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Effect of an Eco-friendly Treatment on Water Resistance of Knitted Cellulosic Fabrics

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Abstract

Cellulosic fabrics are known for comfortability, absorption, softness, and sustainability, which give them an advantage over synthetic fibres. But these fabrics are easily wetted by water due to hydroxyl groups in cellulose molecules. This feature is undesirable in rainwear, self-cleaning coatings, and bandages that require water repellence. The purpose of this study is to develop the water-repellence of cellulosic fabrics without affecting their breathability. In this study; three cellulosic fabrics (Tencel, Viscose, Cotton) with interlock construction were manufactured with yarn count (30/1 Ne). these fabrics were treated with propolis eco-friendly material to enhance water repellency for special use. Treatment concentrations of 1%, 5%, and 10% were applied. Manufactured and treated fabrics were tested for thickness, weight increase, air permeability, and moisture management properties. Regression analysis was applied to ensure the significance of results and to suppose regression equations for predicting the properties of treated cellulosic fabrics. From the results, the main aim of the research for enhancing the water repellency of cellulosic fabrics without affecting breathability was achieved. The effect of different concentrations of treatment was found to be significant on thickness, weight increase, and all moisture management measurements, but it has a non-significant effect on the air permeability of the fabric. Tencel fabrics treated with propolis at a concentration of 10% gave the highest rank in all properties, followed by viscose fabrics treated with a concentration of 10%, then cotton fabrics treated with a concentration of 10% as well, although the Tencel and viscose fabrics with a treatment concentration of 10% reached 100% of wet resistance. Zero penetration of water from the top of the fabric to the bottom, but the cotton fabric sample did not reach this percentage, despite the improvement in the wettability property without reaching this percentage.

"Keywords: Tencel, cotton, viscose, moisture management, knitted fabrics, Interlock, air permeability."

1. Introduction

Based on their wants and needs, people choose their wardrobe. However, people tend to alter according to the season, the temperature, their age, their kind, their job, etc. Comfort is the primary consideration while choosing clothing in any circumstance.[1]

By selecting the right manufacturing characteristics, clothing textiles can aid boost protection. [2, 3]

Due to their comfort, weft knit clothing has seen an upsurge in demand throughout time in both domestic and international markets. Generally speaking, knit materials have considerable stretchability due to their looped structure.[4]

Knitting techniques usually give fabrics unique performance characteristics due to their yarn-looping shape [5, 6].

Cotton and other plant-based fibres are ecological alternatives to textiles made of synthetic fibres made from petrochemicals [7-10]. Since cotton cannot meet global demand, regenerated cellulose-based fibres from a natural source have increased in popularity due to health and environmental concerns [10-13]. Regenerated cellulose fibres' versatility, security, comfort, renewability, and biodegradability can be combined to produce textile products that are extremely effective and environmentally friendly [10,14].

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Large surface area to volume ratio and moisture-retentive properties of most textiles, especially those composed of natural fibres [15].

Moisture transport benefits greatly from the structure of the fabric. Due to their relative instability, knitted fabrics were traditionally regarded to be inferior to woven fabrics; nevertheless, advancements in yarn and production technology have raised knitted fabrics to have attributes that far above those provided by woven fabrics [16,17]. Particularly in activewear, the demand for elastic, wrinkle-resistant, and form-fitting clothing has expanded the use of weft-knitted materials [16,18].

Many scientists are eager to use materials that have never been employed in the textile industry, like nano-metallic particles, to treat textiles and give them functional capabilities. [19].

One of the useful compounds in the hive is bee propolis. This substance contains flavonoids and other elements that exhibit antibacterial activity [20,21].

Due to a number of biological activities of this traditional medicine, propolis, a gum, has been utilised as a traditional treatment for a number of ailments [19, 22, 23].

The use of propolis as a dietary supplement to support and enhance human health is widespread. [23].

The honey bees utilise propolis, a gum they gather from various plants, to plug gaps in their honeycombs [19, 24], Make the internal wall smooth and secure the doorway from burglars. Propolis, sometimes known as "bee resin," is a resinous substance that bees utilise to fill in cracks and crevices in the hive. Beeswax fills in the wider spaces. In addition to volatile oils, propolis contains water and ethanolic extracts. Flavonoids and polyphenolic acid make up the bulk of the methanolic extract, whereas phenolic acids, caffeoylquinic acid, 3-mono-caffeoylquinic acid, flavonoids, and other substances make up the constituents of the water extract. As a natural mixture, propolis is widely used in medicine, cosmetics, and cuisine. There have been numerous attempts to date to employ propolis in textile finishing, but not in the printing process.[19].

The aim of this work is to treat cellulosic knitted fabrics with propolis for producing eco-friendly comfort fabrics for special waterproofing use. Also, to find the effect of the treatment concentration and the effect of different cellulose materials on each property to determine the optimum material and propolis concentration for waterproofing comfort fabrics.

