was added for pulping increased,

the fibre fibrillation increased. In this study, sodium hydroxide as catalyst was added which could improve the delignifying ability of ethanol.

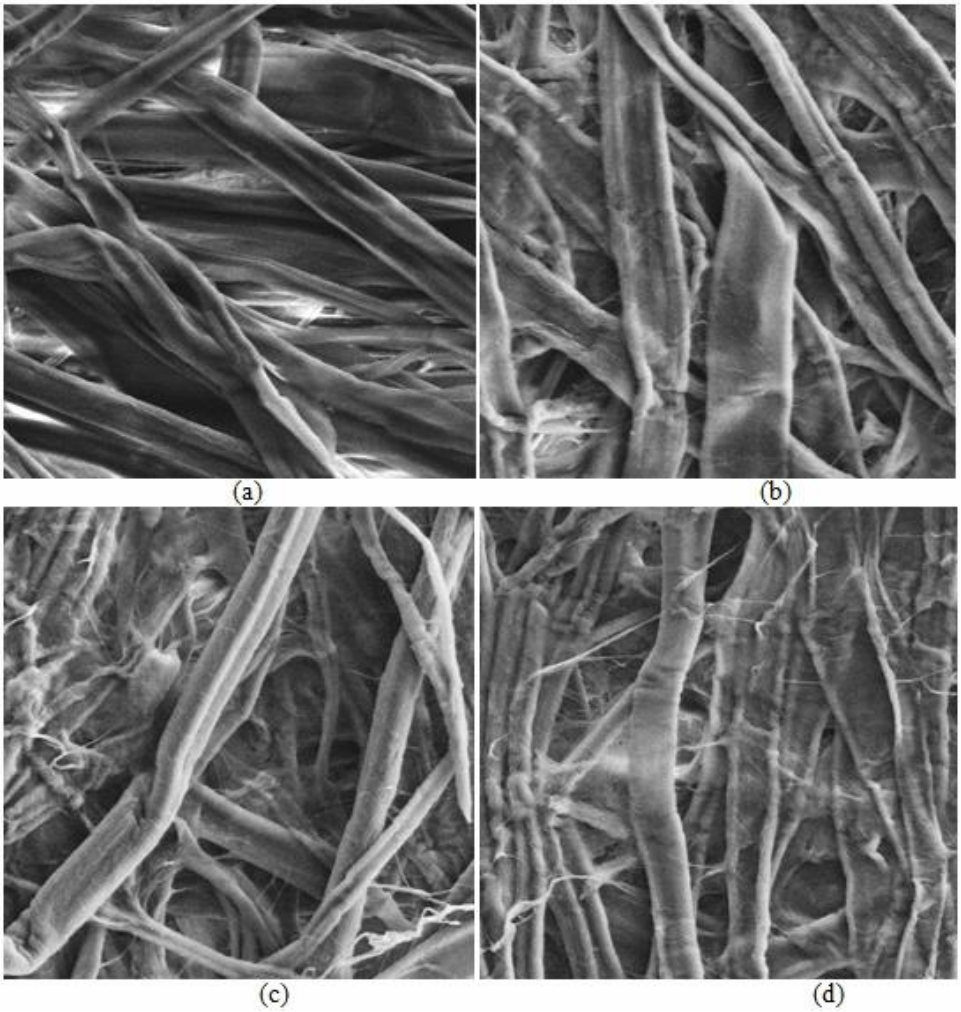

Figure 4. 70% ethanol concentration pulp fibres structure at different PFI revolutions: (a) 0 rev., (b) 6 000 rev., (c) 10 000 rev. and (d) 12 000 rev. (Magnification: 1 000 X)

Muurinen (2000) reported that the chips pulped with an aqueous mixture of ethanol and sodium hydroxide are easier to defiberise than those pulped with soda or by the kraft process. He also stated that the organic solvent reduces the surface tension of pulping liquor at high temperature promoting the penetration of the alkali into the chips and the diffusion of the breakdown products of lignin from the chips to the liquor. Simultaneously, ethanol also degrades lignin.

In this study, the handsheet properties were evaluated which showed in Table 1. Fold endurance is increased as PFI revolution increased. For unrefined Acacia hybrid pulp, fold endurance value is very low about 1-2 times. This

means that unrefined pulp is very weak. After undergone refining process, there is a dramatic improvement among the three refined organosolv pulps. According to Biermann (1996), fold endurance is used to measure the strength and flexibility of paper. Therefore, the higher the value of fold endurance, the stronger the handsheet will be.

Table 1: Handsheets properties of Acacia hybrid pulp with different ethanol concentration and at different PFI revolutions.

