Effects of Pre-treatment with Commercial Cellulase and Hemicellulase and Laboratory Beating of Unbleached Pine Kraft Pulp on Freeness, Paper Strength, and Fiber Quality

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The effects of laboratory beating on unbleached regular grade pine kraft pulp (UPKP), pre-treated with commercial cellulase/hemicellulase enzymatic preparation (C/HEP) were assessed using degrees of Schopper-Riegler (°SR) and fibre-quality numbers (FQN). The tests showed a significant increase in the °SR (used in papermaking laboratories and industry to assess the degree of beating) of the UPKP after its enzymatic pre-treatment in the amount of 0.25 to 5.0 mL/kg of pulp and beating. However, only a several percent reduction of beating time was observed when the effect of this pretreatment of pulp on the speed of its beating was determined using another method. The treatment of the pulp selected for research with C/HEP before beating negatively influenced its strength properties after this process. The results correlated well with the most important basic fiber properties from the standpoint of papermaking.

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Keywords: Pine regular kraft pulp; Cellulase/hemicellulase enzyme preparation; Pre-treatment; Beatability; Tensile and tear strengths; Fibre-quality numbers

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INTRODUCTION

The papermaking industry is looking for new solutions to reduce costs and thus be able to reduce the price of paper products and increase the profitability of their production. One approach to achieving this goal is the introduction of biotechnological methods, *i.e.* using enzymes, in the production of pulp, paper, and cardboards. Such an approach is promising mainly because biotechnological processes run at low temperatures and have beneficial influences on the environmental side of the production process. These solutions include the application of enzymes in wood debarking (Rättö *et al*. 1993, Kumar *et al*. 2020), processing of wood (López *et al.* 2017) and waste paper into fibrous pulp (Indumathi *et al*. 2022), pulp bleaching (Immerzeel and Fiskari 2023), de-resination of wood and pulps (Gutiérrez *et al*. 2009), modification of paper properties (Surma-Ślusarska *et al*. 2008; Barrios *et al.* 2024), and limitation of the difficulties which cause the biological biofilms in papermaking industrial installations (Torres *et al*. 2011; Pan *et al*. 2018).

Another stage in which a biotechnological solution can be implemented is the beating of papermaking pulps. Such pulps must be subjected to this process in order to reduce the natural stiffness of their fibres and to modify their surface in order to obtain the optimal mechanical strength of paper, which is important in the further processing and use of paper products (Levlin 1975; Paavilainen 1993). However, the consumption of electricity for pulp beating is very high (150 to 500 kWh/tonne of paper) (Lumiainen 2000).

Several studies on the application of different enzymes and enzymatic preparations (EP) to decrease the amount of energy for beating cellulosic papermaking pulps can be found in the literature. For example, Oksanen *et al.* (1997) used four cellulases (EGI, EGII, CBH1, and CBH2), xylanase, and mannanase for this purpose. Three years later, Seo *et al.* (2000) presented the results of treating hardwood and softwood pulps with the enzyme Liftase A40 (commercial preparation) to speed up the beating of pulps. Garcia *et al.* (2002) showed that the treatment of dried, bleached eucalyptus pulp with cellulase from *Paenibacillus* sp. was able to reduce the beating time of this pulp to the breaking strength of 60 N·m/g to the level of the beating time of the undried eucalyptus pulp. In 2006, Bajpai *et al.* (2006), Ahmad *et al*. (2006), and Kim *et al.* (2006) presented the beneficial effects of the use of the enzymes FibreZyme LBR, cellulase/hemicellulase mixture, Denimax BT, and Denimax 992L to reduce the energy for beating cellulose pulps such as: MHT, bamboo, and EBPV (eucalyptus, bamboo, poplar, and veneer waste), respectively. This type of research was also carried out by Gil *et al.* (2009) with the use of Celluclast 1.5L and Viscozyme L enzymes, and Žnidaršič-Plazl *et al*. (2009) using the enzymes of Novozym 342 and 476, Novozym 51024, and Pulpzym HB. In 2015 and 2016, Cui *et al.*, Singh *et al*., and Przybysz Buzała *et al*., respectively, also presented results of the influence of different the multienzyme preparations (endoglucanase, xylanase, and β-glucosidase) on the beating of pulps and their properties. The most recent works on the issue include the work of Tripathi *et al.* (2019) and Haske-Cornelius *et al*. (2020), who determined the effects of processing different papermaking pulps with different EP on their speed of beating and properties.