2. Experimental Work

Research aims:

- use of Eco-friendly materials in the treatment of fabrics against wetness.
- Accessibility to the best cellulosic material treated with natural materials that resist wetting.
- Reaching the best concentration of the treatment material to achieve the wet resistance of the cellulosic fabrics.

Research importance:

- The research contributes to obtaining cellulosic knitted fabrics treated with natural materials to resist wetness.
- Benefiting from the properties of natural materials (propolis) in the treatment of cellulosic fabrics to reach the maximum resistance to wetting.

Research hypotheses:

- There is a statistically significant relationship between treated fabric raw materials and functional performance properties.
- There is a statistically significant relationship between the concentration of the treatment material and the achievement of the functional quality of the treated fabrics.

2.1. Samples' manufacturing

Viscose yarns, Tencel yarns and Cotton yarns were used in the production of three knitted fabric samples. All yarns by yarn count 30/1 Ne were used by interlock structure with medium yarn tension level. Circular interlock knitting machine "Karl Mayer" with 24 gauge and 30inch cylinder diameter.

2.2 *Treatment*

Manufactured three samples from (Viscos, Tencel, and Cotton) were treated with honey gum Propolis by three different concentrations (1% w/w, 5% w/w, and 10% w/w) related to the samples' weight of honey gum. Samples were immersed in the treatment solution at a liquor to- goods ratio of 10:1, padded to pick up 100 %, while the solution consist of 60%water and 40% methanol, then left to dry with air for 8 hours and fixed at 120°C for 10 minutes. Table I illustrates the manufactured and treated samples' design.

Table 1. Manufactured and treated samples' design 'Source: Author's own creation'

Sample Code	Material	Propolis Treatment concentration	Structure	Machine gauge	Yarn count
Tencel 0%	Tencel	Blank	Interlock	**24**	**30/1 Ne**
Tencel 1%	Tencel	1%			
Tencel 5%	Tencel	5%			
Tencel 10%	Tencel	10%			
Viscose 0%	Viscose	Blank			
Viscose 1%	Viscose	1%			
Viscose 5%	Viscose	5%			
Viscose 10%	Viscose	10%			
Cotton 0%	Cotton	Blank			
Cotton 1%	Cotton	1%			
Cotton 5%	Cotton	5%			
Cotton 10%	Cotton	10%			

2.3 Characterization

According to ISO 139, 2005, all test samples were preconditioned at the prescribed ambient conditions (20°C +/- 2 and 65% +/- 2 RH).

The blank knitted fabric and the treated samples were characterised by measuring their thickness, weight-increasing percentage during treatment, air-permeability, and moisture management properties represented in; top maximum absorption Rate (%/sec), bottom maximum absorption rate (%/sec), max wetted radius (mm), and wetting penetration time from top to bottom (sec). The characterization methods used were:

- The thickness of the fabric was measured (ASTM D1777-96, 2019) [25].
- The mass per unit area (weight) of fabrics measured (ASTM D3776, 2017) for calculation of weight increasing percentage during treatment [26].
- Air permeability of fabrics (ASTM D737, 2018) [27].
- Moisture management properties (AATCC-195,2022) [28].

3. Results and Discussion

3.1 Samples' testing results

The Tencel, Viscose, and Cotton fabrics were tested before and after treatment with different concentrations of honey gum. Table II shows results comparing using different types of cellulosic fabrics. Also comparing results between different treatment concentrations.

3.2 Regression Analysis

Linear regression analysis with a p-value of 0.05 has been applied for the determination of regression equations at a confidence interval of 95% for predicting the moisture management properties of the treated fabrics standing on the material type and the concentration of the treatment. Also, correlation coefficients of all tests were calculated to evaluate the effect of material type, treatment concentration on moisture management properties mainly and some other related properties such as thickness, air-permeability, weight increase percentage. to perform regression analysis; two predictors are used as follow:

x1: Cellulosic material type

x2: Treatment concentrations' percentage

3.2.1 Effect of different treatment concentration with different cellulosic materials on the thickness of the manufactured and the treated knitted fabrics

(Figure 1) illustrate that the treatment concentration percentage has an effect on the treated samples' thickness by increasing. According to the regression analysis; the material type (p-value= 0.016) by a highly significant with positive correlation. Also, the treatment concentration percentage (p-value= 0.04) are significantly affected samples thickness with positive correlation. And the linear regression model ($y1 = 0.520 + 0.0637\ x1 + 0.0107\ x2$) is acceptable for predicting the thickness of the samples, as the correlation coefficient R=0.79 revealed that the model is good correlated. The studied samples were prepared with heat treatment for a period of 7 seconds and 14 seconds. The following is an illustration of the designs produced without the heat treatment, and also after being subjected to the heat treatment this may be attribute to the percentage of the fibre bulkiness as cotton sample showed higher percentage of thickness increasing, followed by Tencel then viscose while increasing of propolis concentration.

