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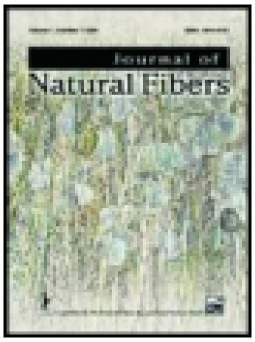

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Reinforcing of Viscose Fabric Using Nano Web of Palm-Cellulose Carbon Mesoporous Nanoparticle Composite

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ABSTRACT
The research aims in reinforcing viscose fabric with extracted cellulose from the palm, which has been doped with carbon mesoporous nanoparticles (CMNs), and electrospinning on the surface of viscose fabric. Hence, the palm cellulose was extracted by a chemical process in different alkaline periods and doped with various concentrations of CMNs, and the solution was electro-spun on the aluminum surface. The morphology, tensile strength, and abrasion resistance of the produced nano web was investigated, and the best condition for preparing nano web was achieved. In the next step, the best condition was the electrospinning on the surface of viscose fabric as reinforcing the viscose, and the morphology (by FESEM), tensile force, abrasion resistance, thermal analysis (DTG, TGA, and thermal conductivity), air permeability, and moisture content of the composite was investigated. The results of this study show that reinforcing viscose fabric with nano web of palm-cellulose doped with CMN have a significant influence on enhancing the properties of viscose fabric.

摘要
本研究的目的是用棕榈提取的纤维素,(掺杂了碳介孔纳米颗粒 (CMN), 增强粘胶织物, 并在粘胶织物表面静电纺丝. 因此, 在不同的碱性阶段, 通过化学方法提取棕榈纤维素, 并掺杂不同浓度的CMN, 然后将溶液电纺在铝表面. 研究了所制备纳米网的形貌、拉伸强度和耐磨性, 确定了制备纳米网的最佳条件. 在下一步中, 最佳条件是在粘胶织物表面静电纺丝以增强粘胶纤维, 并对复合材料的形貌 (通过FESEM), 、拉伸力、耐磨性、热分析(DTG、TGA和热导率), 、透气性和水分含量进行了研究. 本研究结果表明 添加CMN的棕榈纤维素纳米网增强粘胶织物对提高粘胶织物的性能有显著影响.

KEYWORDS
Palm cellulose; viscose; electrospinning; carbon mesoporous; nano web

关键词
棕榈纤维素; 粘胶纤维; 静电纺丝; 碳介孔; 纳米网

Introduction

Cellulosic fibers and fabrics are environmentally friendly textiles due to their special properties (F. Liu, Wang, and Chen 2020; X. Zhang et al. 2018; Kooshamoghadam et al. 2021) gained much attention throughout the world. These fibers are extracted from different plants (cellulosic sources) such as grass, hemp, wood, wheat, etc. Some researchers reported the application of these fibers as reinforcement and increasing the properties of composites (Ghiasi, Davodiroknabadi, and Zohoori 2021; Mohammed et al. 2015; Thakur, Thakur, and Gupta 2014; Yamin, Naddafiun, and Zohoori 2021; Yashas et al. 2018). Raja et al. have used natural fiber as a reinforcing of the composites and

