Designing high-efficiency cap to protect hair from weather pollutants

Assist.Prof. Dr. Hazem Abdelmoneim yassen mohamed
Associate Professor - Faculty of Education, Helwan university
hazem_abdelmoneim@yahoo.com
Assist.Prof. Dr. Khaled Elnagar
Associate Professor- National Institute of Standards
khnagare@hotmail.com

Abstract

Wearing hats and caps in sunny areas to protect from sunrays is frequent in hot areas or as a requirement for fashion lines, especially in summer and spring times. A number of fabrics were woven, their permeability properties were measured, and the extent to which they protected hair from airborne dust and sunlight, by measuring the porosity of the tested fabrics. The best tested fabrics for permeability and porosity were selected and coated with copolymer to increase protection from the sun's rays by measuring the sun protection factor (UPF) using diffuse transmission spectrophotometer. Cap was designed using Gerber software. The results showed that choosing the appropriate fabrics in the manufacture of hats and caps prevents damage to the hair.

Keywords

Hair, Air pollution, UPF, Carbon fiber, Porosity, Permeability, Cotton.

الملخص

ارتداء القبعات في المناطق المشمسة للحماية من أشعة الشمس أمر متكرر في المناطق الحارة أو كشرط لخطوط الموضة خاصة في الصيف والربيع .و هذا البحث جاءت فكرته لمساعدة كثير من العاملين في مجالات الانشاءات و المقاولات وصناعة الحديد و الزجاج حيث ان العاملين في هذه المجالات يتعرضون للشمس و الحرارة باستمرار دائم حيث هناك طفرة في هذه المجالات في مصر و الدول العربية .فتم نسج عدد من الأقمشة وقياس خصائص نفاذيتها ومدى حماية الشعر من الغبار وأشعة الشمس المنقولة بالهواء وذلك بقياس مسامية الأقمشة المختبرة . تم اختيار أفضل الأقمشة المختبرة للنفاذية والمسامية وطليها ببوليمر بولي أكريلات لزيادة الحماية من أشعة الشمس عن طريق قياس عامل الحماية من الشمس (UPF)باستخدام مقياس الطيف الضوئي المنتشر. تم تصميم قبعة باستخدام برنامج Gerber المتقدم. أظهرت النتائج أن اختيار الأقمشة المناسبة في صناعة القبعات والقبعات يمنع تلف الشعر.

الكلمات المفتاحية

الشعر ، تلوث الهواء ، UPF ، ألياف الكربون

Introduction

Hair loss is not considered just on the head, but on every part of the human body in general. It is usual to lose a certain number of hairs (50 to 100 hairs) during the day, but if the hair loss exceeds the normal limit; It may be worrying today, and you should look for ways to treat hair loss. Does wearing hats and caps cause hair follicles to itch, causing hair to fall out, there are many reasons that lead to hair loss, such as:

1- Having some chronic diseases such as diabetes and arthritis (Gamal et al 2021).
2- Infection of the scalp skin with some problems such as ringworm infection (burns et al. 2021).
3- Taking some drugs and medications such as high blood pressure, heart, and arthritis medications (Huang et al (2019).
4- Lack of some nutrients in the body, such as iron and some vitamins (Zhang et al. 2022).
5- Follow a diet to lose weight.
6- Psychological disorders, nervousness, excessive tension, or fear (Huang et al (2019).
7- Infection with alopecia (Babadjouni et al. 2022).
8- Chemotherapy for cancer (Adderley et al. 2020).
9- Harsh hair care and the use of chemicals on the hair (Paula 2022 et al. 2022).
10- Polycystic ovary syndrome in women (Tu et al. 2019).
11- Take birth control pills (Berenson et al 2008).
12- Birth (Ren et al. 2022).
13- Progression in old age and aging (Baltenneck et al 2022).
14- Surgical procedures (Hunt and McHale 2012).
15- Hormonal changes (Sadick and Arruda 2021).
16- Increasing the duration of the exercise (Koblinski et al. 2021).
17- Increase caffeine (Rah et al. 2017).
18- Wearing tight hats may reduce blood flow to hair follicles (Dachs et al 2003; Koblinski et al. 2021).

A study of the effect of environmental factors on hair loss in 92 pairs of identical twins revealed that twins who wore hats experienced more hair loss over the forehead than those who did not wear hats (Gatherwright et al 2013).