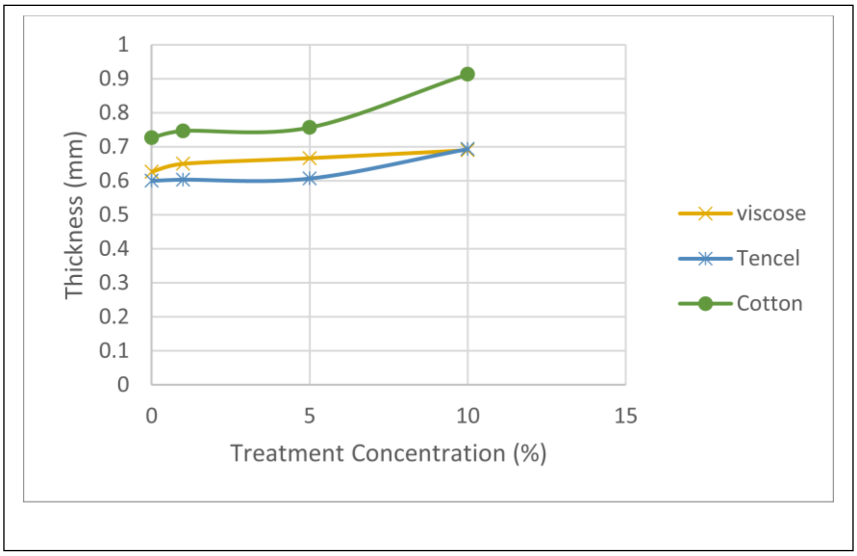


Figure. 1. The effect of treatment concentrations on different cellulosic fibres and their thickness 'Source: Author's own creation'.

3.2.2 Effect of different treatment concentration with different cellulosic materials on the air permeability of the manufactured and the treated knitted fabrics

(Figure 2) illustrate that the treatment concentration percentage has a minor effect on the treated samples' air permeability by decreasing. Also, according to the regression analysis; the material type (p-value= 0.054) with a moderate significant effect on the samples' air permeability with a low positive correlation, and the treatment concentration percentage (p-value= 0.267) with a non-significant effect on the samples' air-permeability. And the linear regression model ($y2 = 98.1 + 18.2\ x1 - 2.14\ x2$) is acceptable for predicting the air permeability of the samples, as the correlation coefficient R=0.63 revealed that the model moderate correlate.

Cotton gave higher air permeability at blank state followed by tencel, then viscose this may be attributed to the bulky of cotton fibers which can give spaces to penetrate air. Also, the intra-yarn gaps are impacted by the fibre cross section as well, which further impacts the porosity of the fabric [29]. But after treating samples; Tencel sample showed air permeability stability at all different treatment concentrations, this caused that it has the highest air permeability at the 10% concentration propolis treatment. This is due to Tencel's uniformly distributed pores across its whole structure [30] enable it to absorb and wick moisture well, making it highly permeable to air since water does not become trapped in the pores and obstruct airflow. Given that tencel fibre is round in shape, air permeability may also rise.

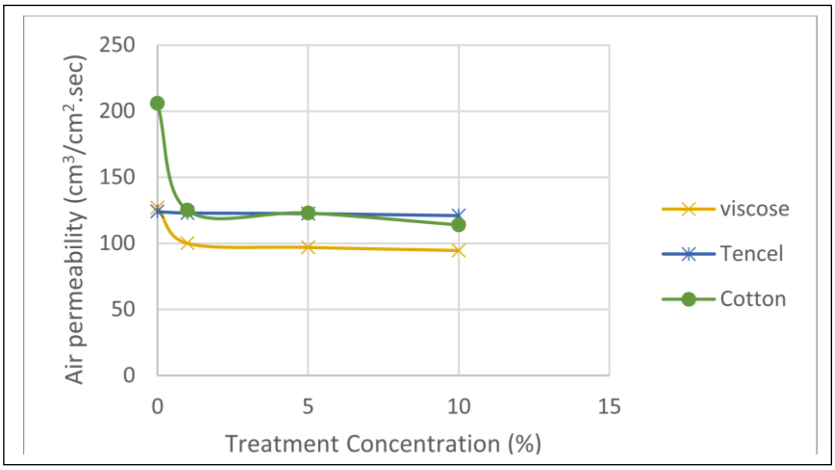


Figure 2. The effect of treatment concentrations on different cellulosic fibres and their air permeability 'Source: Author's own creation'

3.3.3 Effect of different treatment concentration with different cellulosic materials on the weight increasing percentage of the manufactured fabrics

(Figure 3) illustrate that the treatment concentration percentage has a high effect on increasing the treated samples' *weight*. But, according to the regression analysis; the material type (p-value= 0.774) has a non-significant effect on the weight increasing percentage of the manufactured fabrics, and the treatment concentration percentage (p-value= 0.000) has a high significant effect on the weight increase percentage of the manufactured fabrics after treatment with a high positive correlation. Also, the linear regression model (y3 = 0.516 - 0.054 x1 + 0.339 x2) is acceptable for predicting the weight-increasing percentage of the samples, as the correlation coefficient R=0.95 revealed that the model strongly correlated.

