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THE EFFECT OF CHITOSAN ON THE SURFACE PROPERTIES OF CELLULOSE-BASED PAPER OBTAINED FROM THE STEM OF FLAXSEED

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Abstract: *This paper examines the effects of chitosan, starch, and polyvinyl alcohol (PVA) to improve the surface properties of cellulose-based paper obtained from local raw materials. The polymers are incorporated into the paper polythene by spraying. The results showed that the addition of chitosan to paper polythene, which is made of cellulose fibers, has an improvement in surface properties compared to the effect of other additives. The degree of exposure of starch coincided with the degree of exposure of chitosan, but it resulted in a decrease in the water absorption potential of the paper compared to chitosan at the same concentration. In many other properties, especially the most important feature for printing paper, surface smoothness, chitosan-affected papers are superior to starch or PVA-affected paper.*

Keywords: *cellulose; paper; chitosan; surface properties; polymer; starch; polyvinyl alcohol.*

INTRODUCTION. It should be noted that the production of quality paper requires additional pre-treatment of cellulose. One of the most sought after papers today is the foundation paper. The first requirement for this type of paper is that the surface is smooth and durable. To improve these properties, of course, involves the introduction of various chemical additives. The addition of polymers starch and polyvinyl alcohol (PVA) to the paper to improve the surface properties gives a positive result. These polymers bind well to fiber surfaces and are able to increase the distance between fibers and thus establish other unformed bonds between fibers and fibers.

Typically, many synthetic chemical additives are used in the paper industry to improve paper strength and printing. Some of these synthetic additives are not biodegradable and can cause environmental problems, and some pose a risk to occupational health and safety for paper industry workers. Many of the problems that can occur as a result of the use of synthetic chemical additives can be overcome with the help of biopolymers. Many biopolymers are more biodegradable, non-toxic, and environmentally friendly than their synthetic counterparts, so there is a tendency to use these materials as much as possible in paper production. Chitosan is a chemically modified biopolymer (derived from the shells of some crustaceans) that has been shown to have the potential to improve the strength and printing properties of paper based on annual plant fibers.

No studies have been published on the use of chitosan to improve the surface properties of paper made from flaxseed cellulose. This paper discusses laboratory work to study the surface properties of chitosan when applied to paper made from cellulose based on an annual plant, i.e. flaxseed. In order to determine the effect of chitosan, it was compared with the most widely used agent to date - polyvinyl alcohol (PVA) and starch, which discusses the advantages and disadvantages of chitosan as a surface improvement agent.

MATERIAL AND METHODS. Materials used for the experiment.Bleached flaxseed cellulose was used after grinding to 46 ShR. A chitosan with a molecular weight of 9–105 daltons and a high molecular weight of 85% deacetylation was used. In this study, fully hydrolyzed (98%) PVA with corn starch with an exchange rate of 0.035 and a molecular weight of 0.43–105 daltons was used for comparison. In this study, a chitosan solution was prepared by mixing 1% acetic acid at room temperature for 6 h. The pH of the process medium is 5. PVC is prepared by dissolving in distilled water in hot water with a magnetic stirrer at 95-1000C for 20-25 minutes.

The starch powder was prepared by suspending in distilled water, stirring occasionally, heating in a water bath to 950C and keeping the suspension at this temperature for 25-30 minutes after gelatinization had begun. The solutions are then diluted with distilled water and cooled before use. After the different dosage solutions of the polymers are removed from the paper mesh table, they are sprayed on a pre-prepared (untreated) damp paper surface.