Several researchers investigated the effect of enzymatic pre-treatment of pulps on the speed of its beating and concluded that such treatment has a positive effect on this characteristic of pulp determined mainly by the increase in the °SR of the pulps (Oksanen *et al*. 1997; Garcia *et al*. 2002; Bajpai *et al*. 2006; Ahmad *et al*. 2006; Gil *et al*. 2009; Žnidaršič-Plazl *et al*. 2009; Lecourt *et al*. 2010; Przybysz Buzała *et al*. 2016; Haske-Cornelius *et al*. 2020; Wu *et al*. 2020) or reduction of their CSF freeness after a specific time of beating in a laboratory beater (Seo *et al.* 2000; Singh *et al.* 2015; Cui *et al*. 2015; Tripathi *et al*. 2019).

However, after analyzing the results of these studies, there still seems to be some cognitive shortcomings in this topic consisting of: 1) frequent use of the freeness index instead of tensile strength to assess the impact of preliminary enzymatic treatment of pulps on the speed of their beating in laboratory beaters such as *e.g.*, PFI (Oksanen *et al*. 1997; Seo *et al*. 2000; Bajpai *et al.* 2006; Kim *et al.* 2006; Gil *et al*. 2009; Žnidaršič-Plazl *et al.* 2009; Singh *et al.* 2015; Lecourt *et al.* 2010; Liu and Hu 2012; Cui *et al*. 2015; Tripathi *et al*. 2019); 2) the assessment of the suitability of enzymatic pre-treatment of pulp to shorten their beating time, usually in cases of their beating to relatively low values of their tensile strength (Garcia *et al.* 2002; Bajpai *et al.* 2006; Ahmad *et al.* 2006; Žnidaršič-Plazl *et al.* 2009; Singh *et al*. 2015; Tripathi *et al*. 2019, Przybysz Buzała *et al*. 2016, Haske-Cornelius *et al*. 2020); 3) a method for assessing the impact of pre-treatment of kraft pulps with enzyme preparations before their beating on their properties, especially simple ones, that is quick and does not require a few different specialized test stands.

Taking this into account, a study was performed concerning a comparison of the effect of enzymatic pre-treatment of unbleached pine regular grade kraft pulp (UPKP) on the shortening of its beating time to the specific value of degrees Schopper-Riegler (°SR) and tensile strength. Secondly, this study examined the effect of such pre-treatment of pulp selected for testing on its tensile strength in the case of its beating to higher values of this feature. Finally, this research used the Pulmac FS number, B number, and L number indices to quickly determine the reasons that caused the differences in tensile and tear strengths between pulp samples pretreated with EP and reference pulp samples after their beating.

EXPERIMENTAL

Pulp

Air-dried, industrial, unbleached regular grade pine kraft pulp (UPKP) was used for the tests. Pulp was obtained from a Polish kraft pulp mill, where it was made from pine wood (*Pinus sylvestris*). The kappa number of this pulp was determined using the PN74/P50092 standard and was found to be 28.2.

Enzymes

A commercial cellulase/hemicellulose enzymatic preparation (C/HEP) (obtained in the culture of a microorganism *Trichoderma longibrachiatum*) containing endoglucanase activity (830 IU/g determined on CMC), hemicellulase activity (575 IU/g, determined on xylan), and certain activities on the Filter Paper Assay (65 IU/g) and Avicel (65 IU/g) suggesting the presence of some amount of exoglucanases in it, *i.e.*, cellobiohydrolases (CBH-I or II) and β-glucosidases.

Enzymatic Pre-treatment of Pulp (EP)

A 20 g sample of oven-dried pulp was placed in a beaker, flooded with 1000 mL of distilled water, and left for 16 h to properly hydrate the fibres. The suspension was then separated into fibers briefly with a kitchen blender with a blunt fibrizing attachment. After breaking down lumps of pulp into individual fibers, the pulp was drained and the filtrate was saved. Then, the amount of filtrate required to obtain a 10% fibre suspension concentration was metered, and the amount of commercial C/HEP from 0.25 to 5.00 mL/kg of pulp (0.2 to 4.2 CMC IU/g of pulp) was added to the filtrate. The filtrate and pulp sample were placed in a double polyethylene bag and mixed by hand kneading, and then acidified to pH 5 with a small amount of diluted sulphuric acid. The prepared sample was placed in a water bath at 45 °C. Enzyme pulp pre-treatment was carried out for 1 h. After that time, the suspension was transferred to a Büchner funnel lined with a filter cloth, drained, and washed twice with distilled water (1000 mL each). To deactivate the enzyme, a pulp was again diluted to 10%, heated to boiling point in a beaker, and then filtered on a Buchner funnel once more. The samples prepared in this way were placed in a plastic bag and dried in the air for a few days. The reference tests were prepared similarly but without the addition of enzyme preparation to the pulp slurry.