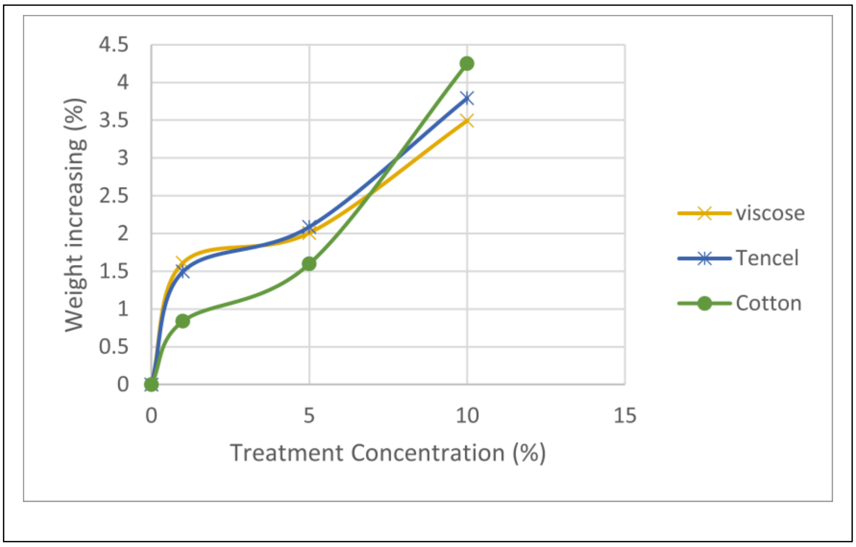


Figure 3. The effect of treatment concentrations on different cellulosic fibres and their Weight increase percentage 'Source: Author's own creation'

3.2.4 Effect of different treatment concentrations with different cellulosic materials on the top maximum absorption Rate(%/sec) *of the manufactured fabrics*

(Figure 4) illustrate that the treatment concentration percentage has a high effect on decreasing the top maximum absorption Rate(%/sec). Also, according to the regression analysis; the material type (p-value= 0.001) has a highly significant effect on the top maximum absorption Rate(%/sec) with a high negative correlation, and the treatment concentration percentage (p-value= 0.001) also, has a highly significant effect on the top maximum absorption Rate(%/sec) with a high negative correlation. The linear regression model (y4 = 643 - 79.7 x1 - 18.3 x2) is acceptable for predicting the top maximum absorption Rate(%/sec), as the correlation coefficient R=0.92 revealed that the model strongly correlated.

Viscose fabrics before and after treating with propolis gave the highest top maximum absorption Rate(%/sec) followed by Tencel fabrics the cotton fabrics this is attribute to the moisture absorption ability of viscose itself [30, 31].

3.2.5 Effect of different treatment concentrations with different cellulosic materials on the bottom maximum absorption Rate(%/sec) *of the manufactured fabrics*

(Figure 5) illustrate that the treatment concentration percentage has a high effect on decreasing the bottom maximum absorption Rate(%/sec). Also, according to the regression analysis; the material type (p-value= 0.634) has a non-significant effect on the bottom maximum absorption Rate(%/sec), and the treatment concentration percentage (p-value= 0.000) has a highly significant effect on the bottom maximum absorption Rate(%/sec) with a high negative correlation. Thelinear regression model (y5 = 36.8 + 1.26 x1 - 3.74 x2) is acceptable for predicting the bottom maximum absorption Rate(%/sec), as the correlation coefficient R=0.92 revealed that the model strongly correlated.

Viscose samples before and after treating with propolis gave the least bottom maximum absorption Rate(%/sec) due to Due to the core/shell structure in viscose fibres, which matches the viscose fibres structure which known by; dense shell and a porous, spongy core [30,31], followed by Tencel samples regarding to composed of fibrils, which are structural subunits in the micro- to nanometre range [31]. Then cotton samples which have the highest bottom maximum absorption rate (%/sec) in all treatment concentrations . but it was observed that higher treatment concentration affected Tencel fabric more than other cotton or viscose regarding to its nano structure which allow the propolis treatment to compact its structure by blocking the pores more.