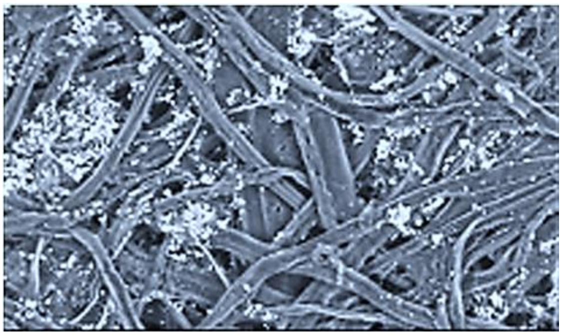
At this time, the paper will have a moisture content of 70%. The advantage of spraying polymers in such a wet state is that the sprayed substances allow fast and uniform distribution within the wet fiber network. Determining the surface properties of paper. The surface properties of the papers were determined according to TAPPI test methods [6] and TAPPI useful methods [7]. The brightness of the paper canvas was measured using a Technibrite Micro TB-1 instrument.

The roughness was measured using Bendtsen as per T 535 um-91. The air resistance of the paper was determined by the Gurley method. The water absorption capacity of the paper was determined using the Cobb Test, T 441 om- 98. Surface oil absorption rate was determined using Dutch Standard NEN 1836 using an IGT printability tester, model AIC2-5. The surface strength of the sized paper was determined using Dennison wax pick test according to T459 om-99. Film-forming properties of polymer-sized papers scanning electron microscope (SEM, model JSM-6400, Jeol). studied in a 10–30 sample area using. The storage of chitosan on paper was analyzed using the Kjeldahl method. The option to improve the smoothness of laboratory-prepared papers by calendering was tested for only the smooth (glazed) side surface properties of each laboratory-prepared sample.

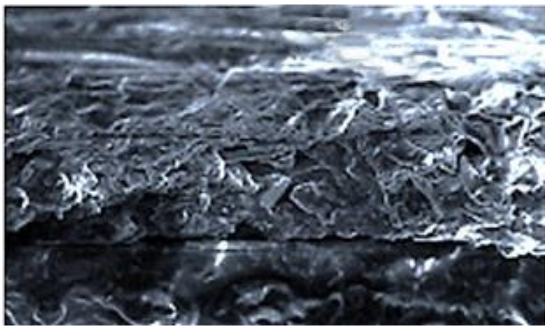
RESULTS AND DISCUSSION. The effect of chitosan addition on the surface properties of paper. One of the properties of chitosan is its ability to form films that improve the surface properties of the paper when applied to the surface of the sheet. At the beginning of this study, it was considered that its ability to form a film should be affected by concentration or addition techniques. Chitosan was prepared in solutions of different concentrations and applied to the papers in constant volumes.

The film-forming properties of the papers were then tested using SEM. Figure 1 shows the film-forming potential of chitosan when using spraying techniques at concentrations of 0.5–2%. At a concentration of 0.5%, chitosan could not form any film on the surface of the paper. At lower concentrations, chitosan is assumed to pass into the paper mass due to its lower viscosity. However, at a concentration of 1% or higher, chitosan was able to form a film on the surface of the paper. Comparison of the control paper with a chitosan-sized paper shows that the chitosan concentration affects its ability to form a film. The high chitosan concentration leads to the formation of a good film due to the high viscosity of its aqueous solutions.

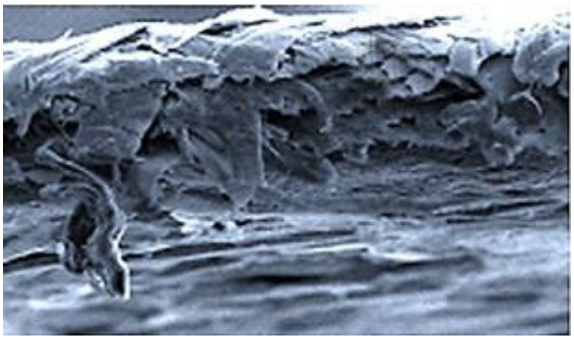
Table 1 shows the properties of paper sized with chitosan. Brightness and transparency are very important parameters for paper printing. The addition of chitosan slightly decreased brightness (0.5–1%) and increased transparency, but the changes were not significant