Beating the Pulp Samples, Determining the Degree of Pulp's Beating and Handsheet Preparation

Pulps were beaten in a Jokro mill according to the PN-EN 25264-3 (1999) standard in order to obtain pulp samples with an appropriately wide range of Schopper-Riegler freeness (°SR). This differentiation was achieved by changing the beating time of the pulp sample in the Jokro mill. The °SR of pulps was determined according to PN-EN ISO 5267-

1 (2002). For determination of tensile strength, tear resistance, FS number, B number, and L number, pulp handsheets of 75 ± 3 g/m^2 and 60 ± 3 g/m^2 were prepared using standard Rapid-Köthen apparatus according to the PN-EN ISO 5269-2 (2001) standard.

Determination of the Pulp Properties

Tensile index and tear index were determined using a Zwick/Roell tester BZ2.5/TN1S (Germany) and a ProTear tear tester (Thwing-Albert, USA) according to the PN-EN ISO 1924-2 (2010) and PN-EN ISO 1974 (2012) standards, respectively. The Pulmac fibre strength number [FS (fibre strength) number, B (fibre bonding) - number, and L (fibre length) number] were determined by breaking the strips of paper (basis weight 60 g/m^2, dimensions 100 mm × 25 mm) in a Troubleshooter Tester TS-100 (Pulmac Corp.) in dry and wetted states using the following equations, and according to the owner manual for this apparatus (Cowan 1995; Pulmac 2001),

FS number = $P_{0,\mathrm{W}} \times 60/G$; [psi/15 mm]
B number = $P_{0.6\mathrm{D}}/ P_{0.6\mathrm{W}}$ and
L number = $P_{0.6\mathrm{W}}/ P_{0,\mathrm{W}}$

where $P_{0,\mathrm{W}}$ is the average of determinations of the tensile strength of a wet sample of pulp (W) in the form of a paper strip at a distance of 0 mm between the jaws of the apparatus; $P_{0.6\mathrm{W}}$ is the average of determinations of the tensile strength of a wet sample of pulp in the form of a paper strip at a distance of 0.6 mm (pine pulp) between the jaws of the apparatus; $P_{0.6\mathrm{D}}$ is the average of determinations of the tensile strength of a dry sample of pulp (D) in the form of a paper tensile strip at a distance of 0.6 mm (pine pulp) between the jaws of the apparatus; and G is the grammage (basis weight) of pulp handsheets (g/m^2).

Elaboration of Results

The determination of pulp °SR was performed twice for each pulp sample, so the results presented in Fig. 1 are the average of these determinations. After the preparation of handsheets from both enzyme pre-treated and reference UPKP samples, they were carefully checked to eliminate these that had defects in the uniformity of the formation of paper structure. This usually required preparing these handsheets from two samples of unbeaten or beaten pulp. In this way, two sets of sheets were obtained, which were then subjected to strength tests. Ten determinations of these properties were performed for each set of handsheets so that, after the testing, there were two mean values of each property. In Figs. 2 and 4, the arithmetic average of these two values are presented. The standard deviation of the measurements of tensile index and tear index were determined automatically in tests for these properties and ranged from 50 to 150 m and 0.3 to 0.9 mN·m^2/g, respectively.

The determination of the FS number of pulps was performed using 20 strips of paper. The standard deviation of the measurement of this feature was in the range of 3 to 5 psi/15 mm.

RESULTS AND DISCUSSION

Figure 1 shows the effect of the dose of commercial C/HEP on the Schopper-Riegler degrees (°SR) of UPKP beaten in a laboratory Jokro mill. Initially, to assess the impact of the treatment of pulp selected for testing with EP on its beating speed, an assessment method used by many authors was used, *e.g.* Liu and Hu (2012). The dosages of this EP on oven-dried (o.d.) pulp were up to 6 times lower, similar, and 2 times higher than those previously reported for this type of enzyme (Garcia *et al.* 2002).

