STUDIES ON MECHANICAL PERFORMANCE OF CYNARA SCOLYMUS/ POLYETHYLENE TEREPHTHALATE NONWOVEN COMPOSITES

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Abstract

Global warming, energy consumption and the desire to obtain products from renewable sources have led to a resurgence of interest in plant-derived products. Plant fibers with some interesting inherent properties like cost, effectiveness, renewable, available in high quality, have low fossil-fuel energy requirements, and can offer good mechanical properties has attracted it use for composite materials. Hemp, jute, flax, bagasse, coconut fiber, and bamboo are among the natural fibers which has attracted attention because of their low cost compared to synthetic fibers such as glass, carbon etc. Natural fiber reinforced composites are finding successful application in the automotive, electronics, and engineering sectors. In this study, Artichoke (*Cynara scolymus*) fibers are obtained from the West Mediterranean Region of Turkey. Firstly the stem of plant was removed than the fibers were gained. Nonwoven surfaces were obtained at different percentages by to the mix *Cynara scolymus* / polyethylene terephthalate (PET) fibers. The mechanical properties (elongation (%), tensile strength (N), modulus of elasticity (MPa)) of composite materials were investigated. The mechanical properties of non-woven surface composites of *Cynara scolymus*/PET fibers were observed with increases in elongation value, strength value and elasticity modulus values compared to a 100% PET based nonwoven surface. In addition, the contact angle values of nonwoven surface composites based on *Cynara scolymus*/PET fibers were decreased.

Keywords: Cynara scolymus fibers, mechanical properties, nonwoven

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1. Introduction

Natural fibres will take a major role in the emerging "green" economy based on energy efficiency, the use of renewable materials in polymer products, industrial processes that reduce carbon emissions and recyclable materials that minimize waste. Natural fibres are a kind of renewable resources, which have been renewed by nature and human ingenuity for thousands of years. They are also carbon neutral; they absorb the equal amount of carbon dioxide they produce. These fibers are completely renewable, environmental friendly, high specific strength, non-abrasive, low cost, and bio-degradability. Due to these characteristics, natural fibers have recently become attractive to researchers and scientists as an alternative method for fibers reinforced composites and nonwoven materials [1].

Nowadays, natural fibers such as sisal and jute fiber composite materials are replacing the glass and carbon fibers owing to their easy availability and cost. The use of natural fibers is improved remarkably due to the fact that the field of application is improved day by day especially in automotive industries. Nowadays, natural fiber composites have gained increasing interest due to their eco-friendly properties. Many researches have been studied on these natural fibers. Natural fibers such as jute, sisal, silk and coir are inexpensive, abundant and renewable, lightweight, with low density, high toughness, and biodegradable [1]. Table 1 shows the mechanical properties of different types of potential natural fibres for composite applications [2].

The increase in the prices of synthetic fibers due to petroleum as well as the activities aimed to protect the environment have increased the use of vegetable fibers in fabric-based fabric industry. Waste-plant based fibers are used in many countries as reinforcements, especially in the automotive sector due to their volume, strength, porosity, resistance to abrasion and flammability, heat and sound absorption characteristics [3].

PET fiber is one of the most important fibers used to form a nonwoven surface and composite. For example, the lengths of cut are adapted to the respective manufacturing procedure. Fibers are also available in different of luster and cross-sectional forms. They are inexpensive, easily produced from petrochemical sources, and have a desirable range of physical properties. They are strong, lightweight, easily

dyeable and wrinkle resistant, and have very good wash wear properties. Therefore, it is mostly used in nonwoven surface and composite production [4].

Table 1. Mechanical properties of different types of natural fibers for composite application [2].

Natural Fibers	Tensile Strength (MPa)	Elongation at break (%)	Young modulus (GPa)
Flax	300-1500	1.3-10	24-80
Jute	200-800	1.16-8	10-55
Sisal	80-840	2-25	9-38
Kenaf	295-1191	3.5	2.86
Pineapple	170-1627	2.4	60-82
Banana	529-914	3	27-32
Coir	106-175	14.21-49	4-6
Oil Palm	130-248	9.7-14	3.58
Ramie	348-938	1.2-8	44-128
Hemp	310-900	1.6-6	30-70
Wool	120-174	25-35	2.3-3.4
Spider Silk	875-972	17-18	11-13
Cotton	264-800	3-8	5-12.6

Cynara scolymus L. (CS), usually known, as globe artichoke is a wintery plant with lignocellulosic content and a perennial, strong root structure, growing longitudinally, with a hard and grooved body, and growing in a temperate and humid climate. Spain, France, Italy, Greece, Turkey, Israel, USA, Argentina and Egypt are the most artichoke-producing countries. During the industrial processing of artichokes, 80-85% of the plant is not used and is separated as solid waste. A total of 36,368 tonnes / year [5] *Cynara scolymus* production is being made in Turkey, especially in the Aegean, Marmara and Mediterranean regions with a total area of about 2900 cultivation area. After collection, 2.7 ton / da waste is left on the field. World countries *Cynara scolymus* production and planting, according to FAO data as of 2016 are given in Table 2 as tons / year and (ha) [6].

