

Properties of Composites of Unbeaten Birch and Pine Sulphate Pulps with Bacterial Cellulose

Abstract

The possibility of modifying the structure and properties of fibrous papermaking pulps with bacterial cellulose was investigated. For this purpose, three ways of obtaining specific composites were developed. The first one consisted in making the biosynthesis of bacterial cellulose in *Acetobacter xylinum* culture in the presence of fibres of papermaking semi-products; the second one involved the addition of suitably disintegrated bacterial cellulose film to different papermaking pulps; and the third one consisted of joining semi-product paper sheets with bacterial cellulose film by putting the bacterial cellulose film on a sheet of paper and drying it in laboratory apparatus of the Rapid-Koethen type. The most important structural and strength properties of fibrous semi-products and their composites with bacterial cellulose were determined and compared. It was observed, among others, that composites produced according to the first two methods (i.e. in *acetobakter xylinum* culture and as a result of the addition of bacterial cellulose to a fibrous semi-product) in general show higher static and dynamic strength indices than semi-products used for composite production. The joining of sheets of two kinds of cellulose (i.e. fibrous semi-product and bacterial cellulose) gives a two-layered composite characterised above all by higher static strength properties than unbeaten pulps and, at the same time, a higher tear resistance in comparison with bacterial cellulose. Joining bacterial cellulose with pulp fibres, irrespective of the joining method, increases the apparent density of the semi-product.

Key words: sulphate pulps, bacterial cellulose, composites, breaking length, tear resistance, apparent density.

Introduction

In these times of intensified development of many industrial branches in Poland, papermaking as a source of packaging, sanitary and graphic means has great development possibilities. To meet the growing demand for papermaking products, including those that have unique properties, new raw materials and semi-products are sought which could be added to paper furnish instead of the classic papermaking semi-products. Due to its properties, bacterial cellulose is very interesting for papermaking, including chemical purity and compatibility with wood cellulose.

At the Institute of Papermaking and Printing, research was undertaken to elaborate

a way of modifying different papermaking semi-products with bacterial cellulose and to determine the properties of the composites obtained [1, 2].

Aim and range of the research

The aim of this work was the production and examination of the structural and strength properties of three different composites of unbeaten, bleached birch and pine sulphate pulps with bacterial cellulose.

Experimental

Three ways of making of composites of industrial bleached pulps with bacterial cellulose were elaborated. The first one

consisted in conducting *Acetobacter xylinum* culture, in which bacterial cellulose is synthesised, suspended in fibres, and then the material obtained is disintegrated, forming a composite sheet on the Rapid-Koethen apparatus. The biosynthesis of the bacterial cellulose was conducted at 30 °C within 7 days using glucose as a carbon source and using a Herstin-Schramm nutrient medium, according to the procedure described earlier [3].

The second type of composite was made adding the suitably disintegrated film of bacterial cellulose to the suspension of pulp fibres, forming a sheet, and then drying it on the Rapid-Koethen apparatus.

In this way composites with a share of bacterial cellulose of 2.5, 5, 10 and 15 wt. % were produced. In order to compare the properties of pulp and composite sheets of comparable basis weight, the bacterial cellulose was added to the suspension of fibre suspension which corresponded to the assumed weight share of bacterial cellulose in the composite.

The third type of composite was obtained by putting the bacterial cellulose film on a sheet produced from pure birch or pine pulps, and then pressing and drying it on the Rapid-Koethen apparatus. The weighted proportion of bacterial cellulose in such composites was 30 wt. %.

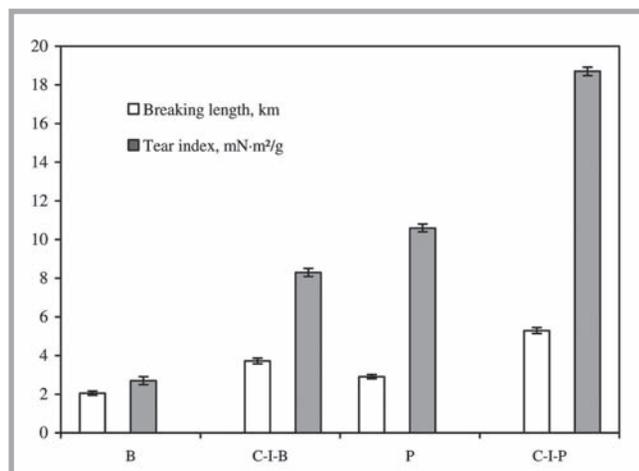


Figure 1. Comparison of strength properties of pure bleached, unbeaten sulphate pulps and the type I composite of these pulps with bacterial cellulose. B – birch pulp, C-I-B – composite of birch pulp with bacterial cellulose, P – pine pulp, C-I-P – composite of pine pulp with bacterial cellulose.

Measurements of apparent density and strength properties of the pulps and composites were performed according to methods commonly used in papermaking [4]. The average standard deviation of the measurements of these indices is given in the Figures.