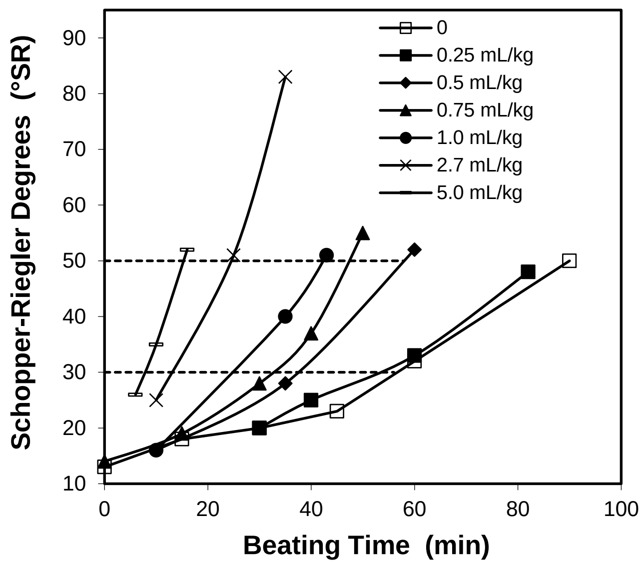

Fig. 1. °SR *vs* beating time of UPKP

Figure 1 shows that, in order to beat UPKP pulp to 30 and 50°SR in a Jokro mill, the beating should be carried out within 60 and 85 min, respectively. The reduction of the time of beating of this pulp to 30 and 50 °obtained as a result of pre-treatment of this pulp with C/HEP expressed in % is shown in Table 1.

Table 1. Reduction of the Beating Time of Unbleached UPKP to 30 and 50 °SR as a Result of Enzymatic Pre-treatment in Comparison with Reference Sample

SFR / EP on kg of pulp	30° SR	50° SR
	% rel.	
0.25 mL/kg	- 5.3	- 6.7
0.50 mL/kg	- 33.3	- 35.6
0.75 mL/kg	- 42.1	- 47.8
1.0 mL/kg	- 57.9	- 52.2
2.7 mL/kg	- 77.2	- 72.2
5.0 mL/kg	- 86.0	- 83.3

The data from Table 1 show that using enzymatic pre-treatment of UPKP in an amount of 0.25; 0.5, 0.75; 1.0, 2.7, and 5.0 ml/kg of pulp, can reduce its beating time in a Jokro mill to 30 and 50° SR by 5 and 7; 33 and 36; 42 and 48; 58 and 52; 77 and 72; and 86 and 83%, respectively. So, using C/HEP in an amount greater than 0.5 mL/kg to o.d. pulp shortening of the beating time is significant (*i.e.*, by 33 to 36%), while for the amount of this EP dosed into the pulp of 2.7 mL/kg, which is 72 to 77% it can be considered very large. The obtained result indicates also that shortening the beating time of enzyme pre-treated pulp to a specific °SR can be broadly regulated by the amount of enzyme dose dispensed per ton of pulp.

The pre-treatment of pulps with C/HEP, due to their hydrolytic action on carbohydrates, may reduce its strength properties (Oksanen *et al.* 1997; Seo *et al.* 2000; Garcia *et al.* 2002; Žnidaršič-Plazl *et al.* 2009; Cui *et al.* 2015). Figure 2 shows the effect of the pre-treatment of UPKP pulp with such EP on their breaking length as a function of their °SR, while Table 2 shows the decrease of this characteristic in relative values (%) for the beating of pulp to 30 and 50°SR.

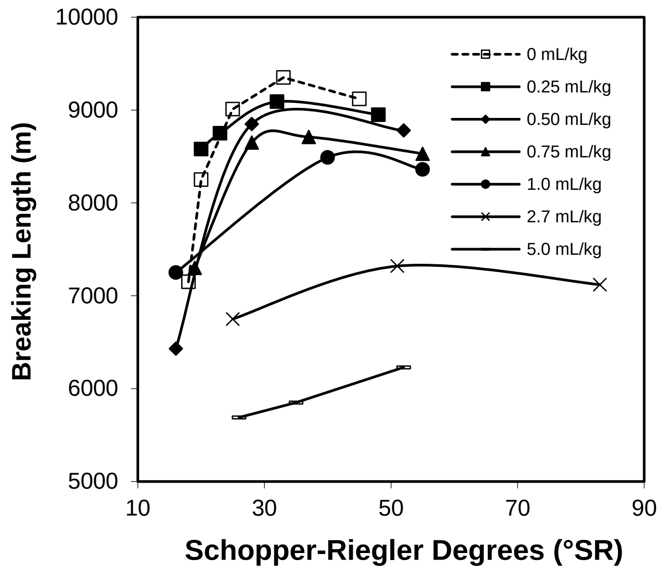

Fig. 2. Effect of enzymatic pre-treatment of UPKP on its breaking length as a function of °SR

