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Full Length Research Paper

Effect of cellulase treatment of long fiber fraction on strength properties of recycled corrugated medium

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It is a well-known fact that the physical strength properties of fibers decrease with recycling. The aim of this study was to investigate the positive effect of using commercial cellulase enzymes on the physical strength properties of corrugated medium. The long fiber fraction of pulp is the most appropriate application point of a cellulase enzyme. Therefore, the pulp used in this research has been obtained at fractionation screen levels of modern Karton paper mill Turkey. The long-fiber fraction of the pulp for corrugated medium was pre-treated with four different commercial enzymes, Roglyr Bio 1537, Maximyze 2520, Benstone and Bensoft Plus. The handsheets for physical testing were prepared after blending of beaten long-fiber and unbeaten short-fiber fractions. The obtained test results have indicate that the application of enzyme on appropriate fiber fraction have positive effects on the strength properties of the corrugated medium. The short span compression test is one of most important strength properties of corrugated board and increase from 8.41 to 20.5% with enzymatic pre-treatment and beating of the long fiber fraction.

Key words: Corrugated medium, enzymatic pre-treatment, cellulase, long-fiber fraction, paper strength properties, short span compression.

INTRODUCTION

In parallel with the current global economy, corrugated raw material consumption in Europe has decreased 4.8% in 2009. Despite this, consumption of raw materials from primary fiber sources such as kraft liner has increased 4%. The reason for the overall reduction is the decrease in the consumption of raw materials from secondary fibers (recycled liner, 11.6%) (FEFCO, 2009). For a more efficient utilization of recycled fiber products, their physical strength properties must be improved to a competitive level. The strength loss of secondary fibers is caused by hornification (Nazhad and Paszner, 1994) (decrease of swellability and conformability of fibers) and loss of relative bonded area (Garg and Singh, 2006). The strength of fibers can be recovered to a certain degree by beating. However, generation of fines during the beating process decrease the run ability of the paper machine. Decrease of drainage properties of pulp caused by the fines, become an important limiting factor for recovering of paper strength by beating. Mechanical pulp content in waste paper grades used for corrugated medium is an additional source for generation of more fines during the beating.

Stork et al. (1995) investigated drainage properties of different pulps after treatment with different enzyme combinations. Fines and fiber surface fibrils may be preferentially attacked by the enzymes due to their high specific surface area and accessibility. Fiber surfaces are stripped, or cleaned, through hydrolysis which involves the removal of exposed cell wall fragments, which can create new fines during beating (Jackson et al., 1993). Bajpai et al. (2006) reported approximately 25 kWh/t reducing of refining energy, after treatment of pulp with enzymes with cellulase and hemicellulase activities. Enzyme treatment reduces the coarseness of mechanical and kraft pulp fibers, where the reduction of coarseness

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Abbreviations: SBE, Specific beating energy; **CMT,** concora medium test.

was greater for the longer and coarser fiber fractions (Mansfield et al., 1996). Industrial fractionation technology used in combination with cellulase treatments that specifically target the long coarse fibers resulted increases in tensile strength as much as 10% (Mansfield et al., 1999).

The objective of cellulase treatment prior to the refining process is either to improve the beat ability response or to modify the fiber properties. The addition of cellulase and hemicellulase after beating is to improve the drainage properties of pulp, which determine the speed of paper mills (Bhat, 2000). During the enzymatic treatment of whole pulp the significant amount of the enzyme will be spent for degradation of easy accessible fines. Similar to the other paper grades, most of the strength properties of recycled fluting are determined by the long fibers. Therefore, the recovery of strength properties of long fibers is expected to improve paper properties without a yield lost in a short fiber fraction. The aim of this study was determining the potential of enzymatic pre-treatment and beating of fractionated fibers on improvement of strength properties of pulp for recycled corrugated medium. Different cellulase enzymes were used for stripping and cleaning of excess microfibrils from the surface of coarse fibers.

