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Alginic/Stearic/Octadecane as Phase Change Material (PCM) for Enhancing the Thermal Comfort-ability of Different Polyester Fabrics Constructions

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Abstract

One of the most extensively used textile materials is polyester, which comes in a variety of textile, yarn, and fiber forms. This is dependent on the characteristics of the polyester polymer and its intended usage of it. To give different polyester fabrics, the ability to change their thermal state over a wide range and be used for thermal protection for a variety of purposes, regardless of ambient temperatures, this research aims to improve the thermal heat profiles for those fabrics when constructed with Phase Change Material (PCM). To create PCM composite treatment materials, various polyester fabric constructions were simply treated utilizing Octadecane as PCM-loaded - loaded on alginic/stearic acid. Following treatment with the KES thermal conductivity system and Differential Scanning Calorimetry (DSC), the textiles' qualities were assessed, and their physico-mechanical properties were also looked at. Conclusion: Polyester textiles can be coated with PCM composites, and the covered version performs better than the uncovered version. Additionally, it was found that these treatments improved the mechanical and physical qualities but had no effect on the permeability to air and water vapor following examination of the attributes of blank/uncovered and covered polyester textiles.

Keywords: Polyester, Octadecane, Phase Change Material (PCM), Thermal profile

1. Introduction

Climate change can be a natural process where temperature, rainfall, wind, and other elements vary over decades or more. For millions of years, our world has been warmer and colder than it is now. But today we are experiencing rapid warming from human activities, primarily due to burning fossil fuels that generate greenhouse gas emissions. Increasing greenhouse gas emissions from human activity act like a blanket wrapped around the earth, trapping the sun's heat and raising temperatures. Examples of greenhouse gas emissions that are causing climate change include carbon dioxide and methane. These come from burning fossil fuels such as gasoline for driving a car or coal for heating a building. Clearing land and forests can also release carbon dioxide. Landfills for garbage are another source. Energy, industry, agriculture, and waste disposal are among the major emitters.[1]

Heat is the form of energy that can be transferred from one system to another due to a temperature difference or gradient. Heat is a vector quantity, flowing in the direction of decreasing temp, with a negative temp. Gradient. The thermal energy transfer that will occur across a medium, which may

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be a solid or fluid due to a temperature difference [2]. Any material that is heated absorbs heat while its temperature is rising constantly. Through the process of reverse cooling, heat that was trapped in the material is released into the environment. The temperature of the material decreases constantly, during the cooling process [3].

Since the late 1980s, a new type of insulation material has appeared on the market, phase change materials (PCMs). Integrated into textiles, they can improve their thermal behavior. PCM materials are characterized by the fact that they store energy temporarily, as they store energy temporarily, whether at high or low temperatures, for later use. So that it is distinguished that it moves from one physical state to another. Latent heat is the thermal energy that can be stored by altering a material's phase at a constant temperature. The thermal properties of phase change materials allow them to be perceived as the material of choice for thermal insulation of the human body. The possibility of keeping the wearer in as long as possible in his thermal comfort zone. Therefore, a product ideally having a thermal window from 19°C (vasoconstriction temperature) to 37°C should contribute to localized thermal regulation. Phase Change' is the process of going from one state to another, e.g. from solid to liquid. Standard phase change materials (PCM) are generally a polymer/carrier filled with thermally conductive filler.[4]

So this study aims to achieve adaptation to high temperatures by covering polyester fibers with a PCM composite material prepared to have the ability to change the phase state, which provides a special and new feature for polyester fibers, which is the property of thermal stability. After PCM treatment, polyester fibers exhibit intelligent thermal stability over a range of ambient temperatures.

As a result, it is more suitable for padding and sandwich panels with a variety of thermal applications for stability and insulation.

Wax compounds known as phase change materials, such as octadecane, have the unusual ability to absorb and expel heat energy without changing the temperature, which possesses freezing and melting points of 25.4 and 28.2°C respectively and when combined in a microcapsule, heat energy will be stored and released, keeping the mixture's temperature in the range of 30-34°C, which is quite cozy for the body.

There are several techniques to integrate the encapsulated PCM with melted polymer fiber, including a) microcapsules, where the PCM microcapsules are firmly anchored inside the fiber structure during the spinning process, b) padding by matrix coating during the finishing process of fibers, yarn, or fabrics; in this method, PCM microcapsules are embedded in a coating material such as acrylic, polyurethane, etc, and c) printing by foam dispersion, in which microcapsules are combined with a water-blown polyurethane foam mix and applied, with the water being drawn out of the system as the fabric dries.