Ethanol concentration Acacia hybrid pulp	50%				60%				70%			
PFI revolutions	0	6000	10000	12000	0	6000	10000	12000	0	6000	10000	12000
Fold (Times)	1	123	497	812	1	77	215	640	1	35	96	754
Burst Index ($kPa.m^2/g$)	94	215	307	347	94	195	311	337	93	197	232	343
Tear Index ($mN.m^2/g$)	134	571	693	806	173	577	796	777	138	530	606	746
Tensile strength (N.m/g)	5.8	48.5	56.9	64.7	5.1	43.7	62.3	60.9	5.5	40.1	45.4	63.3

In burst index, the results showed that an increment as PFI revolution increase from unrefined pulp to refined pulp which increases about 72.9% with 50% ethanol concentration, 72.2% with 60% ethanol concentration and 72.9% with 70% ethanol concentration. The burst index is highly correlated to the tensile strength. As tensile strength increases, burst index increases.

There was an increment trend which showed in tear index for all three acacia hybrid pulp, as PFI revolution continuously increases. Tear index for 50% ethanol concentration raises from 134 to 806 which increased about 83.4%. For 60% ethanol concentration, the tear index is grown from 173 to 777 which increased about 77.7%. Meanwhile, there was a growth around 81.5% for 70% ethanol concentration.

In this study, tensile strength showed a growth as PFI revolution increases about 91% from unrefined pulp to refined pulp. Zoltan (1994), and Seth and Bennington (1994) also proved that increased of tensile strength increases PFI revolution. Tensile strength is dependent upon fibre-to-fibre bonding. As PFI revolution is increased, the fibre surface area is increased. The higher the tensile strength, the stronger the handsheet will be. Pulp has lower tensile strength before undergoes refining process. The increment of tensile strength is due to external fibrillation. The increase in the tensile strength is caused by external fibrillation reported by Kang and Paulapuro (2006).

CONCLUSIONS

Aqueous ethanol penetrates easily into the structure of pulp fibre resulting in delignification process. Besides that, ethanol also degrades lignin during pulping. Therefore, 70% ethanol concentration Acacia hybrid pulp has lower pulp freeness compare to 50% and 60% ethanol concentration Acacia hybrid pulp.

In this study, pulp freeness decreases with PFI revolution increases. When action of refining is done on the pulp, fibrillation is occurred on pulp fibre wall. As the process of refining continues, fibrillation increases. Refining removes the primary wall exposing the cellulose microfibrils and increases pulp surface area. Fibrillation leads to more surface area for fiber-fiber contact which will eventually allow for a stronger sheet of paper.

ACKNOWLEDGEMENTS

The authors acknowledge the research grant Fundationtal Research Grant Scheme (FRG 0198-SG-1/2010) provided by Ministry of Higher Education, Malaysia and the cooperation's provided by Forest Research Institute Malaysia, Kepong, and Sabah Forestry Industries, Sipitang, Malaysia throughout this study

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EFEKTI OPLEMENJIVANJA CELULOZNIH VLAKANA ORGANOSOLVNIH ACACIA HIBRIDA I KARATERISTIKA LISTOVA PAPIRA

SAŽETAK

Ovaj rad istražuje uticaj svježine celuloze kod različitih stepena oplemenjivanja organosolv celuloze na različite karakteristike listova papira. Cilj ovog istraživanja je da se uporede karakteristike lista papira kod neoplemenjenog i oplemenjenog organosolv celuloznog vlakna koristeći PFI mlin. Za organosolv proizvodnju celuloze koristi se organski rastvor etanola. U ovoj studiji se koristila 50%, 60% i 70% koncentracija etanola za kuvanje drvne strugotine Acacia hibrida na šaržnom digestoru kojem se kontroliše temperatura na period od 2,5 sati na 185 °C. Tokom procesa oplemenjivanja koristio se PFI mlin za tretiranje celuloze kako bi se poboljšale karakteristike lista papira. Oslobađanje celuloze se utvrđuje testiranjem metodom Kanadskog standarda (CSF). U ovom istraživanju se oslobađanje celuloze smanjuje povećanjem okretaja PFI-ja. S obzirom da se aktivnosti oplemenjivanja vrši na celulozi, na zidu vlakana dolazi do fibrilacije. Kako se nastavlja proces oplemenjivanja, fibrilacija se povećava. Oplemenjivanje je uzrokovalo povećanje površine celuloznih vlakana što povećava spajanje vlakna-sa-vlaknom. Pored toga, koncentracija od 70% etanola na celulozu Acacia hibrida je lakša za oplemenjivanje u PFI mlinu u poređenju sa upotrebom koncentracije od 50% i 60% etanola. Prema tome, njihovo oslobađanje celuloze je najniže kod različitih obrtaja mlina**.**

Ključne riječi: Celuloza, PFI mlin, oplemenjivanje, oslobađanje, Acacia hibrid