MATERIALS AND METHODS

Recycled pulp and retention aid additive (polyacrylamide (PAM), viscosity 45 to 70 mPa.s.) were obtained from modern Karton paper mill Turkey. The pulp samples were taken at fractionation screens level, thickened and stored at 4°C temperature. Roglyr Bio 1537, Maximyze 2520, Benstone and Bensoft Plus cellulase enzymes were obtained from Mavi Jeans (Hungarian Industry Products KFC), Buckman Laboratories, and Bengü Kimya, respectively. The enzyme activity was determined by dinitrosalicylic acid (DNS) method (Bailey, 1988). Diluted enzyme solution (30 µl) was incubated in 300 µl of 4% (w/v) carboxymethylcellulose (CMC) low viscosity solution (100 mmol/L acetate buffers with 0.4% Tween 20, pH 5.0) at 40°C, for 20 min. One international unit (IU) of cellulase activity was defined as the amount of enzyme catalyzing the release of 1 mmol of CMC equivalent per minute (Ringpfeil and Gerhardt, 2001). Only the long fiber fraction was subjected to modification.

The enzyme treatment was carried out in ziplock bags at 3% pulp consistency, pH 6.0, 50°C, for 60 min for Bensoft Plus and 30 min for all other enzymes. Reaction was stopped by placing the pulp in boiling water bath for 15 min. Control pulp was similarly treated in a boiling water bath. Dosages of enzymes were 0.6 IU/ml for Benstone and 0.8 IU/ml for Roglyr Bio 1537 and Bensoft Plus. According to the supplier recommendation, Maximyze 2520 dosage was 0.2%. Beating of pulps was performed in a valley beater according to the ISO 5264-1 standard method, and specific beating energy (SBE) was determined according to the Atik et al. (2005). Beating conditions were 360 g (oven dry pulp), 20°C temperature, 150 and 250 kWh/t SBE. Hand sheets with basis weight of 100 g/m² were prepared by blending 30% long and 70% short fiber fractions and 400 g/t PAM according to the ISO 5269-2 Rapid-Köthen method. Schopper-Riegler degree (SR°) was determined according to ISO 5267-1. Physical strength properties have been determined according to the ISO 187, ISO 536, ISO 534, ISO 287, ISO 9895, ISO 7263, TAPPI T 824, ISO 1924-2 and ISO 2759 standard test methods.

RESULTS AND DISCUSSION

The stripping and cleaning of a coarse fiber surface will change the response of pulp to beating and consequently the strength properties of paper. An approximate SBE optimum of 200 kWh/t was determined for pulp used in the study in term of physical strength properties. Two different SBE levels were applied to the enzyme-treated coarse fibers, 50 kWh/t over and 50 kWh/t below the optimum, in order to determine the interaction between beating and enzymatic treatment of pulp. Drainage values of the long fiber fraction suspected to beating was 25 SR°. The drainage of untreated blended fibers was 35 SR°. The long fiber fraction with coarse fibers have better drainage and after addition of fraction including the fines drainage decrease. After beating of fibers pre-treated with enzymes, the SR° values increased 10 and 14 points for low and high beating levels, respectively (Table 1). Retention aid additive which causes flocculation of fines on fiber surface give the better retention and dewatering properties of pulp suspension. The SR° value of blended unbeaten pulp suspension decreases to 24 after addition of PAM. The final drainage properties of blended and enzyme treated pulps with retention additive are in parallelism with drainage of long fibers and approximately 10 points below it.

Figure 1 illustrates the effect of beating levels on density of obtained hand sheets. In all cases the higher the SBE results, the higher the density of paper. Enzymatic treatment also plays an important role on density of sheets, and the values are higher from 4.6 to 8.8% than the control. The highest value is obtained for Bensoft plus cellulase where the longest treatment duration was applied. The effect of enzymatic treatment on the bursting index was different for certain enzymes (Figure 2). Benstone and Bensoft plus cellulase cause the decrease of bursting strength, while the Roglyr and Maximyze cause the increase of bursting strength of papers. Roglyr 1537 and Maximyze 2520 enzymes do not indicate an important effect on bursting strength, while the strength increase with applied amount of SBE (Figure 2).