Polyester is one of the textile materials that are used in technical products like ropes, tire reinforcement, safety belts, tapes, and fabrics for conveyor belts and plastic reinforcements with high energy absorption. Polyester is soft and strong, resistant to shrinkage, and does not stretch. It is a polymer that is produced from coal, water, air, and petroleum products. Polyester is a category of polymers that contain the ester functional group in their main chain [5].

Polyester fabrics, specifically poly(ethylene terephthalate) (PET) fabric, are the largest volume of synthetic fabric produced worldwide. The total volume produced in 2016 exceeded 50 million tons with a rate of growth far greater than any other fiber, natural or synthetic. Low cost, convenient processability.

By covering the polyester fabric with PCM composite materials designed to have the capacity to alter phase state, this work seeks to impart the distinctive and novel attribute of thermal stability to those fabrics. Following PCM treatment, the polyester fabrics exhibit intelligent thermal stability with a range of ambient temperatures. As a result, they are more suitable for a variety of thermal applications for stability and isolation.

2. Experimental
2.1. Materials and Methods
2.1.1. Chemicals

Sodium alginate medium molecular weight was purchased from Fluka. Stearic acid, sodium lauryl sulfate, dichloromethane (DCM), dicyclohexyl carbodiimide (DCC), potassium carbonate (K_2CO_3), and octadecane were purchased from Sigma-Aldrich.

2.1.2. Fabric Manufactured
2.1.2.1. Textile machine specification

The fabrics were equipped at the Faculty of Applied Arts, Helwan University, with the following machine's specifications:

Machine type= Smit
country of manufacture= Italia
manufacturing year=2008
Machine width= 190 cm (comb width)
machine speed= 300 strokes/minute
Weft thread passage= Using elastic tapes (rapier)
Selector (meat selection) = 8-fingered

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2.1.2.2. Jacquard specification

Jacquard devise type= Electronic stubli jacquard
Jacquard strength=3072 Shankle
The number of design hooks=2560 Shankle
The number of iterations=4 iterations
The number of network iterations=35.5 cm
Canvas width without brace=142 cm
Network construction method= parcel
Poison wicking number=72 wick/cm
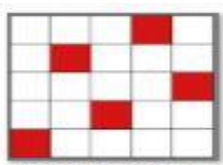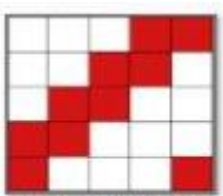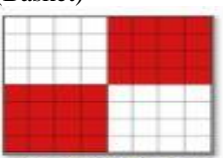used comb= comb(8×9)
sada number=150\1 Quilted denier polyester
stamen colors= One color is dammed white

2.1.3. Fabric specification

Four different polyester fabric construction were prepared at the Faculty of Applied Arts, Helwan University, with the following specifications listed in **Table 1**.

Table 1: polyester fabric weaving construction

Fabric	Code	Construction	Weft density per cm	Weft No	Weight (g/m^2)
Polyester	A1	Atlas 5 weft STRACTURE OF A1 SAMPLE (SATEEN 5)	23	300/1 dyne	206.2
polyester	A2	2/3 Twill STRACTURE OF A2 SAMPLE (TWILL 2-3)	23	300/1 dyne	206.2
polyester	A3	2/2 thread in both directions (Basket) STRACTURE OF A3 SAMPLE (BASKET 2-2)	23	300/1 dyne	206.2
polyester	A4	4/4 thread in both directions (Basket) STRACTURE OF A4 SAMPLE (BASKET 4-4)	23	300/1 dyne	206.2

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2.2. Method
2.2.1. Synthesis of anhydrous fatty acids

Anhydrous fatty acids were prepared according to the method reported before by Hassabo and Mohamed. [6] In brief, 10 g of stearic acid dissolved in 2 ml of dichloro methane is mixed, stirred well, and placed in an ice bath in an argon atmosphere. Then dissolve 5 g of dicyclohexylcarbamide in dichloromethane, then add the mixture to it and continue to stir in an ice bath for two hours, and the precipitated part will be separated through the filtering process, and the solvent will be evaporated to give us the anhydride [7, 8].

