

Effect of chitosan substance on the mechanical properties of paper obtained on the basis of flax cellulose

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Abstract. Chitosan occurs in different molecular weights and degrees of deacetylation. Molecular weight and degree of deacetylation are the main factors affecting particle size, particle formation and aggregation. The use of chitosan improved the dry strength of the paper, especially by adding 1% low molecular weight chitosan. But the increase in concentration reduced its dry strength. This can be explained as follows. The connection must correspond to the distance between the segments between the fibers, because they form an inter-fiber connection area. Even if the water molecule is separated from the organic bond with the fibers or not, a large amount of water destroys the bond state of the paper. These factors are important in the paper industry. Paper-like materials were obtained on the basis of cellulose obtained from the stem of the flax plant. The effect of fibers and adhesives in the composition on the quality indicators of the obtained paper was considered. The effects of chitosan and starch glue were compared. It can be explained that the hydrogen bond on the fiber surface is mainly monopolized by the water molecule, because the fiber forms a macroscopic liquid bridge. The weakness of this bridge indicates the wet tensile strength of the paper.

1 Introduction

Chitosan occurs in different molecular weights and degrees of deacetylation. Molecular weight and degree of deacetylation are the main factors affecting particle size, particle formation and aggregation [1-3]. These factors are important in the paper industry. To improve paper properties, chitosan is added to paper and used to improve its derivatives. In both cases, chitosan mainly improves the strength of paper sheets [3-5]. By using chitosan and its derivatives in the paper industry, a number of quality indicators have been improved. In particular, it has been shown to improve the strength properties of aged paper sheets [6]. When chitosan and its derivatives were added to the cellulose mass, the breaking length of the obtained fibers increased several times [7-9]. On the other hand, when the paper was immersed in the solutions of chitosan and its derivatives, the opposite tendency

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to the tear factor was observed. Overall, it has been shown that the mechanical properties are improved by using chitosan in papermaking [10, 11]. Chitosan and its derivatives also improve electrical, printing, barrier and antibacterial properties of paper [5-7, 10-12].

Nowadays, paper and paper products are used in many cases for packaging various items and products. Therefore, it is important today to obtain papers with high dry and wet strength, low water absorption and high tear resistance properties [13].

2. Materials and Methods

The purpose of the work is to study the effect of chitosan with different molecular weight on the quality indicators by introducing it into the paper. First, chitosan of two different molecular weights was analyzed by identifying quality indicators [1-4].

Chitosan samples (low molecular weight and medium molecular weight) were characterized for their ash content, molecular weight and degree of deacetylation for paper production. It was known from the previous experiments that the higher the degree of diacetylation of chitosan, the faster it will react. Taking this into account, the chitosan diacetylation level of 95% was selected for the experiment. During the research, samples were obtained by adding low molecular weight and medium molecular weight chitosan to the paper pulp. Paper samples were obtained on the basis of cotton wool and basalt fiber. 1% and 2% solution of chitosan was used.

3. Results and Discussion.

The purpose of the work is to study the effect of chitosan with different molecular weight on the quality indicators by introducing it into the paper. First, chitosan of two different molecular weights was analyzed by identifying quality indicators. The results are presented in the table below (Table 1).

Table 1. Quality indicators of chitosan of two different molecular weights.

#	A type of chitosan	Quality indicators					
		Color	The smell	Degree of deacetylation	Moisture %	Ash content %, (550 ⁰ C)	Molecular weight (g/mol)
1	Low molecular weight chitosan	colorless	odorless	95	7.5-8.5	±1	0.85
2	Medium molecular weight chitosan				5.5-6.5	±3	2.45

For the research, samples were taken by traditional paper making method by adding low molecular weight and medium molecular weight chitosan to the paper pulp. Paper samples were obtained on the basis of cotton wool and basalt fiber. The dosage of all chitosan solutions on the surface of the wrapping paper was kept constant around $1.0 \pm 0.2 \text{ g/m}^2$. The viscosities of chitosan solutions with different degrees of deacetylation were different at $30 \pm 1 \text{ }^\circ\text{C}$. After surface application of chitosan, the wrapping paper was dried in an oven at $103 \pm 2 \text{ }^\circ\text{C}$ for 120 s. After oven drying, all surface-treated papers were homogenized according to ISO: 187 for 24 hours at $27 \pm 2 \text{ }^\circ\text{C}$ and $65 \pm 5 \text{ \%}$ relative humidity.

