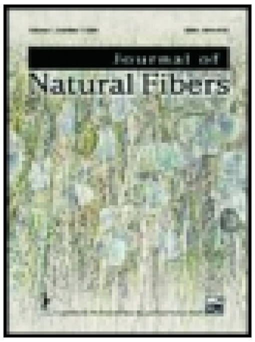

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Nonwoven Production from Waste Rice Straw by Using Enzymatic Method

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ABSTRACT

In this study, the nonwoven fabric is produced by rice straws to utilize agricultural organic waste. Rice straws dried after harvest are pretreated with NaOH, pectinase enzyme and wetting agent. Washed and softened fibers are cut at 4–5 cm staple length, blended in carding engine with cotton at 9/1 ratio. By carding band and needle punch process nonwoven fabric is obtained. SEM, EDX and FTIR analyses are applied on the fabric. Product's inspection verified that pretreatments provided smoothness, removed noncellulosic substances, and decreased hydrophobic structure. Thus, a new nonwoven material to be used in textile is produced.

摘要

本研究以稻草为原料，利用农业有机废弃物生产非织造布。用NaOH、果胶酶和湿润剂预处理稻草收获后干燥。洗涤和软化的纤维在4～5厘米的短纤维长度下切割，在梳棉机中以9/1的比例与棉混纺。通过梳理带和针刺工艺获得无纺布。将SEM、EDX和FTIR分析应用于织物上。产品检验证明，预处理提供了光滑性，去除了非纤维素物质，降低了疏水结构。因此，生产用于纺织的新型非织造材料。

KEYWORDS
Rice straw; recycle; nonwoven; alkalization; enzyme; natural fiber

关键词
稻草; 回收利用; 非织造布; 碱化; 酶; 天然纤维

Introduction

The petrol resources are on the point of depletion and its use for the raw material of synthetic products caused environmental problems to reach to global scales. The organic wastes obtained from agricultural and other sustainable resources enhance the raw material sources for producing ecological and low-cost new products. According to the advanced technologies report, 50–65 million tons of agricultural wastes occur annually in Turkey. The large part of these are being collected and disposed of without being utilized, and this increases the costs and also causes economic losses. Agricultural wastes are biomass sources consisting of wheat, rice plant, cotton, sunflower, corn wastes and greenhouse wastes. Biomass sources are the materials that can be used in the production of bio-products such as bioenergy, industrial chemicals and various consumer goods instead of fossil-based resources. By using bio-refining from biomass sources including organic wastes, instead of petrol methodologies, chemical substances (such as monomers, polymers, organic acids etc.) fibers, bioplastics and renewable energy (biogas, biodiesel, ethanol etc.) can be produced.

The energy consumed to derive fuels produced from agricultural wastes is more than the energy provided by biofuels. Furthermore, during the processes of converting agricultural wastes to biofuels, much more industrial wastes are generated. Agricultural wastes are used in the production of bio-composite materials. In bio-composite practices, agricultural wastes are used in the production of flake-boards and they are also used as reinforcing the material in concrete to increase its strength.

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These bio-composites are an alternative to glass wool or carbon-based other composites. In the literature, there are several studies on the pretreatments applied to the straw fibers, including but not limited to: retting of linen fibers with and without pectinase enzyme and chelate (Foulk et al. 2004), retting of linen fibers with Bioprep 3000 and ethylene diamine tetraacetic acid (EDTA) alkaline pectate lyase (PL) (Akin et al. 2007), high concentrated alkali treatment to curaua plant (Gomes et al. 2007), the finding of strength of blighted linens by using Bioprep 3000L and Texayzm BFE enzymes is high (Foulk, Akin, and Dodd 2008), threating rice straws cut in 2 to 4–6 mm length for 2 h in 1–5% NaOH at 150° C (Fahim 2011), oxalic acid and hot water influence on NaOH processed rice straws (Liu and Huang 2013), reviewing pectinase and calcium mechanisms in composting applications, collected work of linen types and used pectinase varieties (Akin 2013), wheat straws processed with 1–3-5% alkaline solution (Mittal, Saini, and Sinha 2016).