2.2.2. Synthesis of alginic acid ester

Alginic acid ester was prepared according to the modified method reported before by Hassabo and Mohamed. [6] In brief, 10 g of alginic acid is used with 10 g of anhydride, they are grinded well, and this mixture is heated for a period of 15 minutes to 25 minutes at a temperature of 160°C, then left to cool at room temperature. Then it is washed with the resulting chloroform, obtained ester was dissolved in water and the pH Was adjusted to neutral. The final solution was dialyzed in deionized water for 1 day and finally lyophilized for 2 days [7, 8].

2.2.3. Synthesis of PCM composite based on alginic/fatty acid ester

PCM compounds are prepared by mixing alginic acid ester with paraffin compounds (n-octadecane) in a molar ratio (2:1) polymer to paraffin at a temperature of 110°C for 4 hours. [9]

2.2.4. Fabric treatment

The treatment solution was prepared as follows 10 % (w/w) alginic/stearic/octadecane composite was dispersed in 100 ml hot water (80°C) in presence of tween 80 2 g/l as surfactant. The solution was homogenized using a homogenizer for 15 min at 20000 rpm. Then the fabrics were treated with treatment solution using the pad-dry-cure method by immersing them in the treated bath for 15 min at 80°C and then squeezed with 100 % wet pickup, after that, the fabrics were dried in an air oven at 100°C for 5 min.

2.3. Measurements and Analysis

Fourier Transform Infrared Spectroscopy (FT-IR) analysis was utilized to evaluate the phase change materials and their composite to analyze the chemical alterations and interaction phases. Based on the FTIR spectrometer model (JASCO FT-IR-6100), the FTIR spectrum was measured using the ATR technique,

and the spectral range of 4000-400 cm^{-1} was recorded.

The differential scanning calorimeter analysis was carried out using a DSC 131 Evo (SETARAM Inc., France) device. the standards were used to calibrate the instrument (Mercury, Indium, Tin, Lead, Zinc, and Aluminium). The purge gases employed were nitrous oxide and helium. The test was set up to include a heating zone with a temperature range of 25 to 100°C and a heating rate of 10°C per minute. The samples were weighed using 120 ul of the aluminum crucible.

A parameter used to describe a material and the temperature at which it is intended to function is called the duration index (DI) (J/cm^3/K). Equation 1 serves as a gauge to determine the duration of a PCM during a phase transition at a constant temperature.**[10]**.

$$DI = \Delta H \rho / \Delta T \qquad \text{(Eq. 1)}$$

Where T is the temperature difference between the temperature of interest and the measured temperature, H is the enthalpy of PCM change of state, and PCM is the density (ambient, or body temperature).

Equation 2 relates the textile material on which PCM is applied to the overall resistance to dry heat transfer (R), which is the insulation value of clothing systems;

$$R = (\Delta T \times A)/H, \qquad \text{(Eq. 2)}$$

Where; A: Areal Material, Temperature Difference between Material's Two Sides, T = TF - TR (Material's Front and Rear), and Heat Flow (H). The unit for clothing insulation adopted from studies of hygienic comfort is "clo" (m^2.°C/W), where 1 clo = 0.155 m2.°C/W (zero (0) clo corresponds to a person in a typical business suit and one (1) clo corresponds to a person wearing a naked body). **[11-13]**.

Thermal Conductivity Measurement and Q-max Measurement (warm/cool feeling).

Fabric Samples. Three fabric samples from each fabric type before and after treatment were obtained and claimed to have a quick dry function. The samples were used as received and their fabric information was summarised in **Table 1**. Before measuring the thermal property of the quick dry. They were conditioned according to ASTM D1776.

Thermal conductivity refers to the ability of heat transfer through the fabric. In this study, thermal conductivity was measured according to the standard of KES-F7. The thermal conductivity of fabric can be calculated by using the following equation: [14]

$$k = \frac{W \times D}{A \times \Delta T}$$

Where k = thermal conductivity (W/cm · °C); W = Heat flow (W); D = average thickness of

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samples; A = area of heat plate = 25 cm^2; ΔT = Temperature difference = heat plate temperature (30°C) – cooling base temperature (20°C) = 10°C.