Table 2. Reduction of the Breaking Length of UPKP at 30 and 50°SR Due to its Enzymatic Pre-treatment in Comparison with Reference Sample

°SR / EP on kg of pulp	30 °SR	50 °SR
	%	
0,25 mL	- 1.6	- 1.1
0.50 mL	- 2.7	- 2.0
0,75 mL	- 4.6	- 4.2
1.0 mL	- 13.0	- 6.7
2.7 mL	- 25.0	- 18.9
5.0 mL	- 37.5	- 31.7

Figure 2 and the data in Table 2 show that, after pre-treatment with C/HEP in an amount of 0.25 to 0.75 mL/kg followed by its beating to 30 and 50 °SR, the breaking length of UPKP pulp was reduced by 1 to 5%. This reduction can therefore be considered relatively small. After increasing the amount of this EP up to 1 mL/kg and 2.7 to 5.0 mL/kg on o.d. pulp, this reduction is increased to 7 to 13% and 19 to 38%, respectively.

One of the main goals of this work was to compare the beating speed of UPKP due to C/HEP pre-treatment in laboratory beater based on the increase in the °SR of the pulp for a given beating time, and also based on the shortening of the beating time (Y–axis) to its specific tensile strength (X–axis) (expressed in this work as the breaking length index). For this purpose, a graph was prepared showing such a relationship for the pulp samples untreated and subjected to C/HEP pre-treatment and beating in such beater (Fig. 3). This relationship indicates that such pre-treatment of pulp allowed the shortening of the beating time of the pulp in comparison with the reference sample in the breaking lengths range from 7200 to 9000 m only in the case of using the amounts of the enzyme dosed on o.d. pulp 0.25 to 1.00 mL/kg (Fig. 3) (*e.g.*, by up to 18.5% for a dose of EP 0.75 mL/kg of pulp when it is beaten to a breaking length of 8000 m). In the case of presenting the effect of enzymatic pre-treatment in such form, the effect of shortening the beating time of pulp due to the use of this treatment was therefore much smaller and more limited than when the effect of such pre-treatment on shortening the pulp's beating time is presented in the form of the relationship of the °SR (Y–axis) *vs.* time of beating (X–axis).

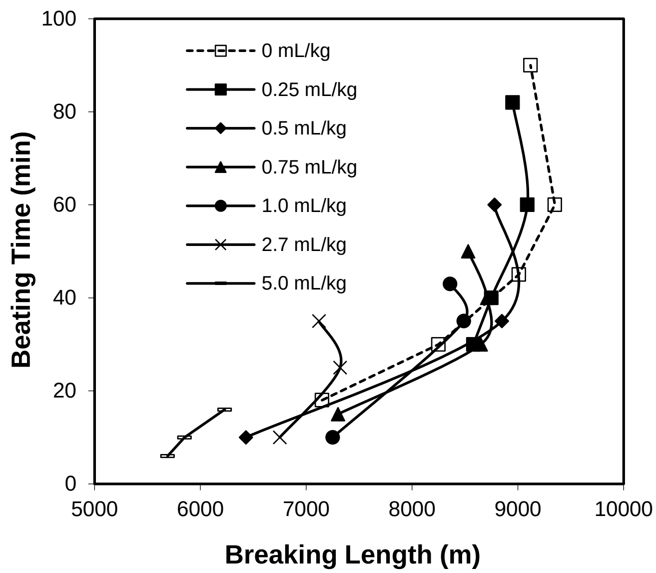

Fig. 3. Effect of enzymatic pre-treatment of UPKP on the time of beating needed to obtain the specific breaking length

The research also showed that an unfavourable phenomenon of enzymatic pre-treatment of pulp was the reduction of the maximum level of breaking length that pine pulp can achieve. For example, for dosed amounts of enzyme at 0.25, 0.50, 0.75, 1.00, 2.70, and 5.00 mL/kg, this level was limited to approximately 9000 m, 9000 m, 8750 m, 8500 m, 7300 m, and 6300 m, respectively. This can be a problem for papermakers who require the highest level of this characteristic from pulp. The phenomenon of lowering the tensile strength of handsheets of pulps treated with hydrolases has also been reported (Oksanen *et al.* 1997; Seo *et al.* 2000; Garcia *et al.* 2002; Žnidaršič-Platz *et al.* 2009; Cui *et al.* 2015; Tripathi *et al.* 2019).