In this study, carding band-based nonwoven surface has been produced by rice straws with a rate of 90% which can be used as reinforcing the material in bio-composites and investigated by SEM display and FT-IR analysis. With this aspect, it is considered that the material would give a new point of view on putting agricultural wastes to good use.

Materials and methods

In this study, the wastes of rice straws collected from paddy fields in Edirne/Turkey. The density of rice straws was 0.7–1.0 g/cm^3. Pretreatment, comprising 20% NaOH, 2% Bioprep 3000L enzyme and 2% wetting agent, was applied to rice straws at room temperature for 10 days. Enzymating treatment was done in polypropylene (PP) tanks with 1:15 ratio.

In Figure 1, treatment of sodium hydroxide, enzyme and wetting agent is seen. Detergent flushing for pH balancing and softening treatment was made following the enzymatic treatment. They were kept at room temperature for 24 h for drying. The enzymating treatment was done under room temperature to show that there is no need to consume additional energy while using waste as raw material.

The enzymating treatment can be done by utilizing big heating tanks in shorter periods, i.e. less than 10 days. The efficiency depends on the size and abilities of the business/factory.

In Figure 2, detergent and softening wash applied rice fibers are seen. Fibers have been cut 4–5 cm staple length, blended in laboratory-type carding machine belongs to MESDAN S.P.A. with cotton at 9/1 ratio, thus carding band has been obtained.

In Figure 3, Laboratory-type carding machine and carding band made of rice straw fibers are seen. A nonwoven fabric was produced by processing the carding bands by needle punch.

Figure 1. Enzymatic treatment.

Figure 2. a) Flushing process b) Drying.

Figure 3. Laboratory-type carding machine and carding band made of rice straw fibers.

Methods of analysis

SEM was used to analyze the micro structure and interfacial properties of the produced carding band-based nonwoven material, (Madhoushi 2009; Nallis 2009; Qin et al. 2011; Sudhakar and Srinivas 2014; Wu et al. 2014), while FTIR was used to analyze the chemical bond structures of the material, bond vibrations of the molecules or displaying the energy changes derived from one spin energy level to another, (Liu, 2013; Nemr et al. 2015; Prasad, Rao, and Kumar 2006; Zhu et al. 2013).

Result and discussion

Rice straws contain 41–57% cellulose, 33% hemicellulose, 8–19% lignin, 8–38% cinder (Yao 2008). Moreover, there is 63% crystalline region in its content. With this content, it resembles cotton. However, the lignin existence in its structure decreases its water absorption. Therefore, to increase the wetting capability, pretreatment was applied. Fibers extracted from sample quantity of rice straw are approximately 75%.

FTIR analysis

In Figure 4, FTIR spectrums of raw rice straw and pretreated sample. FAR FT-IR instrument (Perkin Elmer) was used in the analysis. Observation of the absorption bands showed that the

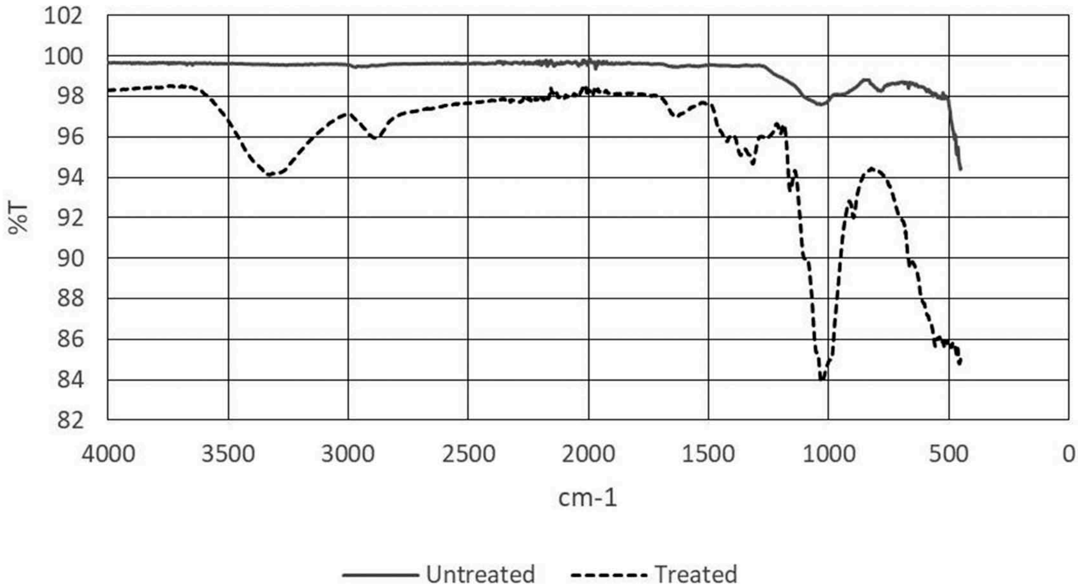

Figure 4. FTIR spectrum of rice straw.

changes between rice straw and pretreated rice straw were mainly due to the formation of oxygen functionalities which were associated with 1032–500 cm range. OH and NH groups indicate a successful hydrophile process on rice straws at the peak of pretreated rice straw 3327 band (Abdul Hamid et al. 2010). 2977 band shows C–H tension (Chen et al. 2011), 2873 peak indicates the existence of CH_3 and CH_2 dense bands and rice straws have been modified regularly (Han, Branford-White, and Zhu 2010). The values on 1600–1700 are the values showing lignin and aliphatic esters in hemicellulose. The band around 1030 is pointing out olefinic addition structure with C=C vibration. These results indicated that treatment gave rise to a large increase in carboxylic and lactone group C=O bonds.

SEM analysis

In Figure 5, the morphologic structure of rice straws which untreated by alkali is seen. Rice straws have an outer layer consisting of lignin, silica and other noncellulosic substances; it is seen that it has a thick cell wall and relatively small lumen. On SEM displays (Figure 5(a)), cross section of unprocessed rice straw (Figure 5(b) and Figure5(c)) and the structures of fiber bundles were observed (Reddy and Yang 2006). Furthermore, in Energy-Dispersive X-Ray Spectroscopy (EDX) (Figure 5(d)), elementary analysis of substances contained by raw rice straws was performed. Based on the results, there are 53% oxygen, 24% carbon, 2.37% potassium, 1.37% chlorine, 0.32% aluminum, 0.23% sodium and 0.14% fluorine in its structure.

In Figure 6, the morphologic structure of alkali-treated rice straws is seen. On SEM displays (Figure 6(a)), the cross section of processed rice straw (Figure 6(b,c)) and the structures of fiber bundles were observed. It was also observed that, after alkali and enzyme treatment, a small amount of foreign substances existing on the surface of fiber could be removed; the bonding materials between fibrils such as hemicellulose, lignin and pectin decreased and fibrillation on the fiber surface occurred. The roughness of the surface was increased. As a result of fibrillation on the fiber surface (Figure 6(d)) In EDX, elementary analysis of substances contained by pretreated rice straws has been performed. Based on the results, there are 54.2% oxygen, 44.79% carbon, 0.23% Silisium, 0.2% aluminum, 0.17% sodium, 0.16% chlorine, 0.11% calcium and 0.10%

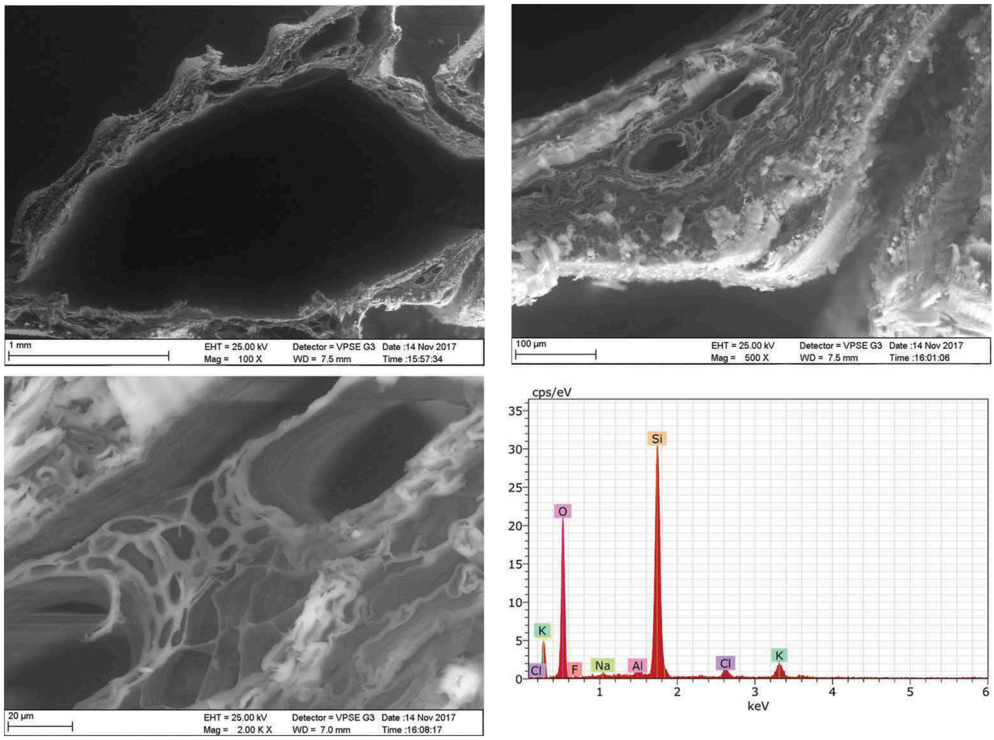

Figure 5. a) 100× Rice straw b) 1000× fiber bundles on rice straw c) 2000× single fiber cell d) Energy-dispersive X-ray spectroscopy (EDX) of raw rice straws.

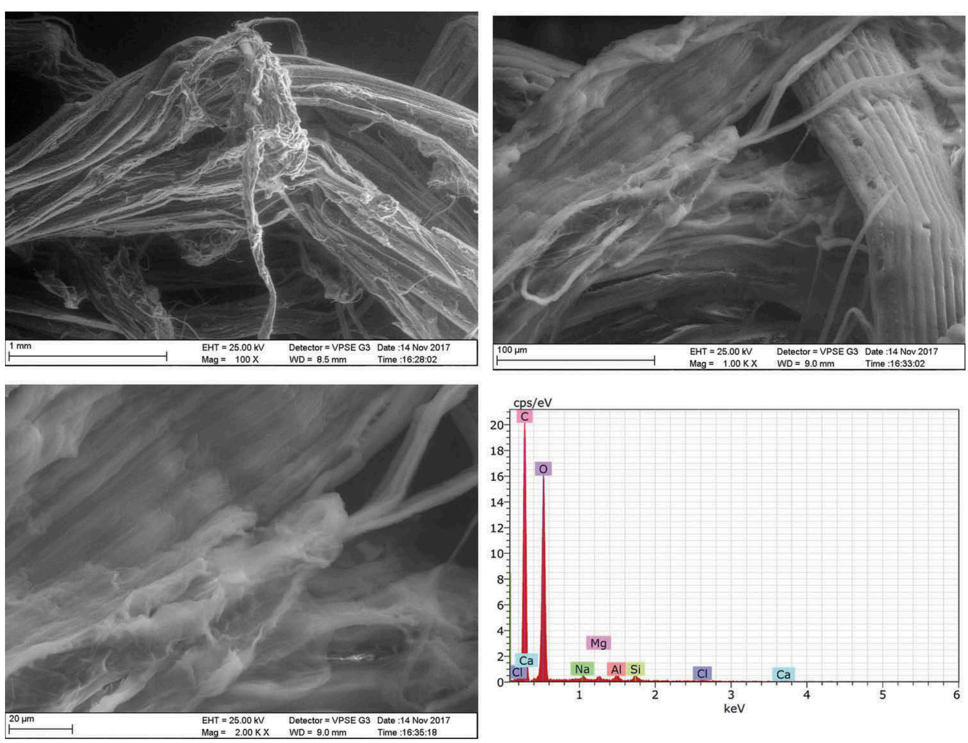

Figure 6. a) Pre-treated rice straw fibers 100× b) Pre-treated rice straw fibers 1000× c) Pre-treated rice straw fibers 2000× d) Energy-Dispersive X-ray spectroscopy (EDX) of Pre-treated rice straws.

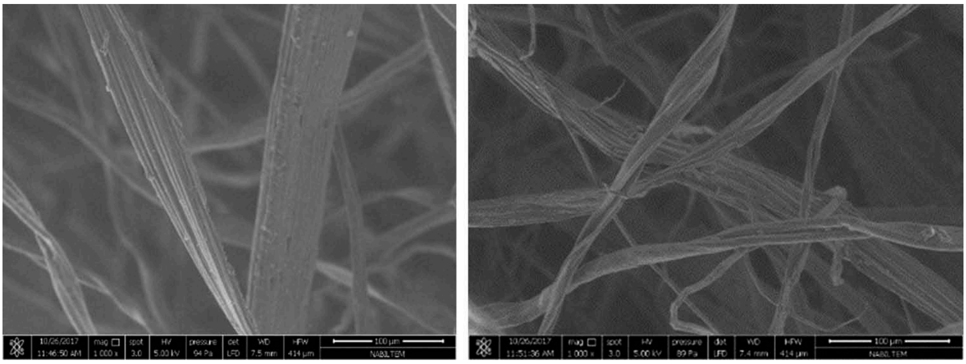

Figure 7. a) Carding band b) Display of needle punched felt cloth (1000x).

Magnesium in its structure. After alkali treatment, the ratios of oxygen and carbon were increased while Silisium ratio was decreased and the treatment generated a cleaning effect. By the removal of foreign substances, the ratio of cellulose reaches up to 80% as well. This increase in the cellulose amount of the fiber positively affected both the strength of the fiber and the mechanical characteristics of the produced bio-composite where the obtained nonwoven surface was used as a reinforcing material by increasing the bonding capability in the interface in the composite material.

In Figure 7(a), SEM images of carding band obtained from laboratory type carding machine is seen. In Figure 7(b), the structure of needle punched carding band is shown. It is seen that, the obtained nonwoven fabric has been needle punched in several directions and its fibers intertwined thus a felt cloth has been obtained and after this stage, it became a reinforcing material which can be used in the production of bio-composite materials.

Conclusions

In this study, rice straws one of the agricultural wastes, recycled and a new cellulosic fiber which can be used as a textile raw material was obtained and a nonwoven fabric has been produced by using this fiber. According to SEM and FTIR results, positive surface modifications of rice straws have been obtained with alkali and enzyme treatments. A small amount of noncellulosic foreign materials has been removed. It has been found from the decrease in the intensity of the peaks indicating carbonyl groups that a successful hydrophilization process has been done and the roughness of the fiber surface has increased in this respect. In addition, the obtained felt cloth has got a potential to be used as a reinforcement material in industrial fields. By this mean, it is possible to establish a manufacturing facility to perform pretreatment on wasted rice straws collected from the paddy fields and produce fibers. It can be heckled in carding machines present in the market and carding band can be obtained. Then, felt type nonwoven fabric can be produced by using needle punch machines. Obtained felts can be used in Automotive, white goods industry, in buildings for sound and thermal insulations, and can be used as a reinforcement material in the production of bio-composite materials.

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