Tensile strength of papers in all cases is higher for high beating degree level. Roglyr 1537 was determined to be the most effective enzyme, considered under aspect of tensile strength (3.66% increase) (Figure 3). Fines content in a short fiber fraction used in the study prevent thereaching the increase of tensile strength to 10% level described by Mansfield et al. (1999), which application was performed on virgin fibers. Bajpai et al. (2006) reported tensile strength improvement of about 5.24% at MD for bamboo long fraction kraft pulp blended with new kraft cuttings. Modulus of elasticity was one of the paper properties most affected by the enzymes (Figure 4). The only decrease was observed in pulp pre-treated with Bensoft plus, where the longest treatment time was applied.

The scope of this research was to corrugated medium

Table 1. Drainage properties of pulps.

Pulp	0	150 (kWh/t)				250 (kWh/t)			
	Control	Roglyr 1537	Benstone	Bensoft plus	Maximyze 2520	Roglyr 1537	Benstone	Bensoft plus	Maximyze 2520
Long fiber fraction (SR°)	25	35	35	36	35	42	38	38	39
Blended pulp (SR°) (PAM added)	24	26	25	27	29	31	27	27	32

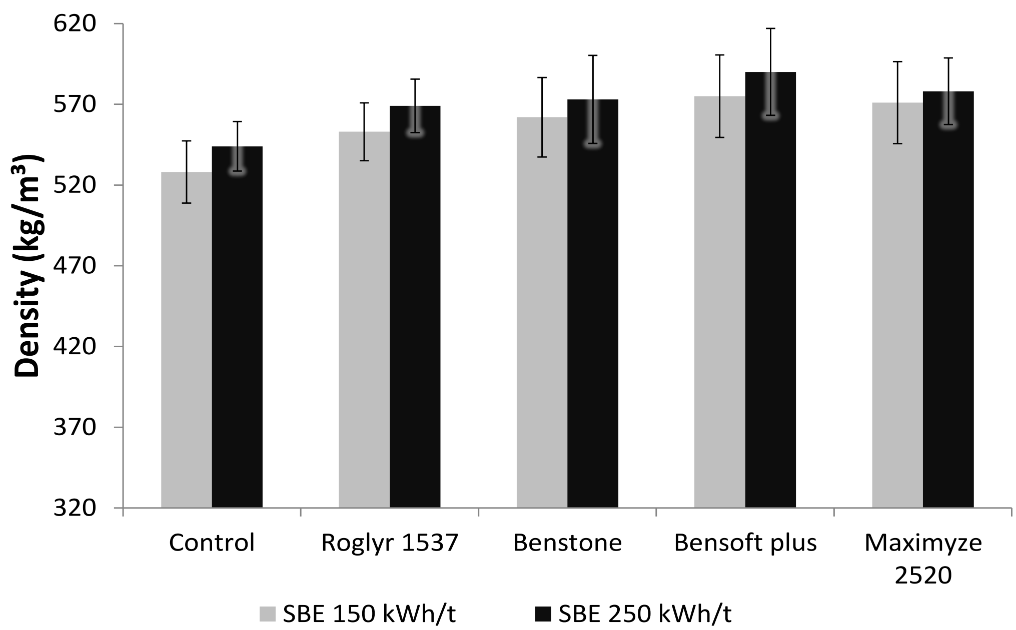

Figure 1. Density of papers according to the applied enzyme and SBE.