To convert it into SI unit (W/mk): KSI (W/mk) = k x 10^2

Q-max Measurement (warm/cool feeling). Q-max is the index indicating the coldness and warmth feeling which affects the sensation of coldness or warmth of skin touching the fabric. It is determined by the heat loss from the skin to the fabric.

Tensile strength and elongation at break are conducted on a tensile strength apparatus type FMCW 500 (Veb Thuringer Industrie Werk Rauenstein 11/2612 Germany) at 25°C and 65 % relative humidity according to the ASTM Test Method D5035-2011. [15] The dry crease recovery angle (CRA) was measured according to AATCC Test Method 66 – 2014. [16] Fabric roughness was measured using Surface Roughness measuring instrument SE 1700 using ASTM Test Method D 7127 – 13. [17] Stiffness was performed using the cantilever apparatus according to ASTM test method D 1388-14e1. [18] Air permeability (AP) was evaluated according to ATSM (D 737-96). [19] Water vapor permeability (WVP) was evaluated according to ATSM (E96/E96M − 16). [20]

3. Results and discussion
3.1. Characterization of synthesized composite
3.1.1. FT-IR analysis

Utilizing FT-IR, alginate stearate was characterized. **Figure 1** shows the IR spectra of alginate, stearic acid anhydride, and alginate stearate. Alginate's FT-IR spectra exhibit peaks at 2932 cm^{-1}, which are associated with -CH stretching peaks. Additionally, another peak was identified as a CH$_2$ peak at 1357 cm^{-1}. Additionally, **Figure 1** supported the addition of a stearic acid anhydride to alginate for chemical modification. Following are some examples of how FT-IR spectra reveal chemical alteration for stearate of alginate: O-H: 3438 cm^{-1}, C-H: 2915 and 2842 cm^{-1}, C=O: 1747 cm^{-1} (methyl ester), C=O: 1694 cm^{-1} (fatty acid ester), COO: 1627 cm^{-1} and COO: 1433 cm^{-1}, and C-O: 1204 and 1147 cm^{-1}. [21]

3.1.2. DSC Analysis

Table 2 shows the DSC data for manufactured composites with and without Octadecane composite, alginate, stearic acid, and Octadecane (PCM material) (PCM). **Table 2** makes it obvious that the inclusion of alginate in the finished composite form causes the latent heat of the hosting materials to be increased. The biopolymer's melting point was also dropping when it reacted with stearic acid, and it continued to drop once Octadecane was added. The ultimate melting temperature complied with phase.

Based on the information in **Table 2**, the DI values of the Octadecane-produced composite indicate that it can be organized to protect the body from the changed temperature in the environment.
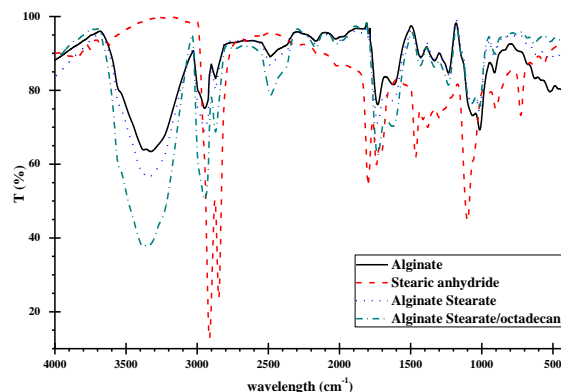

Figure 1: FT-IR spectra of hosting materials with/without Octadecane

Table 2: DSC data for hosting materials with/without Octadecane from 2nd heating

Hosting materials	T$_o$ (°C)	T$_p$ (°C)	ΔH (J/g)	DI * (J/cm^3.K)
Alginate [22]	251.1	288.32	43.24	
Stearic acid [23]	65.2	69.7	166.52	
Octadecane [9]	29.3	33.4	241.44	
Alginic Stearate	30.14	36.11	57.92	6.75
Alginic/ Stearate/Octadecane	31.56	40.22	192.38	35.62
Duration index: based on ΔT from melt point to body temperature (37°C) and average density of 0.8 g/cm^3				
T$_o$: Onset Temperature, **T$_p$**: Keeping Temperature, **ΔH**: Enthalpy				

3.2. Characterization of treated fabrics
3.2.1. Differential scanning calorimetric (DSC)

Through convection, radiation, and skin evaporation, heat is lost to the environment. The DSC results of polyester fabric coated with alginate/stearic acid and octadecane are shown in **Table 3**. In comparison to uncovered polyester fiber, it has been found that covered polyester fabric in these composites imparts the thermo-regulating capability (Blank) and the latent heat that sweat produces. The crucial task of textiles in terms of thermal protection is to create a constant microclimate next to the skin to support the body's or any surface's demand for thermoregulatory behaviour [24]. When textile clothing is combined with PCM material, the current insulation feature of the structure can provide an improved warm thermal capacity while maintaining comfortability.

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The polyester fabric was wrapped in PCM composite material to improve the thermal insulator properties and reduce temperature changes. A practical technique to store and release heat while adjusting the surrounding temperature is to use PCM materials [6, 25-27].

More so than covered polyester with Alginate/Stearic offers higher latent heat. Alginate/Stearic acid/Octadecane composite-coated polyester fibers are more pleasant than those uncoated, according to calculations of the overall resistance to dry heat transfer. Finally, it can be concluded that polyester fibers can be covered with PCM composites, and the covered fibers produce better results than their uncovered counterparts.

3.2.2. Thermal Conductivity Measurement

Table 4 displays the thermal conductivity of variously constructed polyester textiles. A1, A2, A3, and A4 have almost comparable thermal conductivities, with A4 having a much higher thermal conductivity than the other three. A4 has a maximum thermal conductivity of 0.083. The specifications of the cloth weave may be able to explain the cause. The only fabric characteristic impacting heat conductivity is thickness because all of the manufactured textiles have the same weight and density. The information in **Table 4** makes it evident that impact.

According to reports, heat conductivity declines as cloth thickness increases [28-30]. Additionally, the primary element that influences a fabric's heat conductivity is its porosity. Large pores are conducive to trapping more air, which is an excellent heat insulator. The cloth with larger pores hence often exhibits superior heat conductivity. A looser structure in thicker fabric traps air inside the gaps. The thicker cloth exhibits superior thermal insulation and lower heat conductivity as a consequence.

The cloth has superior thermal conductivity the higher the rating for thermal conductivity. The maximum thermal conductivity was shared by A1 and A2, whereas A4 had the lowest. This shows that the products with A1, A2, and A3 had the fastest drying properties, however, A4 products were a poor option.

Q-max Evaluation (warm/cold sensation). The machine can directly determine Q-max, and a greater Q-max value indicates a colder initial contact sensation. For four samples (A1, A2, A3, and A4), the Q-max values are 0.137, 0.112, 0.127, and 0.083, respectively. As can be observed, Brand C had the lowest sample with a Q-max value shows that A1, A2, and A3 fared better in terms of warmth/cold sensations, which may be explained by their fabric characteristics.

The statistics in **Table 4** indicate that as fabric thickness grows, so does its Q-max. The fabric may have a densely packed structure and high walls or courses per inch due to its high thickness. A tightly woven fabric might offer a smooth surface that increases the cloth's touch with the skin. As a result, body heat may be easily transmitted to the environment, and touching can make it seem colder.

Additionally, prepared PCM was used to treat the textiles. Polymer-containing materials are crucial in the process of reducing fabric thickness because they generate a thin layer on the surface of the fabric, reducing both its thickness and thermal insulation. But because prepared materials can retain temperature, all treated fabrics now have better thermal insulation properties.

Since it imparts a cooling sensation when in contact with human skin, the initial touch sense suggested by Q-max is crucial. In this study, treated polyester textiles all have a cooler hand feel and are thus better for clothing than untreated ones.

Table 3: DSC, Duration index, and Total Resistance results of covered polyester fabric with PCM composite material (Alginate/Stearic acid/Octadecane composite)

	Sample description	T_o (°C)	T_p (°C)	ΔH (J/g)	DI * (J/cm^3K)	R ** (clo)
A1	Uncovered/ Blank	32.90	33.00	0.732	0.14	0.513
	Treated	33.91	37.45	64.296	16.65	0.013
A2	Uncovered/ Blank	35.53	35.64	0.618	0.34	0.375
	Treated	36.46	43.57	74.810	109.81	0.005
A3	Uncovered/ Blank	34.74	34.85	0.604	0.21	0.373
	Treated	36.68	40.51	69.553	175.26	0.011
A4	Uncovered/ Blank	34.48	34.62	0.773	0.25	0.206
	Treated	34.93	41.19	113.630	43.89	0.004
* Duration index: based on ΔT from melt point to keeping temperature and average density of 0.8 g/cm^3						
**R: Total Resistance to Dry Heat Transfer						
To: Onset Temperature, **Tp**: Keeping Temperature, **ΔH**: Enthalpy						

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3.2.3. Evaluation of comfortability

The performance of some textile fabrics is greatly influenced by their air permeability. Particularly, it is considered for materials used in garments, parachutes, vacuum cleaners, airbags, and industrial filters. The weight and construction (thickness and porosity) of the cloth have a significant impact on its air permeability.

Warp and weft strands are interlaced to create woven fabrics. The weft (or filling) spans the width of the cloth whereas the warp is located along its length. Each warp yarn is kept apart from the rest. As a result, the warp is made up of numerous different threads that are fed into the weaving machine. The weft yarn, on the other hand, is typically woven into the cloth one length at a time [31].

The fabric has spaces between the weft and warp strands. Several consumer and industrial uses, such as clothing comfort, flammability, thermal insulation effectiveness, barrier fabric performance, and the accuracy of filter media, are significantly influenced by the void volume of a textile fabric [32].

Air permeability in woven textile materials is caused by the void volume. The velocity of airflow through a material under a pressure difference between the two fabric surfaces determines a textile's air permeability [33]. 10 mm of water is required as the prescribed pressure differential [34, 35]

The number of warp and weft yarns per centimetre (or inch), the degree of twist in the yarns, the size of the yarns, and the type of yarn structure are some of the parameters that affect a fabric's ability to breathe [36]. Therefore, developing a more intricate theory that expresses how the air permeability of all fabric properties is related will result in difficulties.[37]

In daily life, textiles are a material that is heavily utilized. Direct outdoor use of textiles, even synthetic ones like polyester, for weather protection and waterproofing, on the other hand, requires surface treatment or multilayer approaches [38, 39].

These materials are particularly unsuitable for weathering due to their inherent hydrophilicity and structural instability upon contact with water [40]. The most prevalent methods described in the literature include fluorine or silicone chemistry with the immobilization of nanoparticles (such as SiO_2, ZnO, or TiO_2) on fiber surfaces [41-45]. The surface free energy of fluoropolymers, especially those with C-8 fluorinated side chains, is extremely low (18 dynes/cm) [46].

Technical textile manufacturing has seen a phenomenal increase in recent years, which has unmistakably positioned this branch as one of the most promising and active areas for the future of the textile industry. Polyethylene terephthalate (PET), a semi-crystalline thermoplastic polyester, is one of the fibers that are most frequently utilized for the creation of technical textiles. It has great mechanical attributes, is reasonably affordable, has high durability and dimensional stability, is simple to process, and is very resistant to chemical and environmental attacks. Despite these advantageous traits, PET exhibits several drawbacks, including hydrophobicity, poor dyeability, electrostatic charge accumulation, pilling tendency, finishing challenges, and inadequate washability related to its hydrophobic nature [47-49].

Furthermore, PET could not be secure in the event of a fire because Between 249 and 290°C, it melts. Thermal degradation of chemical changes at the pyrolysis temperature (Tp) during combustion. CO, CO_2, H_2O, acetaldehyde, benzoic acid, terephthalic acid, acetic acid, hydrocarbons (CH_4, benzene), vinyl benzoate, and divinyl terephthalate are the primary pyrolysis products of PET. Additionally, molten PET can leak and be highly damaging to human skin and underneath surfaces; additionally, the heat from this molten polyester might quickly ignite flammable objects in the region, adding damage.

Table 4: Thermal conductivity for different samples before and after treatment

		Thickness (cm)	Q_{max}	Heat flow (W)	Thermal conductivity (mW/cm²)
A1	Blank	0.042	0.135	3.18	0.053
	After treatment	0.053	0.137	2.81	0.059
A2	blank	0.045	0.082	2.51	0.045
	after treatment	0.062	0.112	2.4	0.059
A3	blank	0.044	0.105	2.44	0.043
	after treatment	0.057	0.127	2.51	0.058
A4	blank	0.056	0.06	1.73	0.039
	after treatment	0.094	0.083	1.5	0.056

Due to these limitations, research teams are looking for flame-retardant (FR) compounds for polyester fabrics that can both provide flame resistance and alter the burning behaviour of these synthetic items. The primary methods for adding flame retardant properties to PET involve embedding a halogenated phosphonate or related chemicals during extrusion, adding halogen- and/or phosphorus-containing comonomers to the polymer structure during copolymerization, and, finally, treating PET fabrics with flame retardants during finishing or coating procedures [50]

Halogens and phosphorus compounds limit free radicals and decrease the availability of fuel by forming a protective char barrier; nonetheless, fabric surface treatment has been widely employed for PET materials due to its relative ease of use and low cost in comparison to the other two procedures.

Due to its greater environmental friendliness, magnesium hydroxide has replaced halogen-based flame retardants in numerous applications. Their endothermic degradation and water release, which results in cooling, are among the main benefits. dilution effects, etc.

These substances function in both the condensed and gaseous phases. When they disintegrate, they release water into the gas phase, which cools the flame and results in a decrease in polymer temperature. Additionally, they serve as catalysts for the oxidation of carbonaceous waste products, which lowers the CO/CO_2 ratio. Additionally, the oxides created by the breakdown may help generate an insulating charred layer that provides additional protection for the polymer

Figure 2 represent the air permeability and water vapor permeability of treated and untreated fabrics and the data providers that, both examined parameters were decreased upon treatment but still in the acceptable value. This proves that the treatment didn't affect the parameter affect the fabric comfortability.
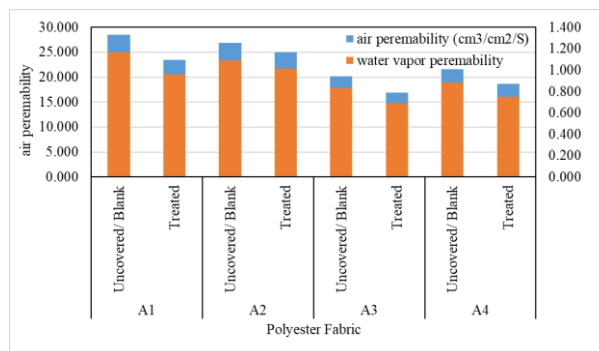

Figure 2: air permeability and water vapor permeability of treated and untreated/blank fabrics

3.2.4. Mechanical and physical performance

Before and after being treated with PCM composite material, the tensile strength, elongation at break, roughness, and crease recovery angle of polyester textiles in the warp and weft directions were tested. The findings are shown in **Table 5**. As was shown, the various fabric architectures have a favourable impact on textile textiles. **Table 5** demonstrates how variations in the physico-mechanical characteristics of textile materials result from different fabric structures. The treatment significantly raised the tensile strength and elongation at the break while only marginally enhancing the crease recovery angle and fabric roughness. This suggests that the hosting polymer material (alginic/stearic) was thoroughly incorporated into the microstructure of the textile fabrics, resulting in a thin coating layer on the fabric's surface that was in charge of the observed modifications. [51-54]

The enormous rise in the crease recovery angle was most likely caused by the covalent chemical bonding, which also resulted in the formation of an intense network with a high degree of cross-linking.

Table 5: mechanical and physical properties of treated and untreated fabrics

Sample description		Tensile strength (kg.f)	Elongation at break (%)	Young's modulus (kg.f/mm^2)	Roughness (µS)	CRA (°)
A1	Uncovered/ Blank	57.41	39.3	34.34	17.23	115
	Treated	66.34	46.7	86.53	17.33	130
A2	Uncovered/ Blank	60.29	48.0	36.73	17.22	115
	Treated	65.75	42.7	33.83	17.11	125
A3	Uncovered/ Blank	61.61	35.3	89.81	17.23	122
	Treated	75.65	44.7	45.15	17.12	133
A4	Uncovered/ Blank	58.82	30.7	53.59	17.33	112
	Treated	69.11	36.0	91.95	17.22	124

4. Conclusion

This study investigated the storage ability of heat, thermal conductivity, and Q-max properties of four different polyester construction treated with synthesized alginate/stearic/octadecane as PCM composite according to the standard of KES-F7. It was found that different products showed a different advantage. From thermal conductivity analysis, mechanical properties and ability to store and release heat which causes thermal, air, and water vapor comfortability for humans due to its excellent heat transfer property, while Q-max results showed that all investigated polyester fabrics were the optimal choice in terms of warm/cold feeling.

5. Conflict of interest

The authors declare that there is no conflict of interest

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