Results and discussion

The composite obtained from the biosynthesis of the bacterial cellulose, carried out in the presence of pulp fibres, was produced and investigated as the first one. In **Figure 1** (see page 127) the most important strength properties of this composite were compared with the properties of pure pulps.

Figure 1 shows that type I composite of unbeaten birch pulp with bacterial cellulose (C-I-B), when compared to pure birch pulp, is characterised by an approximately 80% rel. higher breaking length and by an approximately threefold higher tear index, while the composite of unbeaten pine pulp with bacterial cellulose (C-I-P) showed

76-82% rel. higher values for both the breaking length and tear resistance.

In the next part of this work, composite sheets with the addition of bacterial cellulose to the bleached pulp were produced and tested. These materials were obtained as a result of the replacement of part of the wood fibres with the same amount (by weight) of suitably disintegrated film of bacterial cellulose. These composites were marked as type II. They were characterised by an increased share of bacterial cellulose in the sheets (2.5, 5, 10, and 15 wt. %).

Similarly, as in the case of composites of type I, the properties of composites of type II were determined and compared with the properties of pure birch and pine pulps. The results obtained are illustrated in **Figures 2** and **3**.

As is shown in **Figures 2** and **3**, the composite sheets of bleached, unbeaten birch and pine pulp with bacterial cellulose produced according to procedure II, in comparison to pure birch and pine pulps,

were characterised by a higher breaking length and tear index. As regards the share of bacterial cellulose in the sheets within the range of 2.5-15 wt. %, the improvement in the breaking length of the semi-product was 8-47% rel., while the tear index equalled 7-33% rel. As far as the pine semi-product is concerned, according to **Figure 3**, the changes in the indices studied were similar, because the breaking length of the composite of pine pulp with bacterial cellulose was higher than pure pine pulp by 3-28% rel., while for the tear index it was by 3-16% rel. Thus, this way of producing composites of bleached pulp with bacterial cellulose gives lower improvement of semi-product properties than carrying out the biosynthesis of bacterial cellulose in the presence of cellulose fibres.

The third type of composite of bleached pulp and bacterial cellulose (C-III or sandwich) was obtained as a result of the combination of a pulp sheet with a film of bacterial cellulose by putting the former on the surface of the latter, then

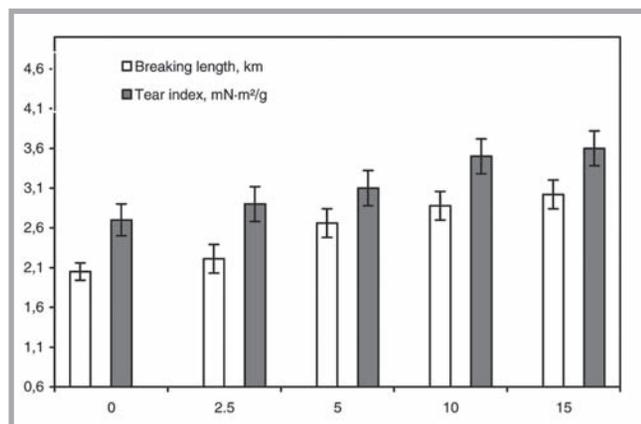


Figure 2. Comparison of strength properties of birch pulp-bacterial cellulose composite of type II (C-II-B) with the properties of pure birch pulp.

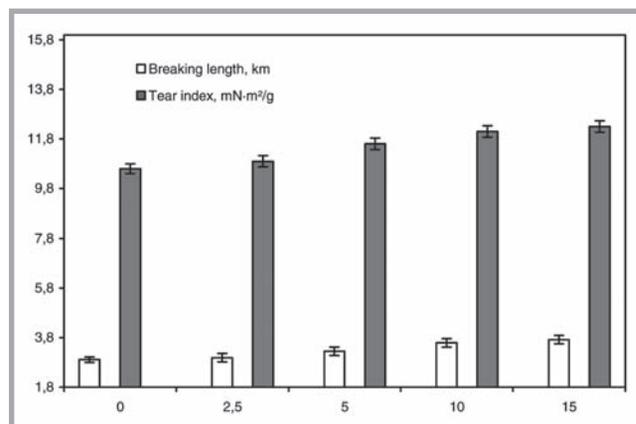


Figure 3. Comparison of strength properties of pine pulp-bacterial cellulose composite of type II (C-II-P) with the properties of pure pine pulp.