In order to assess the influence of the preliminary enzymatic treatment of UPKP on tear resistance, this feature of its handsheets was also determined, and its changes were compared with the control sample. The results of these tests as a function of °SR are presented in Fig. 4. As in the case of changes in the breaking length of handsheets of UPKP the percentage decrease in tear resistance of pulps is presented in a separate table (Table 3).

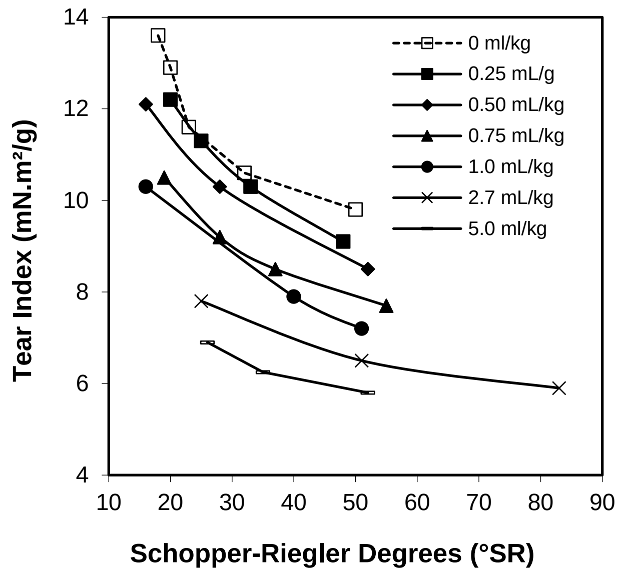

Fig. 4. Effect of enzymatic pre-treatment of UPKP on its tear index as a function of °SR

Table 3. The Reduction of the Tear Resistance of UPKP at 30 and 50 °SR Due to Its Enzymatic Pre-treatment in Comparison with Reference Sample

°SR / EP on kg of pulp	30 °SR	50 °SR
	%	
0.25 mL	- 5.5	- 6.3
0.50 mL	- 7.7	- 8.4
0.75 mL	- 17.3	- 17.9
1.0 mL	- 17.9	- 20.3
2.7 mL	- 31.8	- 31.6
5.0 mL	- 39.1	- 38.9

Table 3 shows that in the case of enzymatic pre-treatment of UPKP with C/HEP in quantities of 0.25 to 0.50 mL on o.d. pulp, the reduction in tear index was in the range of 5 to 8% rel. When the dose of this EP added to the UPKP was 0.75 to 1.00 mL per kg of pulp, it decreased by 18 to 20%, while at the amount of C/HEP being added between 2.7 and 5.0 mL per kg of pulp, it decreased by 32 to 39%, respectively. The reduction in tear resistance of UPKP after enzymatic pre-treatment and beating was, therefore, very similar to the reduction of the breaking length of these pulps (Table 3).

Due to the need to quickly determine the causes of the development of the properties of the kraft pulp in the form of handsheets (*e.g.*, tensile and tear strength) after its initial EP treatment and beating without the use of various specialized test stands, the known in papermaking method of testing the properties of fibers such as their strength, ability to bond, and its length using the Pulmac TroubleShooter TS-100 apparatus was used. These tests enable the determination of the FS number, B number, and L number indices corresponding to these properties.

Figure 5 shows the changes in FS number of UPKP samples enzymatically pre-treated with different amounts of EP and control as a function of the °SR.

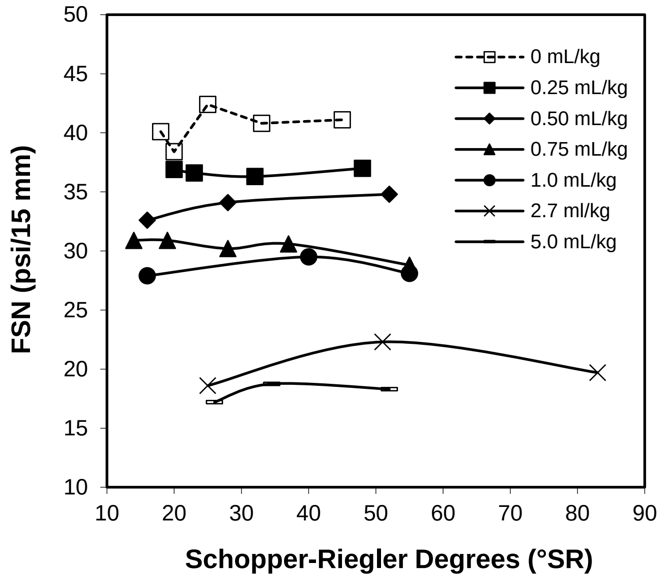

Fig. 5. The effect of enzymatic pre-treatment on the FS number of UPKP fibres as a function of °SR