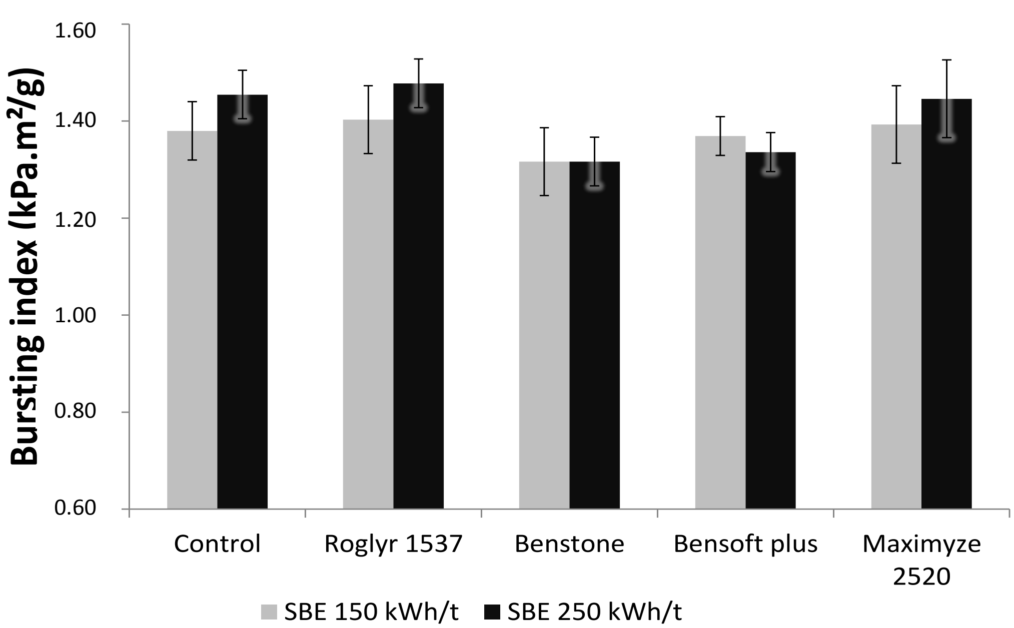

Figure 2. Bursting strengths of papers according to the applied enzyme and SBE.

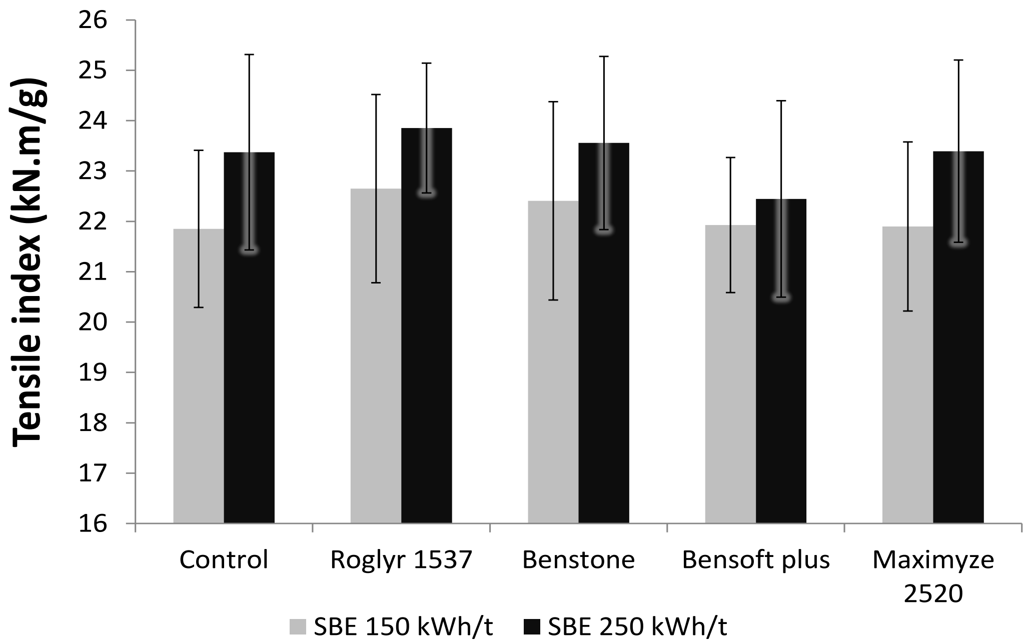

Figure 3. Tensile strengths of papers according to the applied enzyme and SBE.