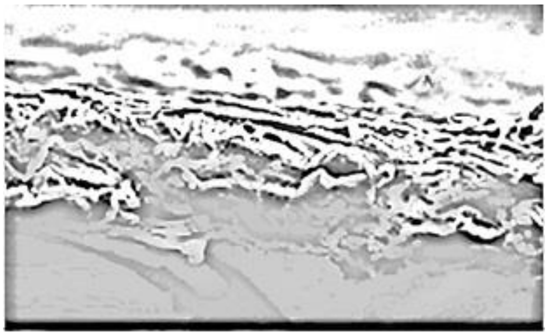
Paper with 1.0% chitosan added



Paper with 1.5% chitosan added



Paper with 2.0% chitosan added



Paper with 2.5% chitosan added.

Fig. 1. The potential of chitosan to form a film on the paper surface at different concentrations

One of the most important among the many properties of paper is its ability to control the ingress of various liquids, especially water-based liquids. When the concentration of chitosan (0.5-1%) was added to the paper mass, the water absorption index of the paper failed, i.e. the water entered the paper very quickly.

However, observations suggest that high concentrations of chitosan (more than 1%) may reduce the water absorption (30–35%) of the sized paper. Decreased water absorption can improve the printing ability of the paper. One of the most important factors influencing the absorption of ink media is porosity. Ink media are attracted to the holes and intercellular spaces of the paper by capillary action. Due to the lower porosity of the coated paper coatings (because the paper is less porous, the air resistance index increases when measured by the Gurley method), it provides higher and better managed ink retention than uncoated paper. The air resistance of paper treated with 2% chitosan increased by about 40-45%. If the air resistance shows porosity, this result indicates that the number of pores on the paper or their size has decreased. Transparency of paper is generally considered to be one of the features that affect the printing of paper. Table 1 shows that the transparency of papers treated with chitosan is significantly reduced compared to those treated with chitosan, and the improvement is greater than that achieved with PVA or corn starch. The corresponding increase in smoothness is probably due to the continuous film on the paper surface of 2% chitosan size. Table 1 shows that the addition of chitosan to the cellulose mass showed that the paper obtained did not absorb oil. Paper treated with chitosan gives a high oil-absorbent stain length, which is consistent with its high transparency.

The addition of chitosan reduced the oil absorption of the cellulose-based paper obtained from the stem of the flax plant by about 14-15%, which is more than PVA or corn starch. Decreased oil absorption is recommended for paper storage and packaging of food products. The data are well consistent with the air resistance results. Also, the film-forming polymers laminate the gaps in the paper fiber network, resulting in a decrease in the porosity of the paper and the absorption of oil. The data show that the concentration of the applied chitosan solution actually affects the film-forming properties and other surface properties of the paper obtained on the basis of flax cellulose. Another important parameter that should affect the chitosan concentration is the measurement obtained during the measurement process.

Table 1.

Influence of chitosan on the surface properties of paper obtained on the basis of flax plant cellulose

The concentration of chitosan to which the paper composition is added	Paper quality indicators						
	ISO brightness (%)	Transparency (%)	Bendtsen (mL/min)	Air resistance (s/100 mL of air)	Water absorption (g/m2)	Surface consistency	Length of oil stain (mm)
0.5	88.6	82.8	64.4	850	-	13A	77
1.0	89.0	83.3	39.5	880	20.5	14A	73
1.5	88.2	84.5	35.4	924	30.0	15A	70
2.0	87.8	90.7	29.6	1049	31.4	15A	70
2.5	86.3	91.2	27.5	1160	33.6	16A	71.5
3.0	85.8	91.8	26.2	1200	35.2	16A	71.9
Sample without chitosan	88.5	82.8	57	740	-	12A	80

This is expected to occur due to the correlation of chitosan concentration with viscosity, which in turn is expected to affect the volume collection volume. While starch and PVA have low viscosity and can pass quickly into fibers, chitosan is very sticky and can stay on the surface of the paper longer during drying, so chitosan uptake can be relatively low and helps to form a film. The effect of starch addition on the surface properties of paper. Typically, paper mass starch is widely used in the paper industry due to its good strength, stability, and strong bonding with cellulose fibers. Examination of the samples under an electron microscope showed that SEM starch was similar to PVC in the 0.5-1.5% concentration range.

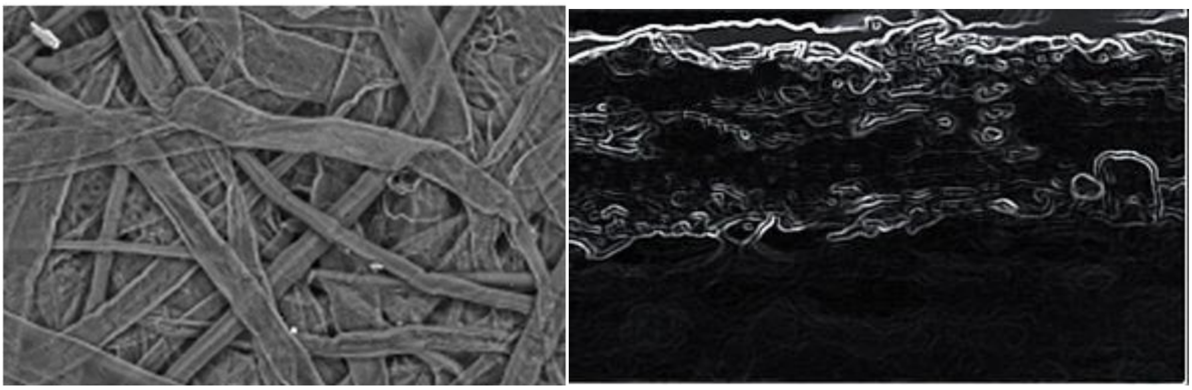


Fig. 2. The potential of corn starch to form a film on the surface of the paper at different concentrations.

However, at a concentration of 2%, unlike PVC, it formed a flat film on the surface of the paper (Fig. 2). Table 2 shows that starch significantly altered all paper properties. For example, at a concentration of 2%, the surface strength and water absorption resistance were greatly increased by paper sized with 2% chitosan or 2% PVC. The surface transparency of the paper treated with 2% starch was 20% higher than the transparency of the paper treated with PVC. On average, the air resistance was also higher for starch paper than for PVC-sized paper. The surface strength of starch paper was higher for all concentrations than that of PVC and chitosan paper

From a practical point of view, the surface properties of starch paper at a concentration of 2% were basically the same as those of chitosan-sized paper at a concentration of 2%, with the exception of water absorption resistance of 6-7% higher.

Table 2

Influence of starch on the surface properties of paper obtained on the basis of flax plant cellulose

Concentration of starch to which the paper composition is added	Paper quality indicators						
	ISO brightness (%)	Transparency (%)	Bendtsen (mL/min)	Air resistance (s/100 mL of air)	Water absorption (g/m2)	Surface consistency	Length of oil stain (mm)
0.5	87.8	81.2	66	872	25.9	14A	82
1.0	88.3	80.3	81	889	23.8	16A	80
1.5	88.8	80.5	100	895	23.1	16A	79
2.0	88.6	79.4	107	955	21.9	18A	78
2.5	89.6	78.6	110	1000	20.4	17A	77
3.0	88.9	77.1	115	1010	19.9	17A	75
A sample without starch	87.4	55	55	740	-	12A	81

Adsorption of starch and cationic polymers in general is influenced by a wide range of factors. These include fiber factors such as surface area and surface charge; provides polymer factors such as charge density, molecular weight and conformation, and factors such as pH, ionic strength, temperature, anion, and so on. All of these factors somehow affect the level of electrostatic attraction and therefore the adsorption of starch. The main driving force of adsorption of cationic polymers on paper fibers is electrostatic attraction. The adsorption mechanism is generally thought of as an ionic bond between the carboxyl groups of the fiber and the cation groups of the polymer. However, some researchers have debated this hypothesis without finding any relationship between the carboxyl content and adsorption levels in the fibers. Other adsorption forces, such as H-bonding, also work in the starch state.

The effect of PVA addition on the surface properties of the paper**.** PVA is a chemical reagent with excellent bonding strength and the ability to increase brightness. The amount of PVA nig did not form a film at a concentration of up to 2% of the paper mass. As mentioned above, PVA has low viscosity and penetrates quickly into paper fibers. PVA was observed to not form a film at a concentration of 2%, but to form a flat film at a concentration of 10-15%. paper surface. The air resistance of papers at 0.5% and 1% concentrations was almost 5–15% lower than control (Table 3). This contradicts our previous observation on chitosan-treated papers, as much of the PVA has penetrated the fibers and has not reduced the size of the holes in the paper mesh. Transparency increased to about 30-35% at 2% concentration.

It showed no change in water absorption resistance compared to the sample treated with PVA. The highwater absorption of PVC-coated paper is a practical drawback. The surface strength of PVA-coated papers (measured by wax selection) was slightly increased, but to a much smaller extent than that of parch-coated papers. From a practical point of view, the surface properties of PVS-coated paper were slightly lower than those of chitosan or starch-coated paper. The results show that PVA cannot significantly improve many surface properties, particularly water absorption, air resistance, smoothness, and transparency.

Table 3

Influence of PVA on the surface properties of paper obtained on the basis of flax plant cellulose

Concentration of PVA to which the paper composition is added	Paper quality indicators						
	ISO brightness (%)	Transparency (%)	Bendtsen (mL/min)	Air resistance (s/100 mL of air)	Water absorption (g/m2)	Surface consistency	Length of oil stain (mm)
0.5	88.1	81.1	52	640	-	12A	79
1.0	89.2	80.2	47	682	-	13A	78
1.5	90.5	79.3	42	797	-	13A	78
2.0	90.6	78.4	45	875	-	14A	77
2.5	91.2	77.6	45	890	-	13A	75
3.0	92.8	76.9	45	905	-	13A	75
Sample without PVA added	88.3	82.0	55	730	-	12A	79

Cellulose and chitosan are very, very compatible fiber-binding systems. Because of their chemical similarity, they form a hydrogen bond with each other. The difficulty of achieving the required geometry (i.e., a separation of less than 0.1 nm) required for hydrogen bonding between solid surfaces is known from the literature. The study concludes that the formation of a film between the intersections of the fibers by the polymers can overcome this problem and lead to strong bonds by “welding” the surfaces together. The hydroxyl groups of chitosan have the potential to form hydrogen bonds with weak polar areas of the fiber surface, so if the fibers are close enough to meet the required geometry conditions, they contribute to increasing the strength of the paper. Therefore, the film-forming potential of chitosan not only facilitates the formation of Van-Der-Vaals forces between the fibers, but also provides favorable conditions for the formation of hydrogen bonds.

CONCLUSION. The aim of this study was to improve the surface properties of the paper obtained on the basis of flax plant cellulose using polymer additives, in particular the natural polymer chitosan. Using a chitosan spray dissolved in acetic acid, it was applied to the paper canvas. It was found that the film formation of these three polymers on the surface of fibrous networks is different. When comparing chitosan, starch and

PVC at the same concentration, chitosan sprayed papers showed the best surface properties except water resistance.

The most probable reason for the high performance of chitosan is its ability to electrostatically (ionically) bond with fibers, anion charges of networks, as well as the high viscosity of aqueous solutions. The general conclusion is that chitosan is recommended as an additive in traditional surface sizes to improve the surface properties for printing flax plant cellulose-based paper.

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