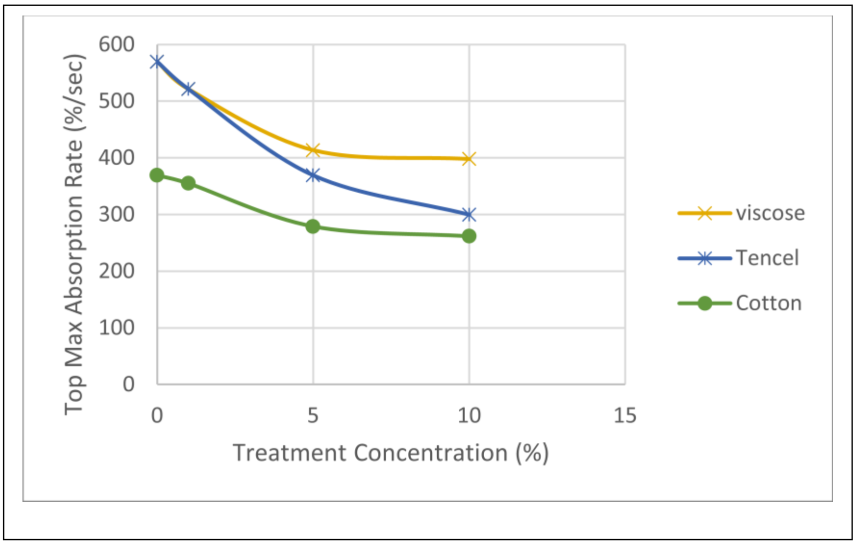


Figure 4. Effect of treatment concentration on different cellulosic materials and their top maximum absorption Rate(%/sec) 'Source: Author's own creation'

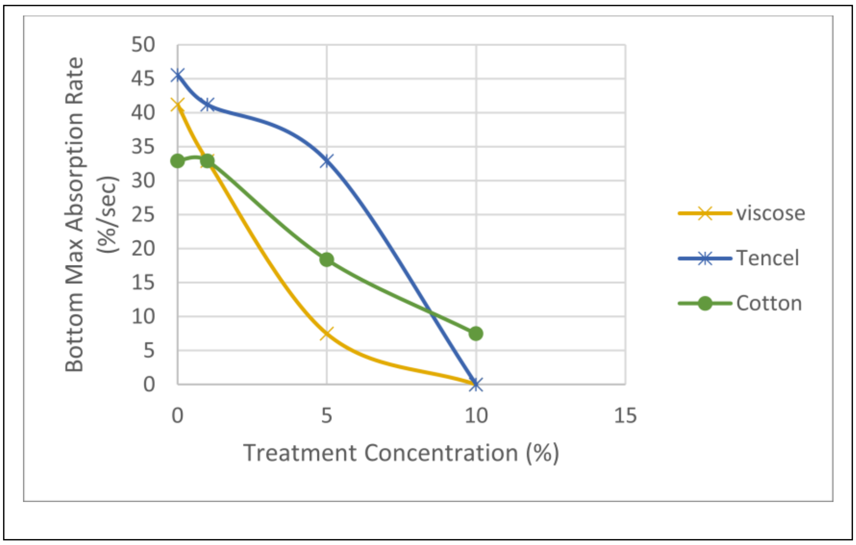


Figure 5. Effect of treatment concentration on different cellulosic materials and their bottom maximum absorption Rate(%/sec) 'Source: Author's own creation'

*3.2.6 Effect of different treatment concentrations with different cellulosic materials on the wetting penetration time from top to bottom (*sec*) of the manufactured fabrics*

(Figure 6) illustrate that the treatment concentration percentage has a high effect on decreasing the wetting penetration time from top to bottom (sec). Also, according to the regression analysis; the material type (p-value= 0.020) has a significant effect on wetting penetration time from top to bottom with a high negative correlation, and the treatment concentration percentage (p-value= 0.000) has a highly significant effect on the wetting penetration time from top to bottom with a high positive correlation. Thelinear regression model (y6 = 43.9 - 15.7 x1 + 7.61 x2) is acceptable for predicting the wetting penetration time from top to bottom, as the correlation coefficient R=0.922 revealed that the model strongly correlated.

Wetting penetration time for the three material increased by increasing the propolis treatment concentration this may be attributed to the effect of the wax in the propolis material which can block the pores in the knitted structure of the fabric. Cotton samples. It's illustrated that Tencel and viscose reached the maximum time of the test in the higher concentration treatment.