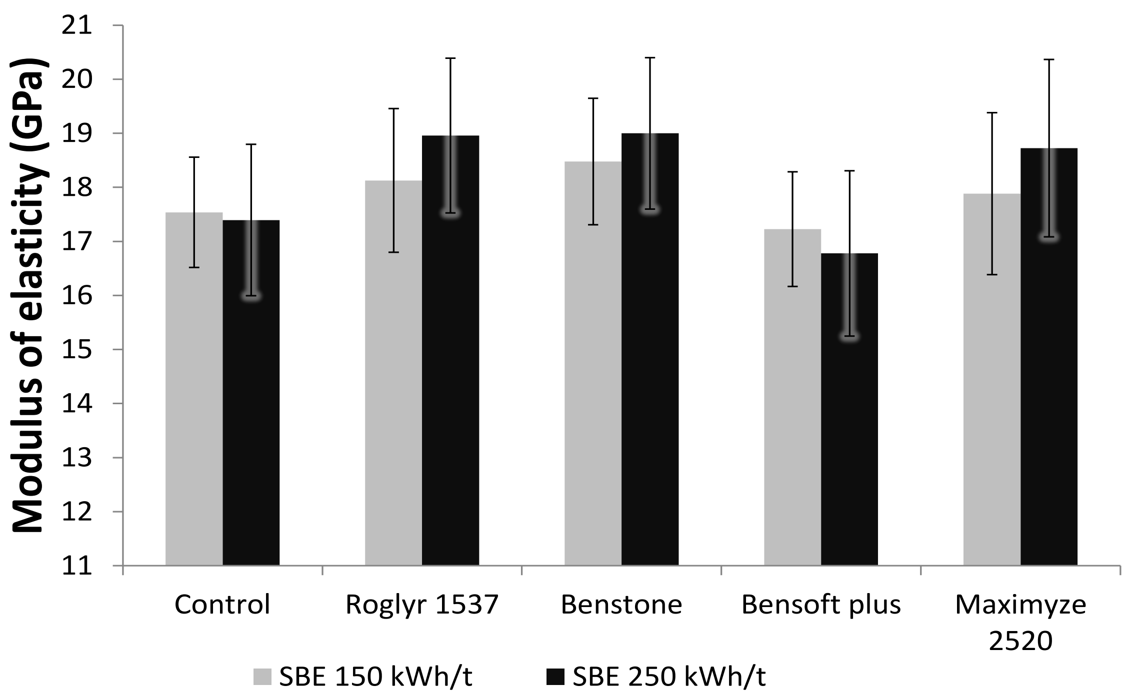

Figure 4. Modulus of elasticity of papers according to the applied enzyme and SBE.

paper; hence the sheets were evaluated according to their utilizing aspect beside the common strength properties of paper. One of the most important tasks of the fluting medium in a corrugated board is to separate the two liners. A measure of this ability is the flat crush test (FCT) strength. A similar test, aimed at the prediction of FCT of the finished complete single-wall board, is the concora medium test (CMT) which is carried out on the fluting medium alone. The CMT-strength is considered to be one of the most important quality properties of fluting materials (Markström, 2005). Maximyze pre-treatment and SBE of 250 kWh/t was found to be the most effective