A number of important quality indicators such as grammage, roughness, hardness, water absorption of paper samples were studied and analyzed. The results are presented in the following tables (Tables 2 and 3).

Table 2. The result of paper treated with low molecular weight chitosan (Grammage 100 g/m²).

#	Variation (variety)		Volume (mL/min)	Hardness (mNm)	Water absorbency (g/m ²)
	Filler % (basalt fiber)	Chitosan (%)			
1	-	1	240	0.32	18.49
2		2	305	0.42	17.80
3	25	1	255	0.38	15.44
4		2	315	0.49	16.74
5	35	1	295	0.41	13.99
6		2	335	0.52	15.01

The analysis of Table 2 above showed that the paper with a concentration of 1% chitosan and basalt fiber can reduce the water absorption rate from about 18.49 to 15.44% compared to other samples. A better result was achieved in the sample treated with chitosan 1% and 35% basalt fiber, which in turn had a negative effect on other quality indicators. However, the increase in chitosan concentration (2%), in turn, decreased the water absorption, but also increased the roughness and hardness of the paper sample. Exceeding these two indicators (roundness, hardness) does not meet the requirements for wrapping paper.

Table 3. Result of medium molecular weight chitosan treated paper (Grammage 100 g/m²).

№	Variation (variety)		Volume (mL/min)	Hardness (mNm)	Water absorbency (g/m ²)
	Filler % (basalt fiber)	Chitosan (%)			
1	-	1	288	0.40	21.69
2		2	325	0.42	19.11
3	25	1	300	0.42	18.90
4		2	325	0.49	22.58
5	35	1	320	0.45	16.55
6		2	345	0.57	18.74

The analysis of Table 3 above showed that the paper with a concentration of 1% chitosan and basalt fiber can reduce the water absorption rate from about 21.69 to 18.90 % compared to other samples. A better result was obtained in the sample treated with chitosan 1% and 35% basalt fiber, which in turn had a negative effect on other quality indicators. However, the increase in chitosan concentration (2%), in turn, decreased the water absorption, but also increased the roughness and hardness of the paper sample. Exceeding these two indicators (roundness, hardness) does not meet the requirements for wrapping paper. Summarizing the analyzed tables 2, 3, it was found that the samples containing 1% chitosan with low molecular weight and 25% basalt fiber were the most optimal option.

Table 4. Strength and elasticity of paper (Grammage 100 g/m²).

#	Variation (variety)		Tensile strength (kN/m)	Elasticity (%)	Tensile strength of paper (Nm/g)
	Filler % (basalt fiber)	Filler % (basalt fiber)			
Lower molecular mass (weight)					
1	-	1	4.8	4.2	60.07
2		2	3.5	3.7	43.26
3	25	1	3.5	3.2	39.26
4		2	3.0	3.8	51.98
5	35	1	4.6	4.2	56.86
6		2	3.8	3.4	42.98
Average molecular mass (weight)					
1	-	1	4.3	2.8	51.78
2		2	4.2	3.2	47.85
3	25	1	4.5	3.3	53.97
4		2	4.1	3.1	48.27
5	35	1	4.8	3.5	60.30
6		2	4.6	3.1	59.39

The hardness of the resulting paper was also checked according to the direction of the formation of the paper. Figure 4 below shows the change in hardness when surface treated with chitosan with different degrees of deacetylation in both directions i.e. machine direction (MY)/cross direction (KY).

The use of chitosan improved the dry strength of the paper, especially by adding 1% low molecular weight chitosan. But the increase in concentration reduced its dry strength. This can be explained as follows. The connection must correspond to the distance between the segments between the fibers, because they form an inter-fiber connection area. Even if the water molecule is separated from the organic bond with the fibers or not, a large amount of water destroys the bond state of the paper. It can be explained that the hydrogen bond on the fiber surface is mainly monopolized by the water molecule, because the fiber forms a macroscopic liquid bridge. The weakness of this bridge indicates the wet tensile strength of the paper.

4 Conclusion

In conclusion to this research work, it was found that low molecular weight chitosan was more effective than medium molecular weight chitosan in all cases of using chitosan in the papermaking process. In addition, it was found that chitosan is absorbed by almost all cellulose fibers, especially in the low-concentration variety of cellulose systems used in industry. As the degree of deacetylation (DD) increases, its absorption increases.

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