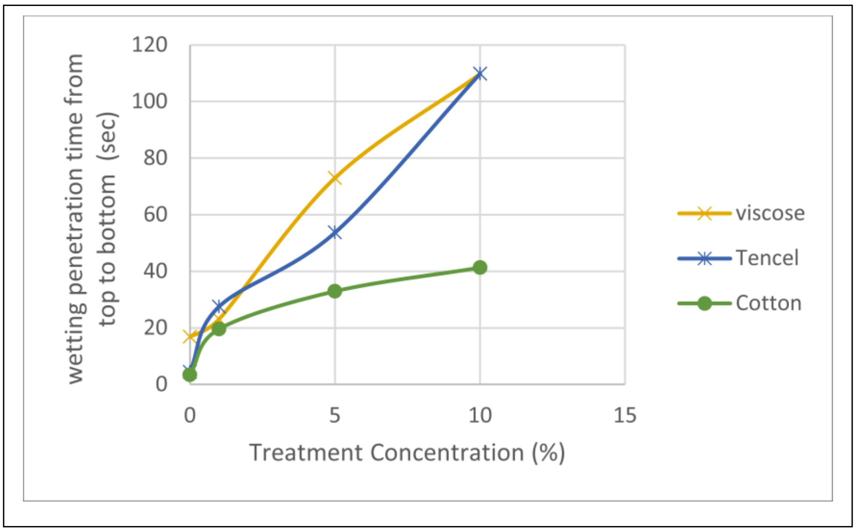


Figure 6. Effect of treatment concentration on different cellulosic materials and their wetting penetration time from top to bottom (sec) 'Source: Author's own creation'

3.2.7 Effect of different treatment concentrations with different cellulosic materials on the maximum wetted radius (mm) *of the manufactured fabrics*

(Figure 7) illustrate that the treatment concentration percentage has a high effect on decreasing the maximum wetted radius (mm) in all manufactured three cellulosic fabrics. Also, according to the regression analysis; the material type (p-value= 0.051) has a significant effect on the maximum wetted radius (mm) with a positivize correlation, and the treatment concentration percentage (p-value= 0.000) has a highly significant effect on the maximum wetted radius (mm) with a high negative correlation. The linear regression model (y7 = 12.6 + 2.22 x1 - 1.50 x2) is acceptable for predicting the bottom maximum absorption Rate(%/sec), as the correlation coefficient R=0.931revealed that the model strongly correlated.

maximum wetted radius (mm) is the highest in cotton samples at al treatment concentration, followed by viscose which has higher *maximum* wetted radius than tencel at 1% concentration, although tencel has higher *maximum* wetted radius at 5% concentration but then they become equal at 10% concentration as the reached water resistance effect by zero wetted radius as the both fabrics became water repellence in this case.

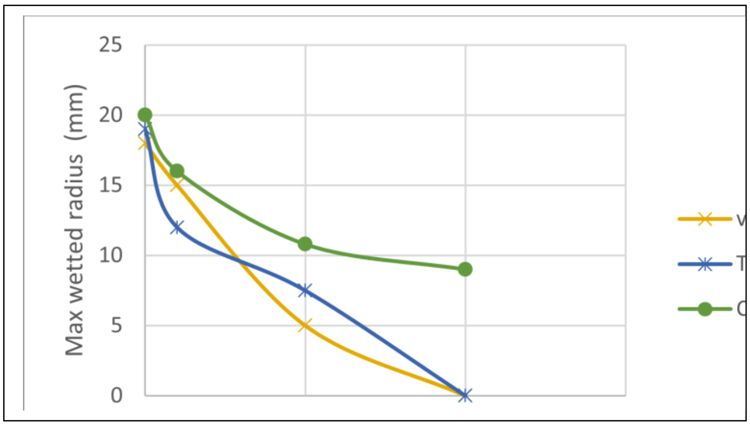


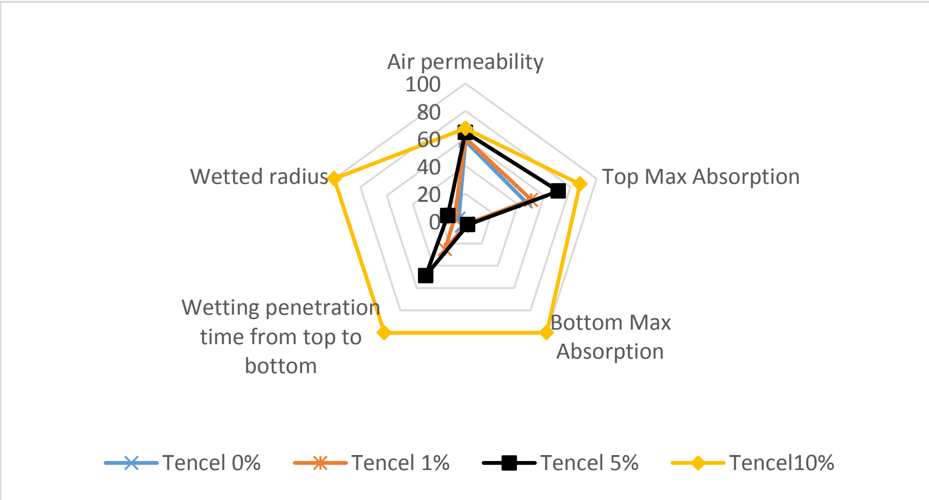
Figure 7. Effect of treatment concentration on different cellulosic materials and their maximum wetted radius (mm) 'Source: Author's own creation'