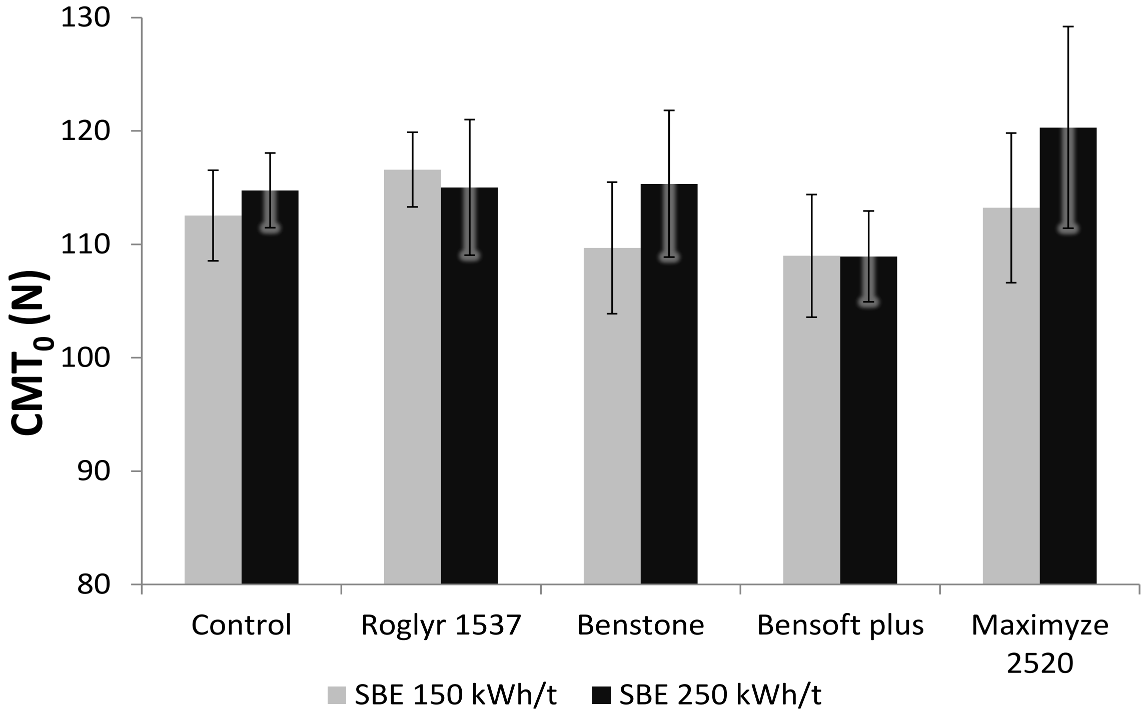

Figure 5. CMT_0 of papers according to the applied enzyme and SBE.

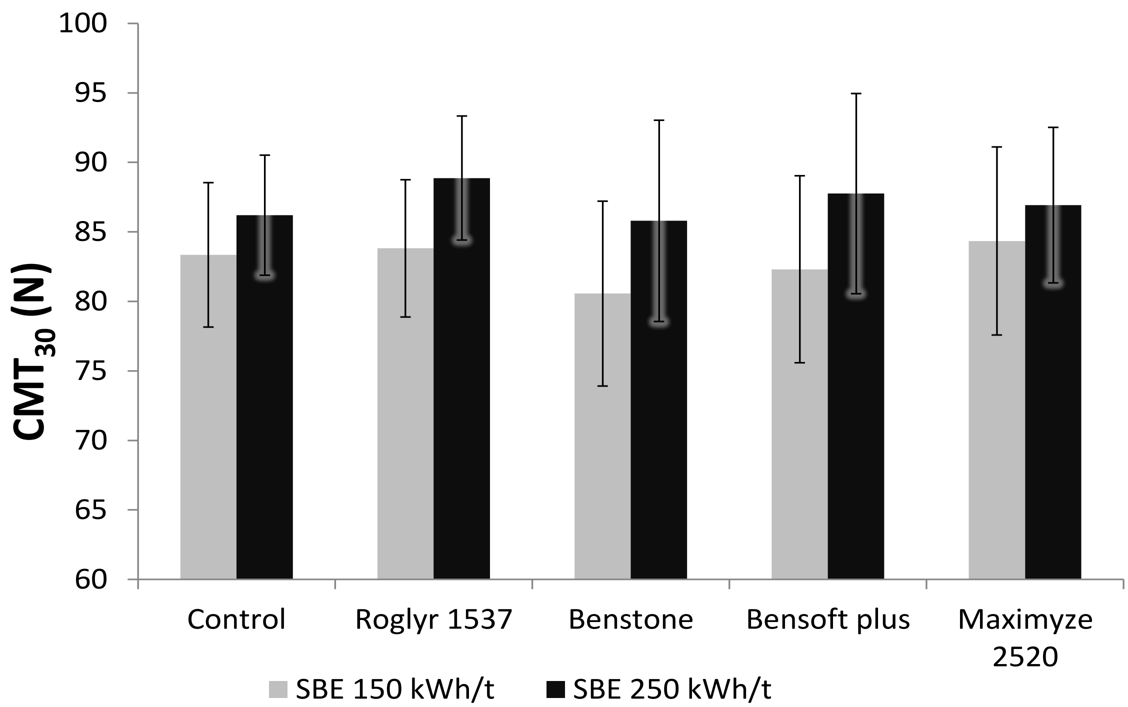

Figure 6. CMT_{30} of papers according to the applied enzyme and SBE.