Figure 5 shows that pre-treatment of UPKP with commercial C/HEP had a negative effect on the strength of fibres. Further, the reduction in FS number was proportional to the dosage of the EP on o.d. pulp and the decrease in breaking length and tear index presented in Figs. 3 and 4. This effect is probably mainly caused by the presence of endogulcanase-type enzymes in the EP used for processing of pulp selected for research, which are considered more detrimental for fibres than exoglucanases. For example, Pere *et al.* (1995) reported that the intrinsic viscosity of kraft pulp after endoglucanases pretreatment is lower than after pretreatment with CBH I and II (both groups obtained from *Trichoderma reesei*) by an average of approx. 450 cm^3/g. However, the relatively small unfavorable effect of endoglucanase enzymes pretreatment of pulp measured based on released sugars and length of cellulosic fibres may also be enhanced by the presence of hemicellulase-type enzyme in the EP, as results from the work of Žnidaršič-Plazl *et al*. (2009) and Haske-Cornelius *et al.* (2020). Apart from that, the arrangement of the curves in these drawings analogous to Figs. 2 and 4 indicates that a decrease in fibre strength (as demonstrated earlier by Page and MacLeod 1992) is one of the main reasons for the reduction of maximal breaking length and the tear index of UPKP after C/HEP pre-treatment.

The reduction in pulp strength properties may also result from changes in the strength and area of bonded surfaces of the fibers in the paper structure (Levlin 1975; Page and McLeod 1992; Retulainen 1996). The results of the determination of the index characterizing these features of pine pulp fibres in the structure of paper handsheets without and with EP pre-treatment before their beating are presented in Fig. 6 as the B-number.

The data in Fig. 6 show that the higher the amount of EP selected for research used for the pre-treatment of UPKP pulp, the greater the degree of bonding of their fibres in handsheets of paper. It follows from this that a decrease in the degree of fibre bonding in the structure of the paper is not the cause of the decrease in the breaking length of enzymatically pre-treated UPKP after beating. On the contrary, it is, rather, a factor in reducing the negative effect of the reduction of fibre strength on the breaking length of pulp selected for research. Several authors have mentioned the possibility of improving the bonding ability of fibres as a result of their pre-treatment with preparations containing cellulolytic enzymes before beating. For example, López-Lorenzo *et al*. (2003) and Liu and Hu (2012) state that this is due to the increase in the flexibility and swelling ability of the fibers, as well as the increase in the number of fibrils on the fiber surfaces after beating as a result of its enzymatic "softening." In addition to these reasons, other authors have also demonstrated the possibility of increasing the surface of fibre contacts in fibre mats as a result of fragmentation of fibre aggregates due to enzymatic pre-treatment of pulps (Pala *et al*. 2002) (based on permeability measurements of fibrous mats) and a beneficial effect of such pre-treatment on surface fiber morphology and chemistry from the point of view of fibres' bonding (Oksanen *et al*. 1997; Gil *et al*. 2009).

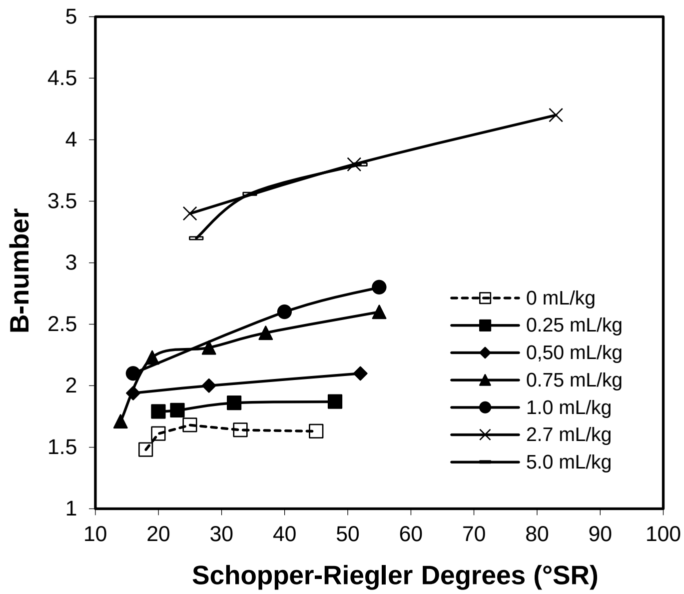

Fig. 6. The effect of enzymatic pre-treatment on the B number of UPKP fibres as a function of °SR

The pre-treatment of UPKP with enzyme preparation containing cellulases can also affect the fibre length (Seo *et al.* 2000; Žnidaršič-Plazl *et al.* 2009; Lecourt *et al.* 2010; Cui *et al.* 2015). As was mentioned earlier in the study the effect of such pre-treatment on fibre length was studied by determining L number. The results of the determinations of this number are shown in Fig. 7 as a function of °SR.