3.3 Radar Charts for Ranking samples

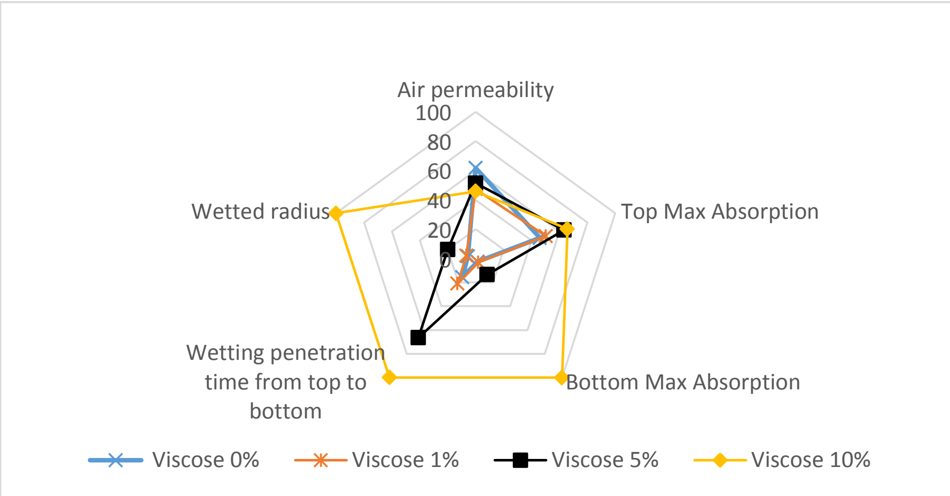
Results of the moisture management properties and air permeability of the samples were illustrated by radar charts (figure8). All areas of radar charts were considered for each sample, and ranked from highest to lowest. Table 2 affirm that sample (Tencel 10%) ranked the greatest sample radar chart area followed by (Viscose 10%) and (Cotton 10%) this affirm that the propolis treatment reached optimum effect concentration at 10% w/w. also, it is illustrated from (Table 2) that each fabric has different behaviour as shown in the difference of ranking in each group separately.

Table 2. Radar Chart Area rank of manufactured and treated (Viscose, Tencel, and Cotton) Knitted Samples 'Source: Author's own creation'

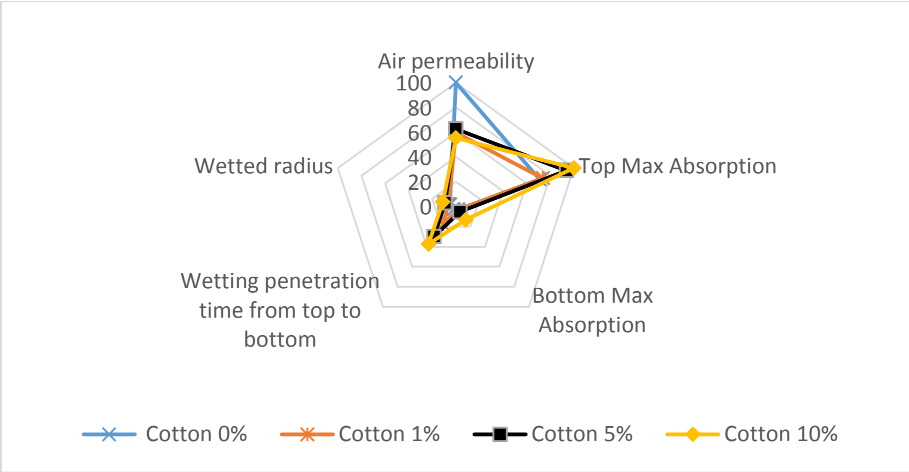
Tencel			Viscose			Cotton		
Water resistance rank	Sample Code	Radar chart area	Water resistance rank	Sample Code	Radar chart area	Water resistance rank	Sample Code	Radar chart area
1st	Tencel 10%	19634	2nd	Viscose 10%	16230	3rd	Cotton 10%	3985
7th	Tencel 5%	3058	6th	Viscose 5%	3491	4th	Cotton 0%	3717
9th	Tencel 1%	1859	10th	Viscose 0%	1623	5th	Cotton 5%	3516
11th	Tencel 0%	1479	12th	Viscose 1%	1451	8th	Cotton 1%	2453



(a)



(b)



(c)

Figure. 8. (a) Radar Charts of Tencel Samples treated with 1%, 5%, and 10% concentration, (**b)** Radar Charts of Viscose Samples treated with 1%, 5%, and 10% concentration, and **(c)** Radar Charts of Cotton Samples treated with 1%, 5%, and 10% concentration 'Source: Author's own creation'