application for CMT_0-strength, which is determined immediately after fluting of the sample (Figure 5). The SBE application is the most important variable that determines the CMT_{30}-strength (30 min, conditioned) of papers (Figure 6). There was no significant contribution of enzyme applications indicated on the CMT-strength of

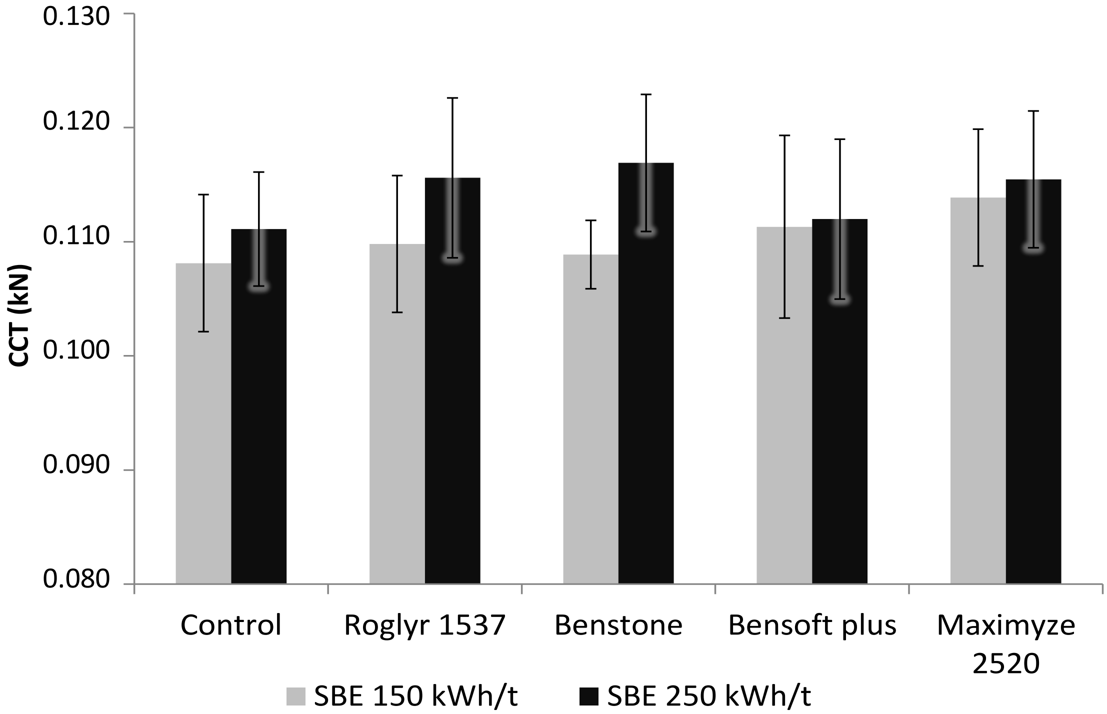

Figure 7. Concora crush resistance of papers according to the applied enzyme and SBE.

paper, but positive effect on drainage properties will result to higher speed of the paper machine.

The box compression test (BCT) is the most important property determining carrying capacity of the corrugated-board box, which can be predicted from edge crush strength test (ECT). The compression strength of liners and corrugated medium contribute to the ECT of the corrugated-board. The compression strength of fluting medium is determined by corrugated crush test (CCT). Different enzymes have different effect on the CCT-strength of paper, Roglyr 1537 and Benstone is more effective at low SBE, while the Bensoft plus and Maximyze 2520 at high SBE (Figure 7). Short span compression test (SCT) is intended to measure the pure compressive strength unaffected by other properties. The SCT has begun to replace the CMT-method more and more (Markström, 2005). SCT results of the paper component should correlate better to the ECT of the corrugated board (Dimitrov, 2010).