The decrease in the length of pulp fibers may be also one of the factors negatively affecting their strength properties (Paavilainen 1990), especially tear resistance (Seth and Page 1988) in the form of paper sheets. The data presented in Fig. 7 show that beating of UPKP after its pre-treatment with EP caused such a decrease. Therefore, the decrease in fiber length certainly contributed to the reduction in the breaking length and tear index presented in Figs. 3 and 4, especially since the decrease in this number is proportional to both breaking length of the pulp selected for research and its tear index, as it can be seen from the comparison of the arrangement of curves in Figs. 7 and 3 and 4. It seems that the cause of the shortening of the fibres after pre-treatment of UPKP with EP selected for research and beating may result mainly from the accumulation of the action of enzymes of different types on weak points of the fibres such as occurring naturally (Green 1962) or induced artificially during pulping (MacLoed 1990), possibly amorphous and hydrated in nature, which contribute to their breaking at these points under mechanical stress during beating. Concentrated in weak points of the fibers action of enzymes was earlier observed by Eriksson (1969) and later confirmed by Garnagul *et al*. (1992) with a small decrease in the degree of polymerization of kraft pulp after cellulase enzyme treatment with the very large decrease in their dry ZSTS.

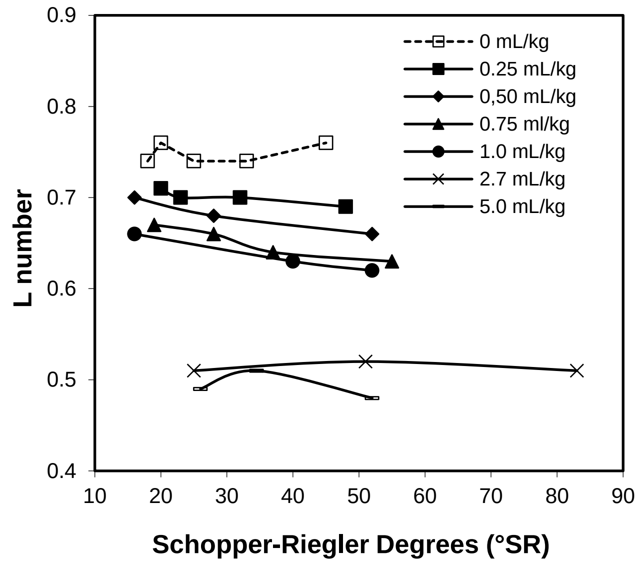

Fig. 7. The effect of enzymatic pre-treatment on the L number of UPKP fibres as a function of °SR

CONCLUSIONS

1. When the increase in Schopper-Riegler degrees (°SR) was used to assess the shortening of unbleached pine kraft pulp (UPKP) beating time after its pretreatment with cellulase/hemicellulase enzyme preparation (C/HEP), these shortenings were in the range of approx. 5% to even 83 to 86% for this EP dose between 0.25 and 5.0 mL/kg of pulp. However, this shortening of beating time was accompanied by a reduction in breaking length and tear index of handsheets prepared from this pulp in the range of 1-2% : 32-38% and 5-6.5% : ~39%, respectively.

2. However, when the effect of C/HEP pretreatment of pulp on the speed of its beating in laboratory mill was determined on the basis of the beating time (Y–axis) *vs.* breaking length (X–axis) dependence curve, only up to several percent reduction in the beating time was observed. Beneficial effects were observed only for the range of breaking length from 7200 to 9000 m and for enzyme doses of 0.25 to 1.00 mL/kg on o.d. pulp.

3. The relatively good correlation of changes in basic papermaking fibre properties determined by FS, L, and B indices with changes in the properties of handsheets prepared from UPKP subjected to C/HEP pre-treatment and beating enable their use for quick determination of the causes of unfavorable changes in the properties of pulps as a result of the action of enzymes.

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