Table 2. *Cynara scolymus* production in the world countries [6].

Country	Area (ha)	Production (tons)
Italy	48 838	365 991
Egypt	12 485	236 314
Spain	14 025	185 796
Peru	6 093	108 801
Argentina	4 769	107 257
Algeria	5 167	97 139
China	11 806	85 532
France	7 832	45 914
USA	2 750	44 720
Morocco	2 981	44 144
Turkey	2 823	36 368
Greece	1 518	13 211

In Table 3, where the physical properties of *Cynara scolymus* body waste fibers are given in comparison with other lignocellulosic fibers, it is stated that their mechanical behavior is similar to sisal, kenaf and hemp fibers. It is therefore possible to conclude that these fibers can be used as alternative reinforcing elements in polymer-based composite structures such as other lignocellulosic fibers [7].

Table 3. Mechanical properties of lignocellulosic fibers [8-9].

Fiber	Fiber diameter (μm)	Tensile strenght (MPa)	Young Modulus (GPa)
Sisal	50-200	80-640	1.46-15.8
Cotton	17	400	5.5-12.6
Flax	30-110	450-600	27.5-38
Hemp	53.7	690-873	9.93
Jute	25-200	393-773	2.5-26.5
Kenaf	43.3-140	223-624	11-14.5
Artichoke	300	100-300	6-18
Okra	40-180	234-380	5-13
Ramie	34	400-698	24.5-128

In this study nonwoven composites were produced at different percentages by to the mix *Cynara scolymus* / polyethylene terephthalate fibers. The mechanical properties (elongation (%), strength (N), modulus of elasticity (MPa)) and contact angle values of composite materials were investigated.

2. Experimental

A. Materials

Artichoke plants are obtained from the West Mediterranean Region of Turkey. A specially designed machine mechanically separated the fibers of the *Cynara scolymus* plants. *Cynara scolymus* fibers are cut into lengths of 50 mm with guillotine. The *Cynara scolymus* fibres were washed with water to remove the adhering dirt (20 °C distilled water for 5 min). After treatments they were conditioned for 48 hours prior to testing under 20 ±2 °C and 65 ±2 %RH conditions. *Cynara scolymus* fibers are shown in Figure 1.



Figure 1. Artichoke (*Cynara scolymus*) fibers.

B. Cynara scolymus fiber/PET Composite Production

Cynara scolymus used in composite construction was combined with PET fibers (75/25 %, 25/75 %) in two different percentages. *Cynara scolymus* fibers and PET fibers have been combed and needle punched for the production of nonwoven surfaces. Nonwoven production methods were preferred to produce nonwoven fabric from wasted *Cynara scolymus*/PET fibers. The nonwoven fabric production was carried out at two steps as a web forming. A wool-type carding machine for forming webs from wasted *Cynara scolymus* fibers and PET fiber a needle-punching machine for bonding of the webs were used. The needle-punching operations were carried out using low capacity machines instead of laboratory machines (CFS1/ 1000 mm, 650 m/min) to bond staple

fibers better. Firstly, wasted *Cynara scolymus*/PET fibers were opened and mixed manually. The webs from wasted *Cynara scolymus*/PET fibers a wool-type carding machine were formed. Parallel-laid webs were obtained. The circular drum was used to collect the web from the carding machine instead of the cross lapper. Then, the webs were fed into the needling machines. After needling, the nonwoven fabric production was completed. The needle-punching machine parameters of all needle-punched fabrics barbed needles were used for all needle-punching machines. The punch densities of the needling machine were held constant at 75 punches per cm^2. For needled fabric, 75 punches per cm^2 were applied. The needle penetration depths were 0.50 cm at the needling machine. The weights per unit area of the produced needle-punched nonwoven fabrics were approximately 50 g/m^2 (Table 4).

Table 4. Working parameters of the needle-punching machines.

Needle penetration depth (mm)	0.50
Feeding speed of needle-punching machines (m/min)	2.1
Delivery speed of needle-punching machines (m/min)	3
Needle-punching speed (rpm)	360
Needle punch density per cm^2 (punches/cm^2)	75

C. Contact Angle Measurement

The contact angle values of the fabric samples were measured by using PG-X Measuring Head Pocket Goniometer test device as specified in ASTM D5725-99 method.

The contact angle will be less than 90° on a hydrophilic surface. If the surface is hydrophobic the contact angle will be greater than 90°.

D. Measurement of Mechanical Properties

Using Instron 4411 according to ASTM D638-91 tested mechanical properties of the composite structures. Testing of the composites on Instron 4411 are shown in Figure 2.



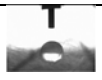
Figure 2. Testing of *Cynara scolymus* / PET nonwoven composite.

3. Results and Discussion

A. Contact Angle Measurement Results

The contact angle of water droplets on fabrics can be seen in Table 5. When the contact angle values were examined, it was determined that 100% PET nonwoven surface was hydrophobic, *Cynara scolymus* mixed PET nonwoven surface was hydrophilic.