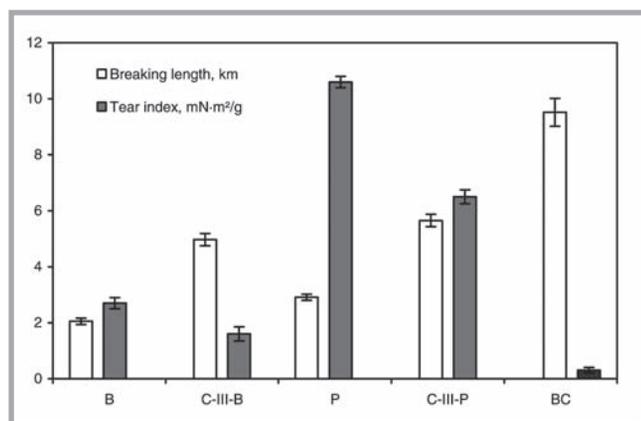


Figure 4. Comparison of the strength properties of birch and pine pulp-bacterial cellulose composites of type III (C-III-B and C-III-P) with the properties of pure birch, pine pulps and bacterial cellulose.

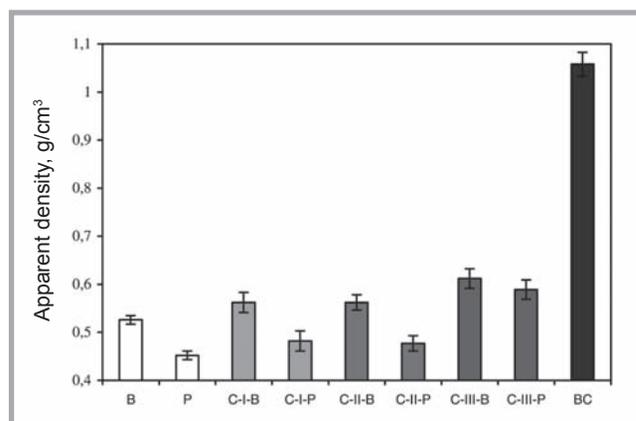


Figure 5. Effect of different types of joining fibrous cellulose with bacterial cellulose on the apparent density of the semi-product.

pressing them and drying them on the Rapid-Koethen apparatus. Comparison of the breaking length and tear index of this type of composite with the properties of pure birch and pine pulp is illustrated in **Figure 4**.

The above data show that the sheets of type III composite (C-III) have a higher breaking length in comparison to pure birch and pine pulps by 142 and 94% rel., respectively. However, their tear index was lower by 39-41% rel. This corresponds to the properties of bacterial cellulose which in dry conditions showed a low tear index and high breaking length.

In addition to strength properties, the effect of joining cellulose fibres with bacterial cellulose on one of the most important structural properties, i.e. the apparent density, was studied. The results of the test of three types of composites studied as well as the density values of pure pulps and bacterial cellulose are presented in **Figure 5**.

As is shown in this Figure, joining fibrous cellulose with bacterial cellulose increases the apparent sheet density. In the case of composites produced in *Acetobacter xylinum* bacterial culture, carried out in the presence of fibres and obtained as a result of the addition of bacterial cellulose to the suspension of pulp fibres, in which the content of bacterial cellulose was 10 wt. %, the increase in the density of the sheets was similar to approximately 6% rel. The highest increase in apparent density exists in composites of type III, produced as a result of putting the bacterial cellulose film on the surface of the pulp sheet. For these composites the increase in density, in comparison to the density of pure birch pulps, was approximately 14% rel. (for composite C-III-B) and approximately 23% rel. (for composite C-III-P). However, it should be taken into account that in this case the share of the bacterial cellulose in this type of composite was higher than in the case of composites of type I and II, being approx. 30 wt. %.

Conclusions

1. Composites of unbeaten, bleached birch, pine pulp and bacterial cellulose of type I, obtained as a result of producing *Acetobacter xylinum* culture in the presence of fibres of these pulps, are characterised by an approximately 80% rel. higher breaking length in comparison to pure birch and pine pulps and by

a higher tear index of approximately 200 and 76% rel., respectively.

2. Improvement of the breaking length and tear index of unbeaten birch and pine pulp sheets can also be obtained by the replacement of some parts of cellulose fibres with bacterial cellulose. At a 2.5-15 wt. % share of the bacterial cellulose in the sheet, the improvement in the breaking length and tear index of the unbeaten semi-product containing birch pulp was 8-47% rel. and 7-33% rel. respectively, while in the case of the semi-product containing pine pulps as the main constituent, it was 3-28% rel. and 3-16% rel.
3. The third type of pulp and bacterial cellulose composite (the composite of type III or *sandwich*), which was produced by joining pulps sheets and bacterial cellulose film, was characterised in comparison with pure birch and pine pulps by an approx. 142 and 94% rel. higher breaking length, respectively. However its tear index was lower by approx. 39-41% rel. This corresponds to the properties of bacterial cellulose, which in dry conditions showed a low tear index and high breaking length.
4. Joining bacterial cellulose with pulps fibres, irrespective of the joining method, increases the apparent density of the semi-product obtained, which is related to the higher apparent density of pure bacterial cellulose.

Acknowledgment

This research were financially supported by the Polish Ministry of Science and Higher Education as a part of Research Project No. 3 T08E 060 29.

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Received 21.03.2008 Reviewed 14.10.2008

19th IUPAC INTERNATIONAL SYMPOSIUM 2009 on IONIC POLYMERISATION

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