Cotton fiber is a collapsed tube made up of microfibrils in helical windings with frequent direction reversals and numerous convolutions along the fiber length. The cellulose chain has three active hydroxyl groups in its chemical structure on each building unit (glucopyranose), one primary in the 6-position and two secondary groups in the 3,4 positions. The reactivity of these hydroxyl groups governs the majority of cotton chemistry (Elnagar et al 2002; El-Nagar et al. 2005; El-Nagar et al. 2006).

STEWART-PINKHAM (1989) applied study on 80 children and found that air polluted with cadmium has adverse effect on the hair of children.

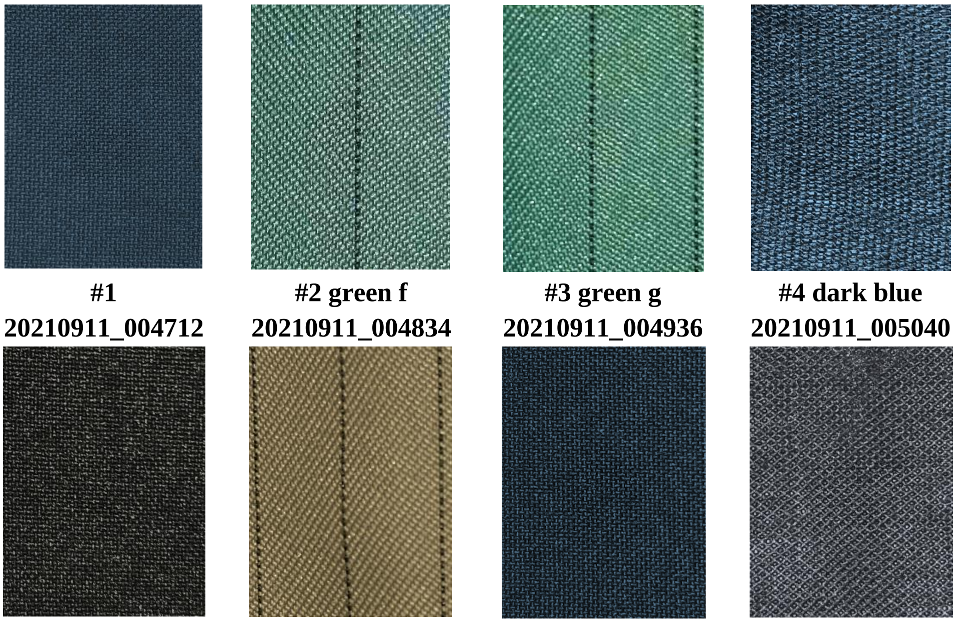
Woven fabrics are made up of warp and weft yarns that are interlaced at 90 degrees. Warp yarns are wound under uniform tension onto a beam and threaded through heddles on loom harnesses, with each harness controlling a group of warp yarns that can be raised independently of other groups. Weft yarns are threaded through the shed, which is the space between raised and unraised warp yarns. A weave draught represents the pattern in which warp yarns are raised over weft yarns to form the weave structure. The simplest weave structure, plain weave, involves warp yarns alternately being raised and lowered over each weft, producing the maximum possible number of interlacing (Meiklejohn et al. 2022).

This work aimed at using different fabrics to design summer caps and evaluate their performance to protect the hair with respect to the porosity, fabric weight, and electrostatic surface charges. The best fabric was coated with polyacrylate coating to increase the durability of the fabric, ultraviolet protection factor (UPF), and antibacterial behavior.

Experimental:

Substrates:

The fabrics used in this work are 100% cotton fibers with a plain 1/1 weaving structure. Samples 2,3 and 6 (in figure 1) have single carbon yarns inserted in the weaving structure every 5 cm. Sample 3 is a coated fabric with polyacrylate film. All these fabrics were weaved in Egyptian Canadian industrial factory, El Obour city. Fabric weights are indicated in table 1. Garment in Yasmina fashion co., Alharm, Giza Egypt.



#1 20210911_004712 | **#2 green f 20210911_004834** | **#3 green g 20210911_004936** | **#4 dark blue 20210911_005040**

#5 black 20210911_005147 | **#6 brown coated 2021091 1_005243** | **#7 black 20210911_005349** | **#8 dark blue 20210911_005453**

Figure 1: Optical Microscope photos for the fabric used

Weaving structure of the used samples were as follow:

Sample #1: warp 70/1 plain 1/1; weft 150/1 continuous fiber.