4. Conclusion

Cellulosic knitted interlock samples were produced from the same gauge and same yarn count with different materials (Cotton, Viscose, and Tencel), Propolis honey gum eco-friendly treatment was prepared with three different concentrations (1%, 5%, and 10%) related to the fabrics' weight. samples were treated with different concentrations of propolis. Al samples (thickness, weight increase, air permeability, and moisture management properties) were tested. Regression analysis was applied on all tested properties for correlations between material type and concentration level with all tested properties. It was found that cellulosic material type has a significant effect on thickness, air permeability, the top maximum absorption Rate, wetting penetration time, and *maximum* wetted radius, although it has an insignificant effect on air permeability and bottom maximum absorption Rate. and the treatment concentration percentage has a highly significant effect on all moisture management properties with a non-significant effect on air permeability which means that this treatment with these concentrations reached the goal of adding the water resistance of the cellulosic fabrics from cotton viscose and tencel without affecting air permeability comfortability of the fabrics using eco-friendly propolis treatment. And it was found that Tencel samples treated with 10% propolis treatment concentration followed by viscose sample with 10% propolis treatment concentration gained the highest properties with zero button surface wetting, then come the other samples in order regarding to the higher effect of the propolis treatment on these materials.

5. Conflicts of interests

"There are no conflicts to declare".

6. Formatting of funding sources

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تأثيرمعالجه صديقة للبيئة على مقاومة الابتلال لأقمشة تريكو سليلوزية

الملخص: تُعرف الأقمشة السليلوزية بالراحة والامتصاص والنعومة والاستدامة، مما يمنحها ميزة على الألياف الصناعية. لكن هذه الأقمشة يسهل ابتلالها بالماء بسبب مجموعات الهيدروكسيل في جزيئات السليلوز. هذه الميزة غير مرغوب فيها في ملابس المطر والطلاءات ذاتية التنظيف والضمادات التي تتطلب مقاومة للماء. الغرض من هذه الدراسة هو تطوير مقاومة الأنسجة السليلوزية للابتلال دون التأثير على قابليتها للتهوية. تم تصنيع ثلاثة خامات من الأقمشة السليلوزية (فسكوز، تنسل و قطن) الخيوط (1/30 انجليزي). تمت معالجة هذه الأقمشة بمعالجة صديقة للبيئة لتعزيز مقاومة الماء للاستخدامات الخاصه. تم تطبيق تراكيز معالجة 1٪ و5٪ و 10٪. تم اختبار الأقمشة المنفذة والمعالجة من حيث السمك وزيادة الوزن ونفاذية الهواء وخصائص التحكم في الرطوبة. تم تطبيق تحليل الانحدار للتأكد من أهمية النتائج ولافتراض معادلات الانحدار للتنبؤ بخصائص الأقمشة السليلوزية المعالجة. من النتائج، تم تحقيق الهدف الرئيسي للبحث لتعزيز مقاومة الأنسجة السليلوزية للابتلال دون التأثير على تهوية الاقمشة. وجد تأثير التركيزات المختلفة للمعالجة معنويا على السمك، وزيادة الوزن ، وجميع قياسات إدارة الرطوبة ، ولكن ليس لها تأثير معنوي على نفاذية الهواء للنسيج. أعطت اقمشة التنسل بمعالجتها بماده البروبلس بتركيز 10%أعلى مرتبة في جميع الخصائص و تلاها قماش الفسكوز بمعالجه بتركيز 10% ثم قماش القطن بمعالجه بتركيز 10% ايضاً،على الرغم ان خامة التنسل والفسكوز بتركيز معالجة 10٪ قد وصلا إلى 100٪ من مقاومة الابتلال بنسبة تغلغل صفرية للماء من أعلى القماش إلى أسفله لكن لم عينه قماش القطن الى هذه النسبه برغم تحسن خاصيه الابتلال دون وصولها الى هذه النسبة.

الكلمات المفتاحية: تنسل ، قطن ، فسكوز ، إدارة الرطوبة ، أقمشة تريكو ، انترلوك.

اهداف البحث: 1- الاستفاده من المواد الصديقة للبيئة في معالجة الاقمشة ضد البلل.

إ2- مكانية الوصول الى افضل خامة سليلوزية معالجة بالمواد الطبيعية المقاومة للبلل.

3- الوصول الى افضل تركيز لمادة المعالجة لتحقيق المقاومة ضد البلل للاقمشة السليلوزية .

أهمية البحث: 1- يسهم البحث في الحصول على أقمشة تريكو سليلوزية معالجة بمواد طبيعية لمقاومة البلل.

2- الاستفادة من خواص المواد الطبيعية (البروبلس) في معالجة الاقمشة السليلوزية للوصول الى اقصى مقاومة للبلل.

فروض البحث:

1- يوجد علاقة ذات دلالة إحصائية بين خاما تالاقمشة المعالجة و خواص الأداء الوظيفي.

2-يوجد علاقة ذات دلالة إحصائية بين تركيز ماده المعالجة و تحقيق الجودة الوظيفية للاقمشة المعالجة.