Table 5. The contact angle water droplets on *Cynara scolymus*/PET nonwoven composite.

Samples	Time (s)				
	0	0.1	0.2	0.3	0.4
100 % PET Nonwoven Materials					
	143.8°	143.6°	144.3°	142.9°	143.4°
75/25 % *Cynara scolymus*/PET					
	76.2°	81.8°	81.6°	79.2°	80.0°
25/75 % *Cynara scolymus*/PET					
	71.7°	69.7°	67.6°	65.1°	65.4°

B. Results of Mechanical Testing

The tensile strength (N), elongation (%) and Young Modulus values of the mixed (75/25 % and 25/75 %) *Cynara scolymus*/PET composites and 100 % PET nonwoven surface are shown in Figure 3-5, respectively. The incorporation of *Cynara*

scolymus/PET nonwovens in virgin PET nonwovens results in a general increment of mechanical properties.

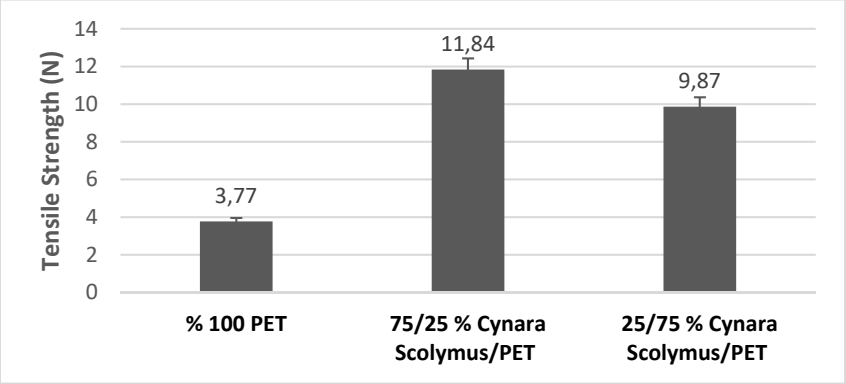


Figure 3. Tensile strength values of nonwoven composites.

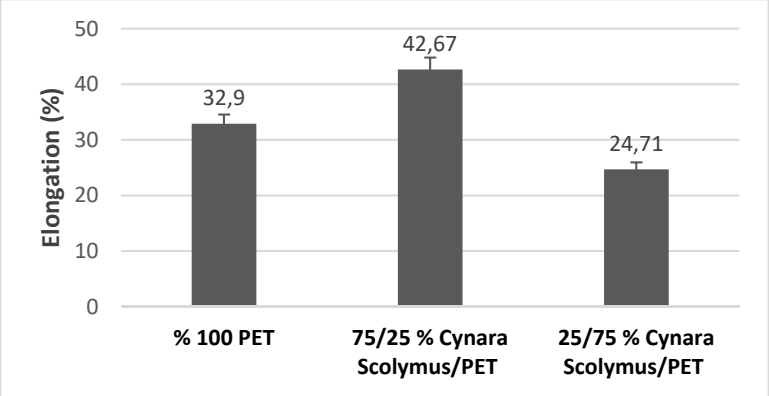


Figure 4. Elongation (%) values of nonwoven composites.

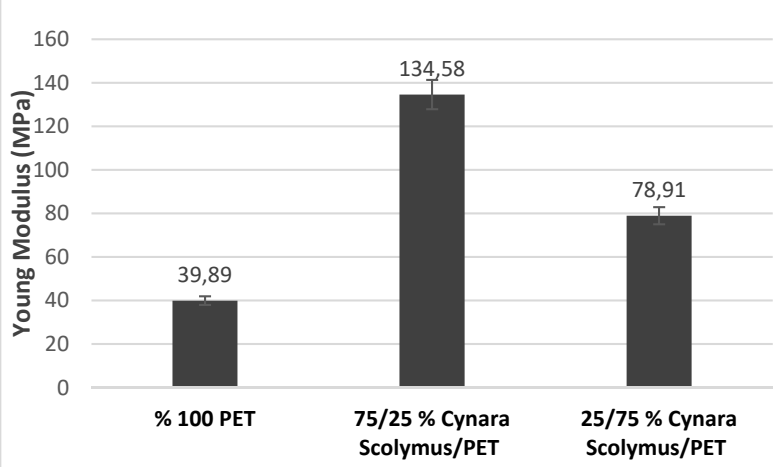


Figure 5. Young modulus values of nonwoven composites.

4. Conclusion

The effects of fiber content and fiber orientation on mechanical and contact angle properties for *Cynara scolymus* were studied in this research work. The study revealed that the fiber content strongly influences the mechanical and water absorption property of nonwoven composites. Amount of the *Cynara scolymus* fiber influence the mechanical properties, but it strongly influences the water absorption property of composites.

The 75/25 % *Cynara scolymus*/PET composite has shown better mechanical and lower water contact angle values. This composite structure is the more hydrophilic sample than the other samples.

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