CCT compressive strength can be affected by moulding and heating of papers with different grammage, during corrugating in a laboratory corrugators; while, the SCT method gives a constant compression index independent of the grammage (Markström, 2005). The SCT-strength of paper is not affected more by beating alone, though after all the enzyme applications, a significant increase of SCT was determined (Figure 8) and reached 20.53% for Maximyze 2520. In all aspects, the enzymatic applications have a positive effect while the Maximyze 2520 is the most balanced enzyme used in the study. The application of SBE over optimal condition increased the most of strength properties of papers, in addition the change of drainage properties of blended pulps were not at unacceptable levels.

Conclusion

Application of beating stage, only for the long fiber fraction in the corrugated medium production process, increases common strength properties of paper. The cellulose pre-treatment of this long fiber fraction contribute to the additional strength improvement of the paper. However, prolonged enzymatic treatment may cause a negative or low effect on some strength properties of paper. Different industrial cellulase has an unequal effect on certain strength properties of corrugated medium; therefore the most suitable one must be determined for a specific situation and a specific strength property. Application of enzyme only on the long fiber fraction will contribute to reduction of enzyme consumption and energy. Furthermore, it will prevent the mass loss of short fiber fraction and decrease the dissolved organic compounds in process water.

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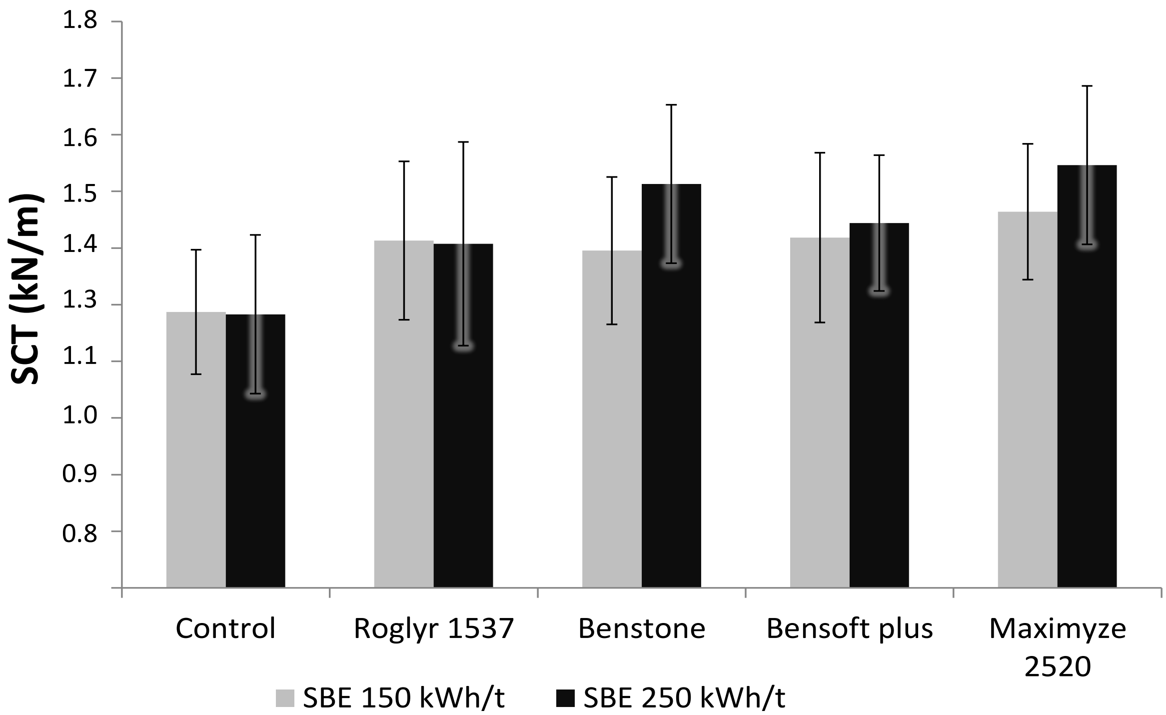

Figure 8. Short span strengths of papers according to the applied enzyme and SBE.

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