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investigated the mechanical properties of composite (Raja et al. 2017). On the other hand, Ratna et al. reported the influence of reinforcing sisal, jowar, and bamboo on mechanical properties of polyester (Prasad, A., and K. Rao 2011). Palm fiber is one of the natural fibers which was investigated by some researchers as reinforcing composites. In previous works, palm fibers were used directly as supporting material in building insulation, filtration, and composite reinforcement (Derrouiche et al. 2015; Zbidi et al. 2009). For instance, Atalie et al. reported the extraction of leaf from palm and investigated some properties of this fiber. They reported that extracted leaf from the palm through three methods has shown good mechanical properties and suggested to use these fibers for technical textile applications (Atalie and Rotich 2018). Some researchers reported different methods of extracting these leaves, such as retting of water or chemicals (Al-Oqla et al. 2014; Jose et al. 2019; Sadrmanesh and Chen 2019). Also, reinforcing natural fibers was investigated by researchers through nanomaterials. Using nanomaterials and particles in fibers and fabrics leads to the preparation of the textiles with special characteristics. Some of the semiconductors and conductors nanoparticles used in textiles are titanium dioxide, zinc, cerium, cadmium, and ferric compounds (Bekrani, Zohoori, and Davodiroknabadi 2019; Gao et al. 2017, 2018; Jung et al. 2018; Kooshamoghadam et al. 2021; Yan et al. 2018; Zohoori, Karimi, and Nazari 2014). But, carbon and carbon compounds in nanometer has gained much attention due to its unique and particular properties, and many researchers have reported the advantageous use of nano carbons in textiles (Amini et al. 2014; Karimi, Zohoori, and Amini 2014; R. Zhang et al. 2017). Electrospinning is one of the best methods to produce nanofibers that contains nanoparticles of carbon. In this method, a polymer solution throws out which has an electrical charge and create a fine and thin film of polymer web (Martin et al. 2013; Kim, Shim, and Kim 2016; C.-K. Liu et al. 2009; Zohoori et al. 2017; Karimi, Zohoori, and Ayaziyazdi 2013; Ayaziyazdi et al. 2013). This method of production, has many applications such as wound dressing, delivery of drugs, tissue, and filtration. It is worth to mention that producing these fibers containing carbon nano materials, can overcome some of the undesirable properties such as Young's modulus (Fazli-Abukheyli, Rahimi, and Ghaedi 2019; Huang et al. 2020; Kimmer et al. 2009; Mirjalili and Zohoori 2016; Qin et al. 2019).

This research has been divided into two sections:

The first section describes extracting cellulose from palm fiber, treated with different periods of sodium hydroxide, mixing it with various concentrations of carbon mesoporous nanoparticles, and electrospinning in order to gain nano fiber web. Then the morphology, tensile analysis, and abrasion resistance of the produced nanoweb were investigated and compared with each other, and the best condition was determined.

In the second section, the best condition of preparing nanoweb, obtained in the first section, was chosen and electrospinning on the surface of viscose fiber as reinforcing, and the mechanical properties of the "viscose\palm cellulose\carbon mesoporous nanoparticles," such as thermal analysis, air permeability, moisture content, morphology, tensile analysis, and abrasion resistance was investigated.

Materials and methods

The sheath of palm leaf was prepared from the Trachycarpus Fortune tree, Yazd, Iran. Carbon mesoporous nanoparticles with specific surface area of 50–100 m^2/g were prepared from Sigma Aldrich. Sodium hydroxide, hydrochloric acid, hydrogen peroxide, and tri-fluoro acetic acid were purchased from Merck.

A Euronda ultrasonic bath model Eurosonic 4D, 350 W, 50/60 Hz (Italy) was used. The morphology of nanofibers was investigated using an FESEM (Field Emission Scanning Electron Microscope) (MIRA3-TESCAN). A universal testing machine (Zwick/Roell, Z020, Germany) was used in order to investigate the tensile property of samples.

In order to the extraction of cellulose, the stems were separated carefully. These stems were dried in an oven for 12 h to remove the sheath husk, they were soaked for 72 h in water. Due to insolubility of existing pectin and hemicelluloses of stems, degumming of stems was done by soaking them in sodium hydroxide (as alkaline agent) (5% (w/v), and then washed twice with warm distilled water (75°C).

Table 1. Specification of specimens.

Sample	A	B	C	D	E	F	G
Electrospun base	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Viscose
Alkaline period (h)	1	1	5	5	10	10	5
CMN (%)	1	1.5	1	1.5	1	1.5	1.5

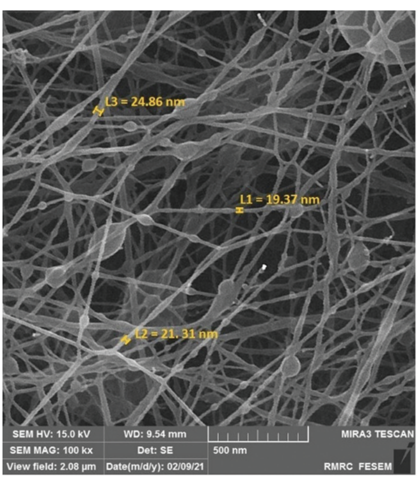
Soaking in NaOH was done in different periods: 1 h, 5 h, and 10 h. Then for neutralization, they were immersed in HCL (70%) at room temperature for 30 s, and then washed again with distilled water. Later, the solution was treated with hydrogen peroxide (H_2O_2) in ultrasonic bath in order to eliminate the existing lignin and hemicelluloses. The remains were later washed at room temperature with distilled water and dried in an oven. Thus, the cellulose was extracted and was ready for the next step. After this, the cellulose was dissolved in tri-fluoro acetic acid. While processing this, in another beaker, carbon mesoporous nanoparticles (CMN) were sonicated in ultrasonic bath at 5°C for 30 min. Two percentages of 1% and 1.5% CMN were prepared. Then the CMNs were added to extracted cellulose and electrospinning was started with a voltage of 20 kV, feeding rate of 0.3 mL/h, drum speed of 120 rpm and collector-needle distance of 15 cm. Finally, six nanofiber specimens were obtained (Table 1). Then, the physical properties of produced nanofiber was investigated and the best condition was determined.

Afterward, 100% plain weave bleached viscose fabric with warp density of 23 yarn/cm and 19 yarn/cm weft density was prepared from the Yazdbaf Company, Yazd, Iran. The surface of this fabric was electrospun to determine the best solution of palm cellulose/CMN (sample D) and was heat set.

Results and discussion

Morphology analysis

FESEM was used in order to investigate the morphology of electrospun nanofibers. As it is clear, the diameter of electrospun nanofibers are between 19 nm and 24 nm. The EDX of the specimen also shows the existence of carbon. The peak for Au is due to the covering of sample by gold (for conductivity in FESEM) (Figure 1). Ashing test was performed in order to prove the existence of CMNs on electrospun nanofibers. In this method, five samples having the same weight were closed and each one was burned in a stove at 600°C and the remaining ash was weighed and compared with the blank one. The difference showed the CMNs between the



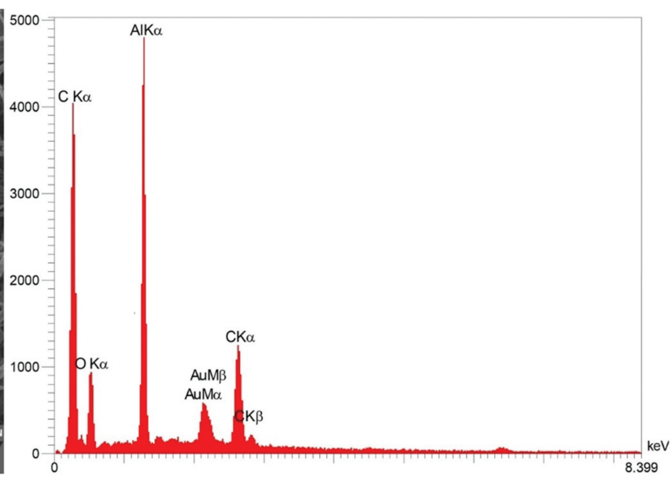


Figure 1. FESEM image of treated sample (left), EDX image of the treated sample (right).

blank sample weight and the other samples. The results showed that the used CMN and remaining CMN had one thousandth of a gram (1/1000 g) difference, which is negligible. So, this test proved that used CMNs are present in electrospun nanofibers.

Abrasion and tensile analysis of aluminum base samples

The abrasion resistance test was done by a rotary platform, double-head method through ASTM D-3884-09. For each sample, a rubbing test of 5 and 10 cycles was done and the difference in sample mass before and after abrasion was investigated. As shown in Table 2, the abrasion resistance of the untreated sample is lower than all the treated samples. By close look, it can be observed that by increasing the period of alkaline treatment, the abrasion resistance increases but the peak is at 5 h, and after that, it suddenly decreases. The reason of increasing the abrasion resistance until 5 h is that the presence of alkaline agent causes the removal of hemicellulose and hydrogen bonds created between the fibrils so that the abrasion resistance increases. But, by increasing the period of alkaline treatment time from 5 to 10 h, the alkali damages the fibrils and hence leads the decreasing of abrasion resistance. The presence of CMNs also increases the abrasion resistance due to its mechanical properties, which cause better resistance in the scaffold.

In order to investigate the tensile property, the specimens were cut to 4 cm × 2 cm sheets and loaded to the device. The test was done at a rate of 5 mm/min. The result indicates that by increasing CMNs, there is increase in the tensile strength and by increasing the duration of the alkaline process, the tensile strength increased until 5 h and after that it decreased (Figure 2). This phenomenon describes that after 5 h of treatment, the bonds of hemicellulose is broken and the homogeneity of fiber disappeared.

All these tests were done in order to determine the best condition for preparing palm cellulose \CMN nanoweb, so in the next step the selected nanoweb (sample D) is electrospun on the surface of viscose fabric and its properties are investigated.

Abrasion and tensile analysis of viscose base samples

Viscose\palm cellulose\CMN and viscose (raw sample) were investigated with rub tester and for 500 cycles and the difference in weight was calculated before and after rubbing. The extracted mean data indicates that the abrasion resistance of the raw sample is 74.63%, and the abrasion resistance of viscose\palm cellulose\CMN is 83.58%. Due to cellulosic base of both viscose and nanoweb, the palm cellulose\CMN showed that it has the ability to increase the abrasion resistance of the composite. On the other hand, the tensile force of the sample proves this too. The tensile force of the raw sample was 349.85 N and the tensile force of viscose\palm cellulose\CMN was 375.11 N.

Thermal analysis of viscose base samples

In order to investigate the thermal properties of samples, DTG and TGA analysis were done. By focusing on Figures 3 and 4, it was illustrated that the first decomposition was done at about 60°C, which is based on moisture evaporation of samples. But the main decomposition occurred in the range

Table 2. Abrasion resistance of specimens.

Sample	Web weight before abrasion (mg)	Web weight after 5 cycles abrasion (mg)	Abrasion resistance after 5 cycles (%)	Web weight after 10 cycles abrasion (mg)	Abrasion resistance after 10 cycles (%)
Raw	5376	3783	70.36	2134	39.69
A	5633	4401	78.12	3491	61.97
B	5411	4537	83.84	3397	62.77
C	5852	5183	88.56	4013	68.57
D	5874	5396	91.86	4364	74.29
E	5901	4679	79.29	3558	60.29
F	5476	4632	84.58	3467	63.31

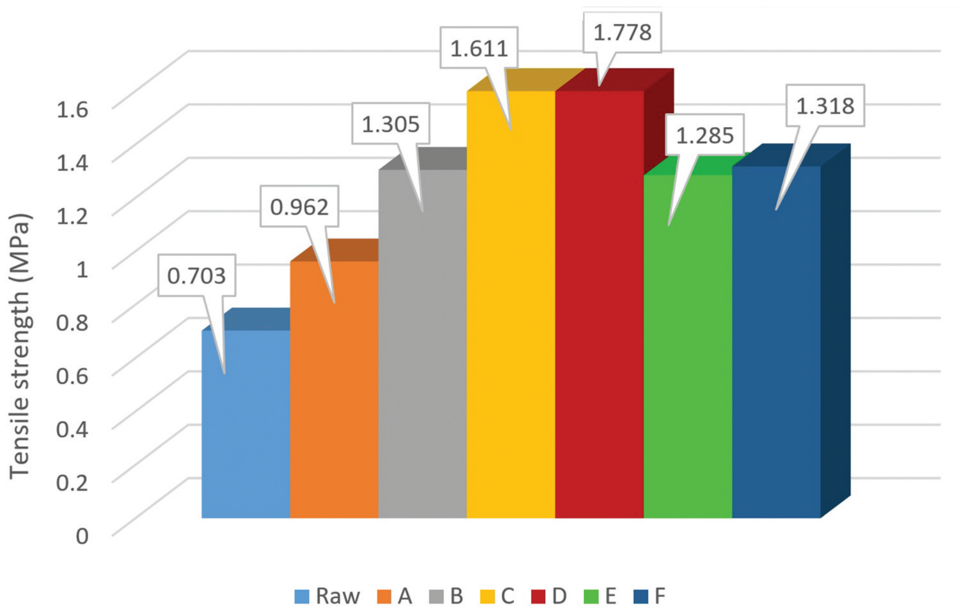


Figure 2. Tensile strength diagram of treated samples.

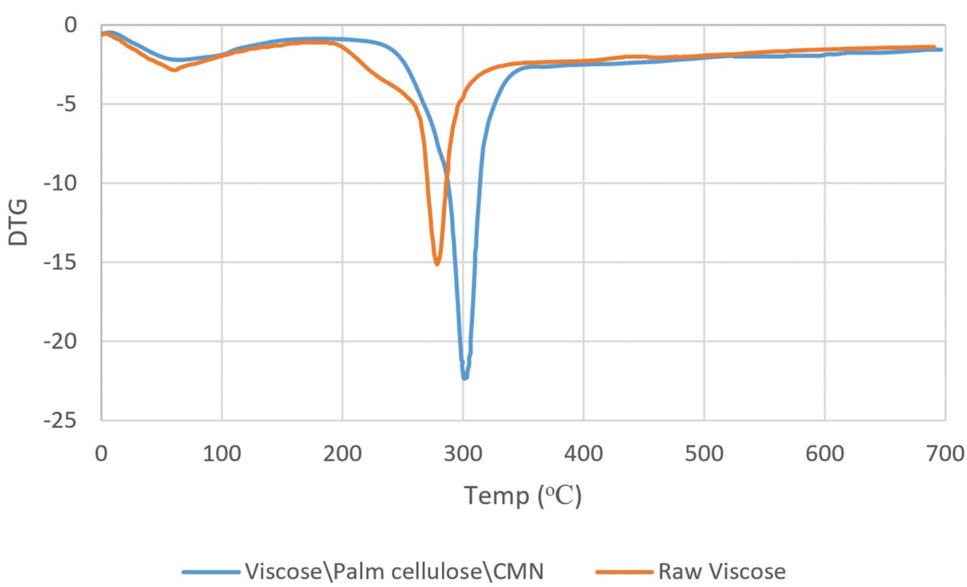


Figure 3. DTG diagram of viscose base samples.

of 240–310°C. Raw viscose began to decompose earlier than the treated viscose based on CMNs compounds. So, these tests proved that the treated viscose has a higher temperature of decomposition than the raw sample.

On the other hand, thermal conductivity of samples were investigated through Equation (1):

$$\lambda = \frac{Q \times E}{S \times \Delta T} \tag{1}$$

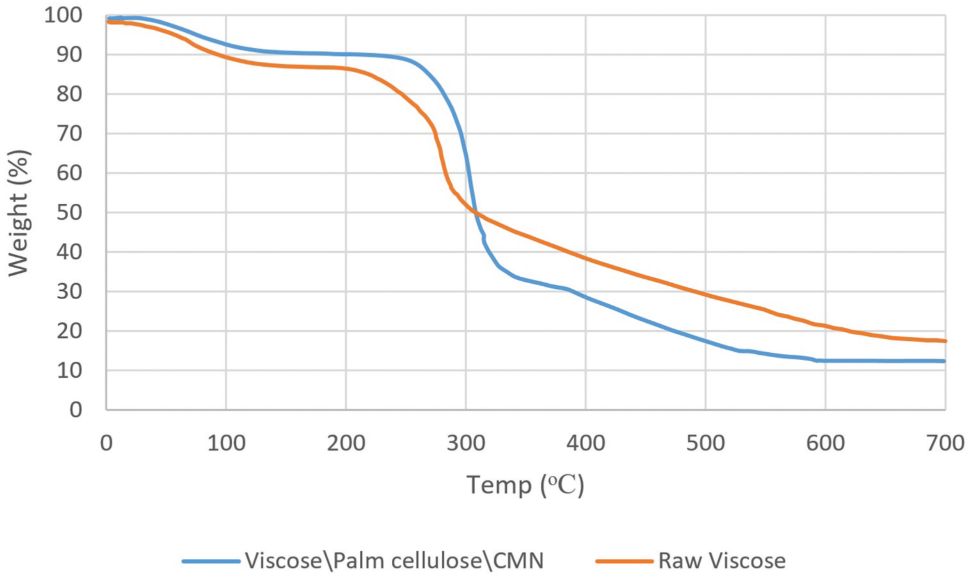


Figure 4. TGA diagram of viscose base samples.

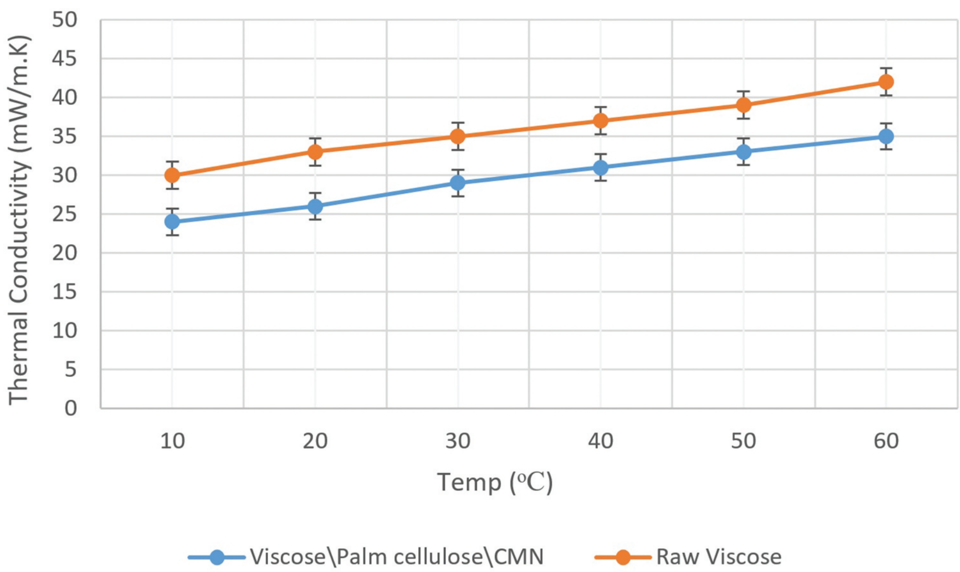


Figure 5. Thermal conductivity of viscose base samples.

where λ is the thermal conductivity (W/m.K), Q is the thermal flux (W), E is the sample thickness (m), S is the section of sample (m^2), and ΔT is the sample temperature difference (K).

The results show that thermal conductivity of viscose\palm cellulose\CMN are lower than raw viscose (figure 5). This can be introduced due to the ability of air moving on raw viscose in comparison to the treated sample, as shown in Figure 6 a layer of palm cellulose\CMN covers the treated sample and causes hard air permeability and as the air is in a good thermal insulation, the thermal conductivity reduced.

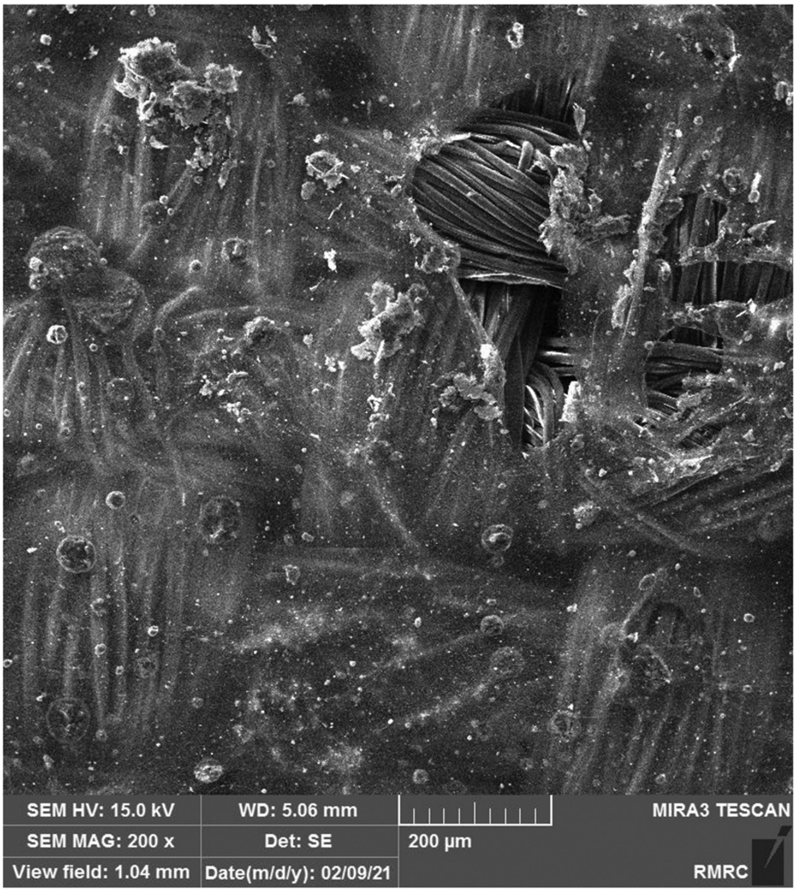


Figure 6. FESEM image of palm cellulose\CMN layer electrospun on viscose fabric.

Air permeability analysis of viscose base samples

Samples of air permeability was investigated by AIR TRONIC (Mesdan Code 3240) through ASTM D737-96 standard. The sample area was 5 cm^2. For each sample, five tests were done. The results showed that the mean air permeability of raw viscose is 163.82 $m^3.m^{-2}.min^{-1}$ and the air permeability of viscose\palm cellulose\CMN is 74.98 $m^3.m^{-2}.min^{-1}$. As shown in Figure 6 the web layer of palm cellulose\CMN, has a good covering of viscose and causes the increase of air permeability resistance. So the composite of viscose\palm cellulose\CMN has excellent resistance to air permeability.

Moisture content of viscose base samples

The moisture content (TH) of raw viscose and viscose\palm cellulose\CMN were calculated due to AATCC-20A standard and was evaluated by Equation (2) as below:

$$TH(\%) = \frac{Wh - Ws}{Ws} \times 100 \quad (2)$$

In this equation, Wh is the weight of the sample after exposure to environmental humidity of 60%, and Ws is the primary weight of the sample after dehumidifying. The result indicates that the moisture content of raw viscose was 11%, but the moisture content of viscose\palm cellulose\CMN increased to 14%. This enhances in moisture content is due to the presence of CMNs, which has absorbent ability.

Conclusion

The focus of this research was on extracting cellulose from palm by a chemical process and doped it with carbon mesoporous nanoparticles (CMNs) and electrospinning it on the surface of viscose fabric as reinforcing it. The properties of the produced viscose\palm cellulose\CMN were investigated and by a good covering of nanoweb, which was proved from FESEM, the thermal resistance was enhanced and air permeability was reduced. Also, due to presence of CMNs, the moisture content of the treated sample enhanced significantly. On the other hand, the abrasion resistance and tensile force of the produced sample were enhanced, which makes this product a good candidate to be used in many applications.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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