Sample #2: 1% microfiber fiber 70/1 (4 yarns/inch) and 99% polyester. Microfiber warp, polyester 70/1 continuous, weft 150/1 polyester.

Sample #3: 1% microfiber (4 yarns/inch) fiber and 99 polyester microfiber warp 70/1 2%, polyester 70/1 continuous, weft 150 continuous. This sample was coated by polyvinyl chloride film.

Sample #4: polyester 100%, warp 70/1, weft 150/1 continuous.

Sample #5: plain 1/1; 65% polyester, 35 cotton, warp70/1 spun blended, weft 150/1 polyester cont.

Sample #6: 1% 70/1 microfiber fiber (4 yarns/inch) and 99 polyester microfiber warp 70/1 1%, polyester 70/1 continuous, weft 150 continuous. This sample was coated by polyvinyl chloride film.

Sample #7: plain 1/1; weft 150/1 continuous, warp 70/1 continuous
Sample #8: 65% polyester /35 cotton, warp cotton 100% 70/1 dtex; warp blend cotton polyester 70/1.

Table 1: Fabric weight of the studied samples.

Parameter	**weight 1**	**weight 2**	**weight 3**	**weight 4**	**weight 5**	**weight 6**	**weight 7**	**weight 8**
Average	120.680	126.670	150.340	109.830	114.683	117.210	115.810	125.941
stdev	0.0007	0.0015	0.0001	0.5774	0.0003	0.0003	0.1558	0.5773

Cap design

Design summer caps are an essential part of any fashion wardrobe. They can be worn in various settings and are perfect for casual or formal occasions. They can be made from various materials, including cotton, linen, or straw. You can also design them in a range of different colors and styles. Cap design and patron as appeared in figure (2) established using Gerber (Accumark V18.1.2) designing the program. Patterns used in this project were created using the design software Accumark made by Gerber Technology, Tolland, USA and can be exported as a 2D DXF drawing (Tarrier et al. 2010; Fink et al. 2021).

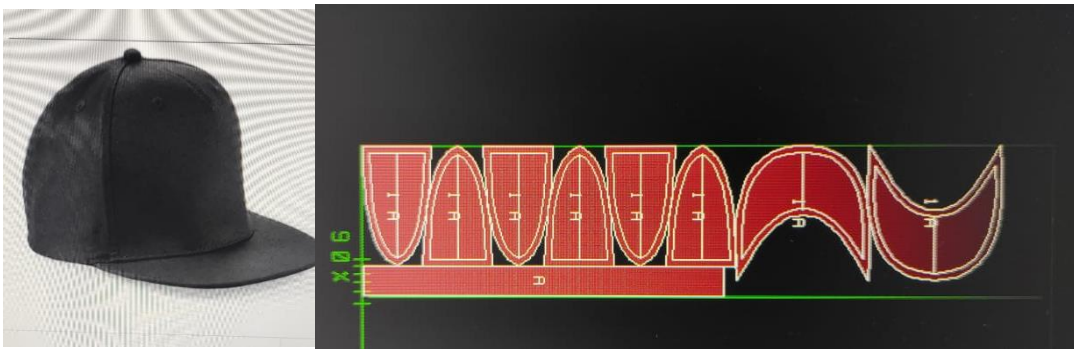


Figure 2: Cab and patron design.

Pore size Testing

The Promoter **Quantachrome 3GWin2-Pore Size Data, which is a** series of capillary flow parameters for the widest range of through-pore size and bubble point applications. Automatic measurements of studied fabrics. Pressure capabilities of 0.015 to 500 psi represent a pore size range. Table 1 shows the identification of the samples for this test. ASTM F316-03(2011). Table 2 shows the sample identifications used as constant values in porosity measurements.

Figure 3: Photo of the porosity meter used

Table 2: Constants used for porosity measurements

Parameter	Sample #1	Sample #2	Sampl e #3	Sample #4	Sample #5	Sampl e #6	Sampl e #7	Sampl e #8
Thickness, µm	206.0	192.0	230.0	255.0	238.0	250.0	174.00	250.0
Diameter, mm	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.000
Sample Area, cm²	3.1400	3.1400	3..1400	3.1400	3.1400	3.1400	3.1400	3.1400
Volume, cm³	0.06468	0.06029	0.07222	0.08007	0.07473	0.07850	0.05464	0.07850

UPF measurement and Electrostatic charge

UPF was measured using UV-VIS double beam spectrophotometer (Perkin-Elmer, Lambda 35, Diffuse transmission technique) according to the American standard (ASTM D6603–2000) and AATCC test method [AATCC 183–2000]. The UPF was calculated using the following equation (Tahlawy et al 2007).

Electrostatic charge was measured using Electrostatic fieldmeter (Model : FMX-003), made by SIMCO-Japan (Paasi et al. 2004).

FTIR Spectroscopy

Sample number 2 and coated Sample number 3 were measured using Thermo Nicolet FTIR spectrophotometer, Transmission mode spectra (400-4000 cm^{-1}) was measured with KBr pellets of finely cut and ground fabrics. Sample 3 is known from the weavers that it is coated fabric with polyvinyl chloride (PVC).

Results and Discussions

Effect of weaving structure on the porosity behavior:

The results in Table 3 shows the porosity and permeability of the fabrics used in this study. The results showed that sample No. 3 is the least mean pore size, and samples 2, 6, and 1 (with values ranging from 11.5 to 15 µm) come in the order. Samples 7 and then 5 (with values of 26.5 to 33.5 µm) while samples 8 and 4 show the highest porosity (values of 133-134 µm). These different porosities showed that the lower the porosity, the higher the pressure the samples needed to measure the bubble point, where the sample No. 3, which is the least porous, needed a pressure of about 7.15 bar, while the medium sample No. 7 needed a pressure of about 0.017 bar, while the highest samples needed a porosity like the other samples. Numbers 8 and 4 have a very low pressure of 0.005 bar. It is also clear that by increasing the porosity of the fabrics and thus the area of the air-permeable openings, which increases its permeability and increases the volume of air that escapes from the samples (Elsa et al. 2021; Zhe et al. 2015; Zhen et al. 2021; Irwin 2016).

Table 3: Porosity results of the cotton fabrics tested.

Parameter	Sample #1	Sample #2	Sample #3	Sample #4	Sample #5	Sample #6	Sample #7	Sample #8
Mean Pore Size, µm	*14.8498*	*11.5108*	*0.0424*	*116.7883*	*33.5430*	*15.7516*	*26.4750*	*120.0750*
Bubble Point Pressure, bar	0.0284	0.0320	7.1467	0.0048	0.0167	0.082	0.0171	0.0048
Bubble Point Flow Rate, l/m	0.000	0.0026	0.0556	0.0003	0.0043	0.0002	0.0034	0.0008
Pore Density (Number) /cm²	5.6E+04	3.91E+04	1.98E+12	192	5.55E+03	4.44E+04	6.6E+03	168
Porosity (Open Area Data), %	7.a489.	4.647	2727	2.11	4.955	7.721	2.531	1.948
Pore Open Area, cm²	4.909	4.909	4.909	4.909	7.909	4.909	4.909	4.909
Pore Surface Area, cm²/cm²	0.0001447	8.307E-05	18.69	6.148E+06	4.452E-05	0.0001628	2.402E+05	5.401E-06
Pore Size Run Range, µm	30.0047 to 5.0350	30.0047 to 5.0350	0.100 to 0.0304	149.8829 to 80.3011	64.9746 to 201131	50.00 to 10.0551	50.00 to 10.0661	140.0438 to 70.3297

FTIR Analysis of samples

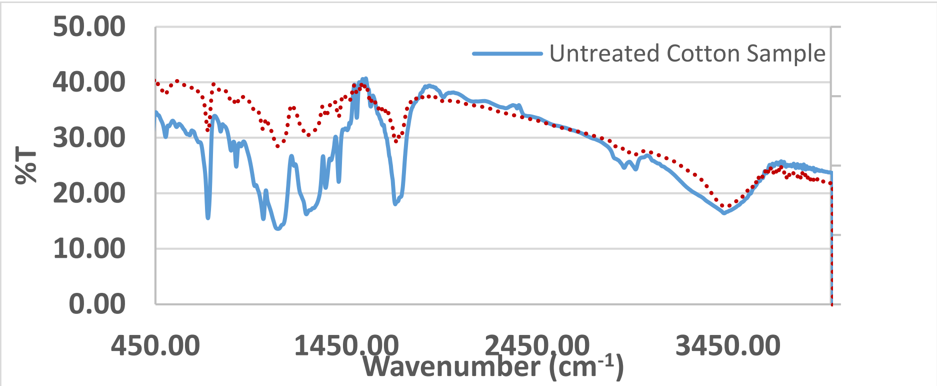


Figure 5: FTIR spectra of the plain and coated

Figure 5 shows the FTIR spectra of sample number 2 and the coated Sample number 3. The spectrum showed transmission peaks at 2945 cm^{-1} for CH_2-antissymmetric stretching; 1725 cm^{-1} for C=O anti-symmetric stretching; 1410 cm^{-1} for standard absorption -OH band; at 1143 cm_{-1} for C-H stretching second overtone; at 973 cm^{-1} for O-CH_2 stretching and at 868 cm^{-1} for the benzenoids group. (Ibrahim et al. 2013; Chunga et al. 2004; Abidi et al 2005; Hooman et al. 2022; Singh and Sheikh 2022).

Effect of weaving structure on the UPF and surface electrostatic charge

Table 4 shows the results of ultraviolet radiation transmittance through the fabrics under study. The results showed that samples 4 and 8 have more transmittance, 33 and 22, respectively. While all other samples showed protection from ultraviolet radiation (El-Tahlawy et al 2007; Ibrahim 2011; Patankar et al. 2022).

When studying the textile structures of the fabrics under study for the properties of static charges on the surface, it was found in Table 4, that the samples numbers 7, 6, 2, and 5 cause static charges, which may cause bad effects on the hair, as the static charges cause hair breakage and the stability of the hairdos, and also cause increased adhesion of dust and pollutants on the hair.

Table 4: Effect of Weaving structure on UPF values and surface Electrostatic charges

Sample #	UPF	Electrostatic Charges
1	65+	0.07±0.010
2	65+	0.53±0.089
3	65+	0.06±0.006
4	٣٣	0.01±0.000
5	55	0.35±0.015
6	65+	0.75±0.035
7	65+	1.93±0.058
8	٢٢	0.03±0.058

Protecting Hair from Environment (dust)

According to WebMD, there are seven main categories of hair and these include straight, wavy, curly, frizzy, coarse, fine, thin, or African American. Depending on the hair type, one will determine the care needed to maintain it. For instance, curly hair needs to be moisturized more often to keep it looking healthy and shiny. Fine hair must be conditioned to look healthy and prevent it from breaking easily. Choosing the suitable hair covers (either by scarves, cabs or hats) helping the person to protect his/her hair and avoid the side effect of the protecting /care materials. The fabric shall be breathable, does not produce any static charges, does not permeate the dust or pollutants from the surroundings, anti-stain, hydrophobic, as well as does not allow passage of harmful ultraviolet (high UPF values).

When natural hair samples were placed in a bag made of fabrics under study in a closed revolving box (42 revolutions per minute) containing dust whose grain size ranged from 5 to 100 microns. Figure No. 5 shows that sample 3 is the hair sample without any treatment, and sample No. 3 is the best sample for preserving hair, as it is a cloth containing many fibers, which gave the cloth a degree of permeability and at the same time impermeable to dust that causes friction with the surface of the hair and the lack of accumulation of dust that is deposited with the help of air humidity (ranging from 50 to 65% relative humidity). On the contrary, sample No. 4 showed, which is the most porous sample, which has a texture structure that does not allow to prevent dust from the surrounding atmosphere, which is deposited on the surface of the outer hair, causing a mud layer, which is a suitable environment for the growth of bacteria and fungi, and therefore it cannot be used in the manufacture of the cap. proposed in the design. Sample 1 with medium porosity gave a significant impermeability to dust, but it caused some small brittleness in the hairs. Samples 5 and 8 did not penetrate the dust significantly and did not cause any breakage in the hairs.

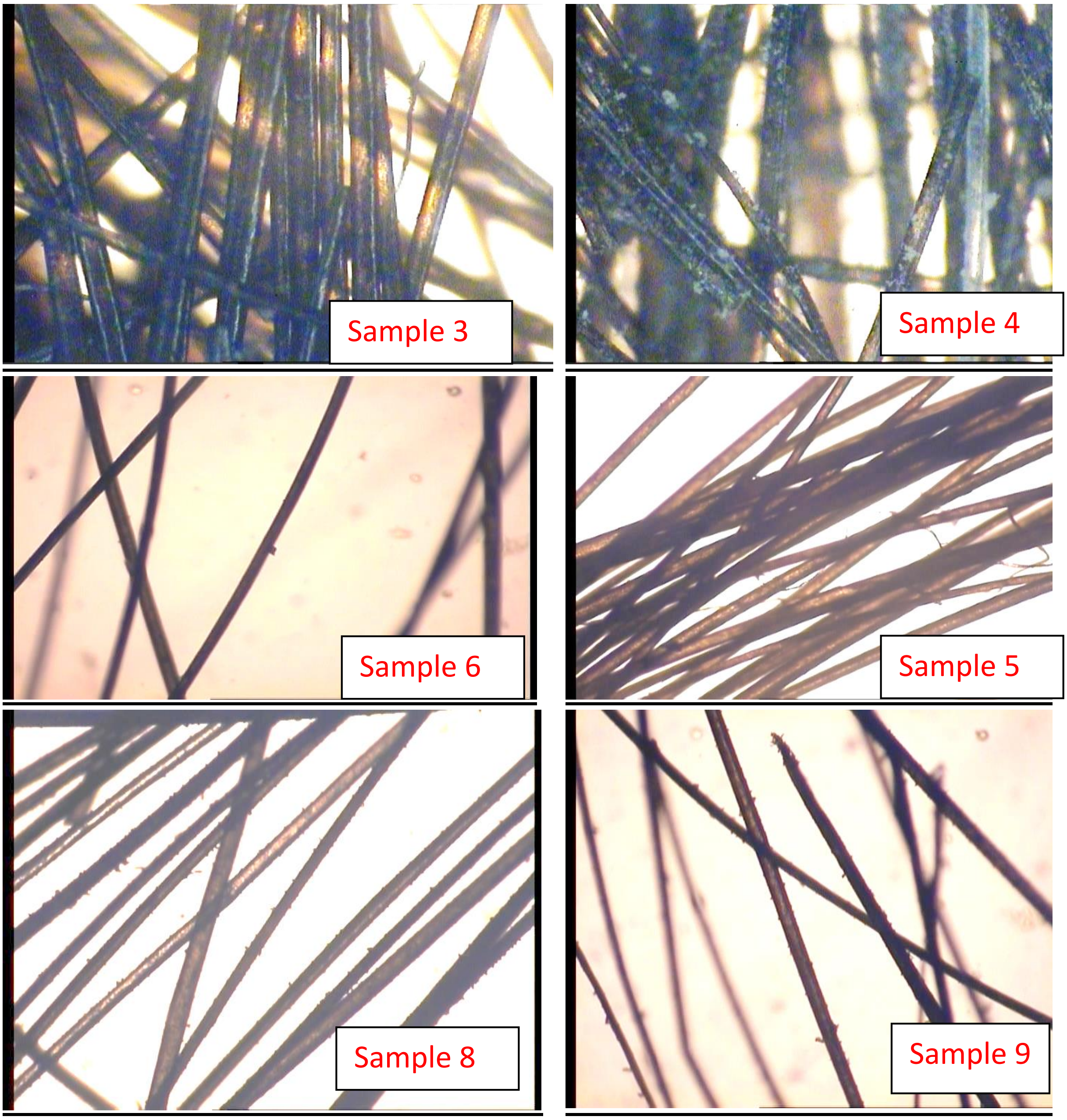


Figure (6): Optical microscope for the Hair in bags made of samples codes 3, 4,5,6,1 and 8 subjected to dust (50-100 micrometer).

Conclusion

Wearing a hat is a great solution to countering UV rays because an extra layer of protection is always a plus. If a hat isn't your favorite summer fashion accessory, protect your hair by styling it in a way that exposes less of your scalp. The study focused on designing a summer cap that can be worn under different conditions. Several proposed fabrics were studied with different weave compositions made of cotton and/or polyester and containing yarns made of many fibers and covered with a layer of polyvinyl chloride. The samples were tested using a porosity meter, infrared absorption analysis and UPF transmittance. The permeability of dust with sizes of 50-100 micrometers was also measured. The results in this research showed that the samples made of polyester and covered with a layer of polyvinyl chloride containing polyester multi-fiber yarns are the most suitable materials with respect to the porosity, UPF, static charges for manufacturing a summer cap that maintains the health and vitality of the hair while maintaining proper porosity and stain-resistant properties and is easy to care for.

Acknowledgment:

Authors thank Prof. Dr. Abdelrahim Ramadan, Faculty of applied arts, Helwan University-Egypt, for his support during the experimental work of this research.

Author Conflict of interest:

Authors have no conflict to declare.

References

Abidi N., Hequet E., Turner C., Sari-Sarraf H. (2005), FTIR Analysis of crosslinked cotton fabric using a ZnSe–universal attenuated total reflectance, Journal of Applied Polymer Science, Vol. 96, PP. 392–399.

Adderley H., Chan J., Alameddine M., Kelly C., Salih Z., Lim K.H.J., Fox R., Tetlow C., Arundell D., Wong H., Harries M., Armstrong A., Thorp N. (2020), Permanent Hair Loss Associated with Taxane Chemotherapy Use in Breast Cancer: a Retrospective Review at Two Tertiary UK Cancer Center, Clinical Oncology, Volume 32, Issue 8, p. e167, https://doi.org/10.1016/j.clon.2020.02.008.

Babadjouni A., Phong C. H., Nguyen C., Mesinkovska N. A. (2022), COVID-19 vaccination related exacerbations of hair loss in patients with moderate-to-severe alopecia areata on systemic therapy, JAAD Case Reports, Volume 29, PP. 181-185, https://doi.org/10.1016/j.jdcr.2022.08.016

Baltenneck F., Genty G., Samra E. B., Richena M., Harland D. P., Clerens S., Leccia E., Le-Balch M, Doucet J., Michelet J., Commo S. (2022), Age-associated thin hair displays molecular, structural and mechanical characteristic changes, Journal of Structural Biology, Volume 214, Issue 4, 107908, https://doi.org/10.1016/j.jsb.2022.107908

Berenson A. B., Odom S. D., Breitkopf C. R., Rahman M. (2008), Physiologic and psychologic symptoms associated with use of injectable contraception and 20 µg oral contraceptive pills, American Journal of Obstetrics and Gynecology, Volume 199, Issue 4, PP. 351.e1-351.e12, https://doi.org/10.1016/j.ajog.2008.04.048

Burns L. J., Hagigeorges D., Flanagan K. E., Pathoulas J., Senna M. M.(2021), A pilot evaluation of scalp skin wounding to promote hair growth in female pattern hair loss, International Journal of Women's Dermatology, Volume 7, Issue 3, PP. 344-345, https://doi.org/10.1016/j.ijwd.2020.11.006

Chunga C., Leeb M., Choe E. K. (2004), Characterization of cotton fabric scouring by FT-IR ATR spectroscopy, Carbohydrate Polymers 58, PP. 417–420. doi:10.1016/j.carbpol.2004.08.005

El-Nagar Kh., Shehata A., Shantz M., Porter B. (2005), Extraction of Residual Chlorinated Pesticides from Cotton Matrix as Part of a Certification Method for Cotton Reference Material, Polymer-Plastics Technology and Engineering, 44: PP. 1257–1267. DOI: 10.1080/03602550500207782

El-Nagar, Kh.; Ramadan, A.A.; El-Sayed, Kh. Egyptian Journal of Applied Sciences 2002, 17 (8), 100–111.

El-Nagar Kh., Saleh S., Ramadan A. (2006), Utilization of feather waste to improve the properties of the Egyptian cotton fabrics, JTATM 5(2), PP. 1-12

Elsa Lasseuguette, Richard Malpass-Evans, Sara Casalini, Neil B. McKeown, Maria-Chiara Ferrari (2021), Optimization of the fabrication of amidoxime modified PIM-1 electrospun fibers for use as breathable and reactive materials, Polymer, Volume 213, 123205, https://doi.org/10.1016/j.polymer.2020.123205

El-Tahlawy K, El-Nagar Kh., Elhendawy A. G. (2007), Cyclodextrin-4 Hydroxy benzophenone inclusion complex for UV protective cotton fabric. JOTI, 98(5), PP. 453 – 462.

Fink P L, Sayem A M, Teay S H, Ahmad F, Shahariar H, Albarbar A (2021), Development and wearer trial of ECG-garment with textile-based dry electrodes, Sensors and Actuators A: Physical, volume 328: 112784, https://doi.org/10.1016/j.sna.2021.112784

Gamal N. M., El-Oseily A. M.A., Mostafa H., Badawy E. R., Abd Elsamea M. H. (2021), Detection of hearing loss in rheumatoid arthritis patients using extended high-frequency audiometry: Is it related to disease activity and severity? The Egyptian Rheumatologist, Volume 43, Issue 3, PP. 219-224, https://doi.org/10.1016/j.ejr.2021.02.006.

Gatherwright J, Liu MT, Amirlak B, Gliniak C, Totonchi A, Guyuron B. The contribution of endogenous and exogenous factors to male alopecia: a study of identical twins. Plastic Reconstruction Surg. 2013 May;131(5):794e-801e. doi: 10.1097/PRS.0b013e3182865ca9. PMID: 23629119.

Dachs J., McNaught I.J., Robertson J. (2003), The persistence of human scalp hair on clothing fabrics, Forensic Science International, Volume 138, Issues 1–3, PP. 27-36, https://doi.org/10.1016/j.forsciint.2003.07.014

Hooman Khatabi, Seyed Mansour Bidoki, Aminoddin Haji (2022), A green approach for In-situ synthesis of silver nanoparticles on cotton fabric by low-pressure cold plasma, Materials Chemistry and Physics, Volume 290, 126548, https://doi.org/10.1016/j.matchemphys.2022.126548

Huang A., Nardone B., West D.P., Colavincenzo M. (2019) 674 Hair loss and psychoactive medications: Stimulants and antidepressants: A retrospective analysis from the RADAR (Research on Adverse Drug events And Reports) Program, Journal of Investigative Dermatology, Volume 139, Issue 5, Supplement, p. S116, https://doi.org/10.1016/j.jid.2019.03.750

Hunt N., McHale S. (2012), “Hair Loss Effects and Surgical/Drug Treatments for the Alopecia”, Editor(s): Thomas Cash, Encyclopedia of Body Image and Human Appearance, Academic Press. PP. 482-489, https://doi.org/10.1016/B978-0-12-384925-0.00075-4

Ibrahim G., E. (2011): Achieving Optimum Scientific Standards for Designing and Producing Fabrics Suitable for Ultraviolet Protective Clothing, Journal of American Science, 7(9). PP. 97-109.

Ibrahim S. F., Essa D. M., Elnagar Kh., Abdel-Razik A.M., Abdel-Rahman A. A.(2013), Evaluation of IR Spectral Analysis and Dyeing Parameters for Plasma and /or Nano-Silver Treatments of Polyester and Nylon Fabrics. Journal of Advances in Chemistry (JAC), 4(1). PP. 387-411.

Irwin M. Hutten (2016), Chapter 6 - Testing of Nonwoven Filter Media, Editor(s): Irwin M. Hutten, Handbook of Nonwoven Filter Media (Second Edition), Butterworth-Heinemann, PP. 343-408, https://doi.org/10.1016/B978-0-08-098301-1.00006-X

Koblinski J. E., O'Haver J. A., Andrews I. D. (2021), An Approach to Hair Loss in Pediatric Primary Care, Journal of Pediatric Health Care, Volume 35, Issue 6. PP. 651-661, https://doi.org/10.1016/j.pedhc.2021.05.001

Meiklejohn E., Hagan B., Ko J. (2022), Rapid sketching of woven textile behavior: The experimental Use of Parametric Modeling and Interactive Simulation in the Weaving Process, Computer-Aided Design, Volume 149,103263. https://doi.org/10.1016/j.cad.2022.103263

Patankar K.C., Biranje S., Pawar A., Maiti S., Shahid M., More S., Adivarekar R. V. (2022) Fabrication of chitosan-based finishing agent for flame-retardant, UV-protective, and antibacterial cotton fabrics, Materials Today Communications, Volume 33, 104637. https://doi.org/10.1016/j.mtcomm.2022.104637

Paula J. N., Basílio F. M., Mulinari-Brenner F. A. (2022), Effects of chemical straighteners on the hair shaft and scalp, Anais Brasileiros de Dermatologia, Volume 97, Issue 2. PP. 193-203, https://doi.org/10.1016/j.abd.2021.02.010

Paasi J., Nurmi S., Kalliohaka T, Coletti G, Guastavino F. , Fast L, Nilsson A., Lemaire P., Laperre J., Vogel ., