UNION OF ENGINEERS AND TEXTILE TECHNICIANS OF SERBIA

UNION OF ENGINEERS AND TECHNICIANS OF SERBIA
FACULTY OF TECHNOLOGY AND METALLURGY IN BELGRADE
FACULTY OF TECHNOLOGY IN LESKOVAC

On the occasion of celebrating
150 years of the Union of Engineers and Technicians of Serbia
65 years of the Union of Engineers and Textile Technicians of Serbia
65 years of continual publishing of the *Tekstilna industrija* journal

INTERNATIONAL SCIENTIFIC CONFERENCE

CONTEMPORARY TRENDS AND INNOVATIONS IN THE TEXTILE INDUSTRY

NAUČNA KONFERENCIJA SA MEĐUNARODNIM UČEŠĆEM

SAVREMENI TRENDOVI I INOVACIJE U TEKSTILNOJ INDUSTRIJI

PROCEEDINGS

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ORGANIZING COMMITTEE

Conference Contemporary Trends and Innovations in the Textile Industry

Confrerence is financially supported by The Ministry of Education, Science and Technological Development of the Republic of Serbia

UNION OF ENGINEERS AND TEXTILE TECHNICIANS OF SERBIA

PREFACE

The international conference Contemporary Trends and Innovations in the Textile Industry is coorganized by the Union of Engineers and Textile Technicians of Serbia, the Union of Engineers and Technicians of Serbia, the Faculty of Technology and Metallurgy in Belgrade, the University of Belgrade and the Faculty of Technology in Leskovac, University of Niš. The Conference is being organized on the occasion of celebrating 150 years of the Union of Engineers and Technicians of Serbia, 65 years of the Union of Engineers and Textile Technicians of Serbia and 65 years of continual publishing of the Textile Industry journal.

The Ministry of Education, Science and Technological Development of the Republic of Serbia recognized the importance of this Conference, and thus, supported it.

The aim of this Conference is to consider current technical, technological, economic, ecological, R&D, legal and other issues related to the textile industry, then the application of contemporary achievements and the introduction of technical and technological innovations in the production process of fiber, textile, clothing and technical textile by applying scientific solutions in order to improve the business and increase the competitive advantages of the textile industry on the domestic and global market.

Leading scientists and experts from the Balkans and other countries, working at faculties, textile colleges and institutes, but also individuals who professionally deal with the issues at hand are taking part in this Conference.

The Conference program involves papers dedicated to the scientific and practical aspects of the following topics: Textile and Textile Technology, Textile Design, Management and Marketing in the Textile Industry and Ecology and Sustainable Development in the Textile Industry. The Conference program includes 45 papers, and a total of 105 participants from 13 countries: Bosnia and Herzegovina, Bulgaria, Croatia, India, Italy, Macedonia, Portugal, Romania, Serbia, Slovenia, Turkey, Ukraine and Spain. Therefore, this Conference is an opportunity for establishing scientific, educational and economic cooperation of our country with other countries. Certain number of papers by domestic authors present the project results dealing with fundamental research and technological development, financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

I would like to thank all those who have made it possible to organize the conference Contemporary Trends and Innovations in the Textile Industry and make it a success. First, I would like to thank the Scientific and Organizing Committee for working hard, spending countless hours and finding the best solutions for numerous organizational aspects of our Conference. Also, I would like to express my gratitude to all sponsors who believed in the importance of this Conference and cofinanced it. I also thank all the other institutions that supported the Conference in various ways, because without their support, the Conference could not have been organized. Last but not least, I would like to thank plenary lecturers, all authors and co-authors and guests for their participation in the Conference.

On behalf of the Organizing Committee
Prof. dr Snežana Urošević, president

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THE INFLUENCE OF CHEMICAL MODIFICATIONS ON THE CHEMICAL COMPOSITION, SORPTION PROPERTIES AND VOLUME ELECTRICAL RESISTIVITY OF JUTE FABRICS

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ABSTRACT: *The influence of chemical modifications on chemical composition, sorption properties and volume electrical resistivity of jute fabrics was studied. In order to partially remove hemicelluloses and lignin, modifications with NaOH (1% and 17.5% at RT) and $NaClO_2$ (0.7%, at boiling temperature) were applied. Compared to the unmodified, the alkali modified fabrics have lower hemicelluloses content, higher moisture sorption and water retention, while oxidized fabrics have lower lignin content and volume electrical resistivity, but higher water retention. Fabrics modified with 1% NaOH and 0.7% $NaClO_2$ have lower iodine sorption, while for fabric modified with 17.5% NaOH (30 min), mercerization phenomenon induced higher iodine sorption and higher value of volume electrical resistivity.*

Keywords: *jute, modification, hemicelluloses, lignin, sorption properties, volume electrical resistivity*

UTICAJ HEMIJSKOG MODIFIKOVANJA TKANINE JUTE NA PROMENU HEMIJSKOG SASTAVA, SORPCIONIH SVOJSTAVA I SPECIFIČNE ZAPREMINSKE ELEKTRIČNE OTPORNOSTI

APSTRAKT:*Ispitivan je uticaj hemijskog modifikovanja tkanine jute na promenu hemijskog sastava, sorpcionih svojstava i specifične zapreminske električne otpornosti. U cilju parcijalnog uklanjanja hemiceluloza i lignina, tkanina je modifikovana sa NaOH (1% i 17,5% na sobnoj temperaturi) i $NaClO_2$ (0,7% na temperaturi ključanja). U poređenju sa nemodifikovanom, alkalno modifikovane tkanine imaju smanjen sadržaj hemiceluloza, povećanu sorpciju vlage i sposobnost zadržavanja vode, dok oksidisane tkanine imaju smanjen sadržaj lignina i specifičnu zapreminsku električnu otporost i povećanu sposobnost zadržavanja vode. Tkanine modifikovane sa 1% NaOH i $NaClO_2$ imaju smanjenu sorpciju joda, dok kod tkanine modifikovane sa 17,5% (30 min) NaOH dolazi do mercerizacije koja povećava sorpciju joda i specifičnu zapreminsku električnu otpornost.*

Ključne reči: *juta, modifikovanje, hemiceluloze, lignin, sorpciona svojstva, zapreminska električna otpornost*

1. INTRODUCTION

In recent years, bast fibers have become the focus of intense interest. From the point of usage, global consumption, production and availability, the only bast fiber that can be called a major fiber is jute. Being a coarse, hard and mechanically stable fiber, jute has always been preferred as packaging material. In the last two decades, jute fibers have been intensively used in production of different composites because of their advantages: low cost, low density, renewability and biodegradability [1].

Jute fibers have three main chemical components: α-cellulose, hemicelluloses and lignin. α-cellulose forms the bulk of the ultimate cell walls with the molecular chains lying broadly parallel to the direction of the fiber axis. The hemicelluloses and lignin are located mainly in the areas between neighboring cells, where they form the cementing material of the middle lamella, providing strong lateral adhesion between the ultimates. High quantity of hemicelluloses and lignin negatively influence on fiber sorption and electrical properties [1].

According to the literature survey, jute fibers have been subjected to various types of chemical modifications to improve their properties [2-5] and to use as reinforcing materials in composites [6, 7]. Among chemical modifications, treatments with NaOH and $NaClO_2$ are still used as the most direct and efficient methods to partially remove hemicelluloses and lignin and studying the influence of the chemical composition on the structure and properties of natural cellulose fiber. Since there are limited resources in current literature dealing with the effect of different chemical modifications, i.e. different chemical composition on the sorption properties and volume electrical resistivity, the results of this work should provide useful additional information on the influence of chemical modifications conditions on sorption properties and volume electrical resistivity of jute fabrics.

2. EXPERIMENTAL MATERIAL AND METHODS

A commercially produced raw jute plain fabric with the chemical composition: 1.88% water soluble components, 1.92% fats and waxes, 0.84% pectin, 13.48% lignin, 21.76% hemicelluloses and 60.09% α-cellulose was used in this investigation as experimental material. All used chemical agents obtained from commercial sources were of analytical grade and used without further purification.

Raw jute fabric was subjected to chemical modifications, such as alkalization and oxidation in order to partially remove either hemicelluloses or lignin according to the procedure described in literature [8]. Alkali treatment with 1% NaOH solution, 1:50 liquid ratio, at room temperature for 30 min and alkali treatment with 17.5% NaOH solution, 1:50 liquid ratio, at room temperature, for 5 and 30 min were chosen to partially remove hemicelluloses and keep the lignin content unchanged. Alkali treatments were followed by neutralization with 1% acetic acid, than, jute fabrics were rinsed with 0.5% $NaHCO_3$, washed and dried at room temperature for 72 h. Oxidative treatment with 0.7% $NaClO_2$ solution at pH 4-4.5, 1:50 liquid ratio, at boiling temperature, for 15, 60 and 90 min was brought to partially remove lignin and keep the hemicelluloses content unchanged. Oxidized jute fabrics were rinsed with 2% $NaHSO_3$, than, washed and dried at room temperature for 72 h.

The weight loss after different chemical modifications of jute fabrics, was determined by direct gravimetric method [9]. The chemical composition of jute fabrics was determined according to the scheme of Soutar and Bryden [8] by successive removal of non-cellulosic components. After that, α-cellulose remains as a solid residue.

The sorption properties of jute fabrics were characterized considering the changes in moisture sorption, water retention and iodine sorption. Reported values are the average values of three parallel measurements, except in the case of determination of water retention value which is average of six parallel measurements. Moisture sorption was determined using an infrared moisture analyzer Sartorius MA35. Samples were exposed to standard atmosphere: 20±2° C, 65±2 % relative air humidity, for 24 h prior to moisture sorption determination. Moisture sorption of jute fabrics was calculated as a weight percentage of absolutely dry material. Water retention value was investigated according to the standard centrifuge method (ASTM D 2402-78, 1978) [10]. Jute fabric, after immersing in distilled water at room temperature for 1h, were centrifuged at 5000 rpm for 5 min. Iodine sorption value was determined according to the Schwertassek method which is described in literature [11].

The dc volume electrical resistance of jute fabrics was determined using the device which was developed at the Department of Textile Engineering, Faculty of Technology and Metallurgy at the University of Belgrade. The measurement of dc volume electrical resistance was performed using the voltage method. The detailed description of the device was explained in literature [12], and equation for the calculation of the dc volume electrical resistivity (in further text resistivity) was presented in literature [13]. Measuring was performed at the same dynamic of moisture desorption from the jute fabrics at room temperature (23±2° C).

3. RESULTS AND DISCUSSION

3.1. The influence of chemical modifications on the weight loss and chemical composition of jute fabrics

The codes and explanations of unmodified and chemically modified jute fabrics together with the weight loss after different modifications are given in Table 1, while their content of hemicelluloses and lignin is given on the Figure 1.

In all cases of jute fabric modifications, it is clear that loss in weight increased proportionally to the increase of the modification time, the highest weight loss (12.95%) was achieved when the jute fabric was modified with 0.7% $NaClO_2$ for 90 min (L90/0.7). Also, the loss in weight increased with increasing the concentration of modification agent (NaOH), Table 1.

Table 1. Chemical composition of unmodified and modified jute fabrics and weight loss after chemical modifications

Sample code	Explanation	Temperature	Weight loss (%)
C	Control – unmodified		/
H30/1	1% NaOH, 30 min	Room temperature	5.87
H5/17.5	17.5% NaOH, 5 min		9.98
H30/17.5	17.5% NaOH, 30 min		12.07
L15/0.7	0.7% $NaClO_2$, 15 min	Boiling temperature	6.19
L60/0.7	0.7% $NaClO_2$, 60 min		10.00
L90/0.7	0.7% $NaClO_2$, 90 min		12.95

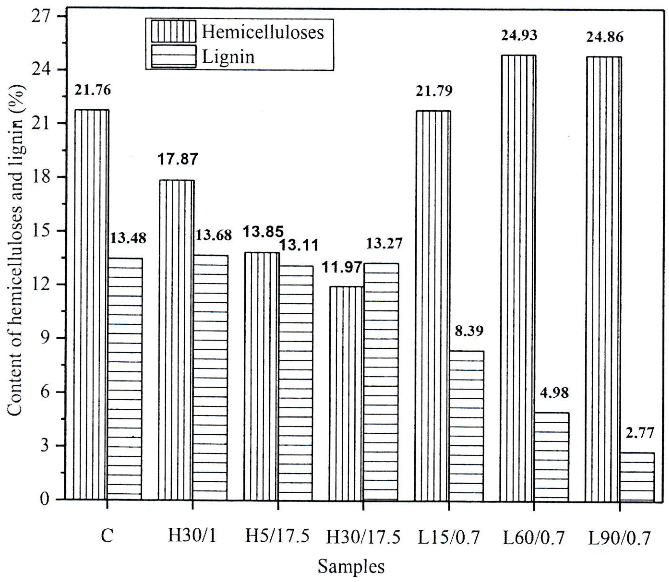

Figure 1. Content of hemicelluloses and lignin in unmodified and chemically modified jute fabrics

There was an evident tendency that the content of hemicelluloses decreased with increasing the concentration of NaOH, Figure 1. During 30 min modification of jute fabric with 1 % NaOH (H30/1), the content of hemicelluloses decreased for 18%, while in the case of treatment with 17.5% NaOH during the same time (H30/17.5), content of hemicelluloses decreased for 45%, compared to the unmodified. These results are comparable with the results obtained for jute and other bast fibers [3, 14, 15]. In the case of chemical modifications with 17.5% NaOH, with increasing the modification time from 5 min (H5/17.5) to 30 min (H30/17.5), content of hemicelluloses decreased for 13.6%, Figure 1. In the case of oxidized jute fabrics, with increasing the modification time, the content of lignin decreased. After 15 min of modification (L15/0.7), the content of lignin decreased for about 38%. These percentages for jute fabrics treated for 60 min

(L60/0.7) and 90min (L90/0.7) are 63% and 80%, respectively. It has to be mentioned that after chemical modification with 0.7% $NaClO_2$, the content of hemicelluloses in modified jute fabrics increased up to 14.5% (L60/0.7) compared to unmodified fabric. Lazic and colleagues [15] also observed similar changes for hemicelluloses content after chemical modifications of flax fibers with different concentrations of $NaClO_2$.

3.2. The influence of different chemical modifications on the sorption properties of jute fabrics

Due to the presence of free hydroxyl groups at jute amorphous regions and at the crystallite's surfaces, the moisture sorption of jute fabrics is high (8.26% for unmodified jute fabric), Table 2. With decreasing the hemicelluloses content for 18, 36 and 45% for H30/1, H5/17.5 and H30/17.5, moisture sorption values increased for 4.7, 9.1 and 13.6%, respectively. Not only content of hemicelluloses influences the moisture sorption, but also the concentration of used NaOH influences the moisture sorption. Namely, increase in NaOH concentration from 1% to 17.5% results in higher moisture sorption for 8.4%. The differences between moisture sorption values of unmodified jute fabric and jute fabrics modified with 0.7% $NaClO_2$ are smaller in comparison with alkali treated jute fabrics, Table 2. From the results, jute fabrics modified for 15 and 90 min (L15/0.7 and L90/0.7) have very similar values for moisture sorption. Their moisture sorption values are about 7.5% lower in comparison with the moisture sorption value of unmodified jute fabric.
Water retention values of chemically modified jute fabrics were higher in comparison with unmodified, Table 2. This is a consequence of introduction a significant amount of hydrophilic groups, structure changes (changes in the size and number of pores and microcracks in fibers) and effective removal of hydrophobic impurities from the surface of the fabrics (fats and waxes) [16]. The effect of hemicelluloses removal on water retention value was significant, since removing of 36% of hemicelluloses (H5/17.5) results in 49% higher water kept by modified jute fabrics compared to the unmodified. From the results given in Table 2, it is evident that water retention value increased with increasing the concentration of NaOH. During 30 min modification of jute fabric with 1 % NaOH, the water retention value increased for about 21%, while in the case of treatment with 17.5% NaOH during the same time, the water retention value increased 43% compared to unmodified fabric. We observed that, jute fabrics with similar content of hemicelluloses (H5/17.5 and H30/17.5) have almost the same (difference about 4%) water retention values. In the case of oxidative modification of jute fabric with 0.7% $NaClO_2$, with an increase of modification time and decreasing of lignin content, water retention values increases, Figure 2 and Table 2. With decreasing the lignin content for 38, 63 and 80% for L15/0.7, L60/0.7 and L90/0.7, water retention values increased for 4, 23 and 40%, respectively. This phenomenon is also evident when hemp fibers [17, 18] were modified with 0.7% $NaClO_2$ at boiling temperature.

Table 2. Sorption properties and crystallinity index of unmodified and chemically modified jute fabrics

Sample code	Moisture sorption (%)	Water retention (%)	Iodine sorption (%)	Crystallinity index (%)
C	8.26	57.23	137.94	66.52
H30/1	8.65	69.35	133.03	67.71
H5/17.5	9.01	85.16	213.17	48.26
H30/17.5	9.38	81.84	236.74	42.54
L15/0.7	7.65	59.53	149.42	63.73
L60/0.7	8.34	70.35	129.41	68.59
L90/0.7	7.67	79.67	98.7	76.04

Obtained results showed that different chemical modifications influence differently the iodine sorption and crystallinity index, i.e. accessibility of the jute fabrics and ratio of amorphous and crystalline regions. In the case of alkali treated jute fabrics, insignificant decrease in fiber accessibility and increased crystallinity were observed only for the lower concentration (1% NaOH). In contrast, when jute fabrics were modified with 17.5% NaOH, with increasing the modification time and decreasing the content of hemicelluloses, iodine sorption increased and crystallinity index decreased. During the 5 min modification (H5/17.5) and 30 min modification (H30/17.5), it can be seen that iodine sorption values increased for 54.5 and 71.6% and crystallinity index decreased for 27.5 and 36%, respectively. Also, during the same modification time (30 min), jute fabrics modified with 17.5% NaOH (30/17.5) have 43.8% higher iodine sorption value and 59% lower crystallinity index in comparison with jute fabric modified with 1% NaOH (H30/1). Our results are in agreement with the results obtained for alkali modified flax fibers [15]. Jute fabrics modified with 0.7% $NaClO_2$ during 15 min (L15/0.7) has higher iodine sorption and higher crystallinity index compared to the unmodified jute fabrics. On the other hand, with increasing the modification time and decreasing the lignin content for 63 and 80% for L60/0.7 and L90/0.7, iodine sorption values decreased for 6.2 and 28.4%, and crystallinity index increased for 3.1 and 14.3%, respectively. This is the consequence of the removal of lignin, as less ordered and easy accessible non-cellulosic adsorbing component and the changes in fibrous morphology during oxidative treatment [12].

3.3. The influence of different chemical modifications on the resistivity of jute fabrics

The resistivity of unmodified and chemically modified jute fabrics was investigated at 45% and 35% air humidity, Table 3.

Unmodified jute fabric has higher resistivity in comparison with chemically modified jute fabrics (excluding H30/17.5). With decrease of air humidity in the chamber, the resistivity of the tested fabrics increases, Table 3. This can be explained by influence of relative air humidity on partly ionization of water molecules, which were around the fibers and neutralization of electric charges on fibers surface by these molecules [8].

Table 3. Resistivity of unmodified and chemically modified jute fabrics

Sample code	Resistivity (GΩ·cm)			
	45 % air humidity		35 % air humidity	
	Warp direction	Weft direction	Warp direction	Weft direction
C	10.27	9.53	19.34	19.24
H30/1	6.61	2.67	10.02	4
H5/17.5	5.93	3.74	8.9	5.47
H30/17.5	26.41	23.41	38.54	36.99
L15/0.7	0.68	0.66	1.15	1.10
L60/0.7	0.48	0.40	0.70	0.65
L90/0.7	0.46	0.37	0.67	0.60

From Tables 2 and 3 it is evident that jute fabrics modified with NaOH have higher resistivity in comparison with oxidized jute fabrics. Obtained results are in agreement with literature data obtained for hemp fibers [12]. We can conclude that resistivity of jute fabrics is mainly determined by their chemical composition, i.e. hemicelluloses. Jute fabric modified with 17.5% NaOH during 30 min has higher resistivity in comparison with unmodified fabric. During the modification with 17.5% NaOH, the alkali penetrates into jute fibers and they swell disrupting the crystalline regions, the cellulose chains rearrange from cellulose I to cellulose II. With increasing the modification time, the resistivity of samples modified with 0.7% $NaClO_2$ decreased. This decrease was higher than for fabrics modified with NaOH. Values of resistivity were 14.4-25.8 times (at 45% air humidity) and 16.8-32.1 times (at 35% air humidity) lower for jute fabrics modified with $NaClO_2$ than for unmodified fabrics. Resistivity of jute fabrics oxidized for 60 and 90 min are very similar. As their content of lignin differs for 44%, we can conclude that content of lignin did not have influence of resistivity.

4. CONCLUSION

In this investigation, alkali and oxidative treatments were applied to obtain jute fabrics with different content of hemicelluloses and lignin, in order to study the influence of chemical composition on sorption properties and resistivity of fabrics. Analyses of obtained results showed that the jute fabrics with lower hemicelluloses content, have higher moisture sorption, water retention and iodine sorption, but lower crystallinity index and resistivity. Observed higher resistivity of jute fabric modified with 17,5% NaOH during 30min (H30/17.5) compared to jute fabric with similar content of hemicelluloses (H5/17.5), can be explained by the reorganization of the amorphous areas in fibers during transformation of cellulose I to cellulose II. In the other case, jute fabrics with lower content of lignin have higher water retention and crystallinity index, but lower iodine sorption. Values of resistivity for oxidized jute fabrics are 14.4-32.1 times lower in comparison with unmodified fabric.

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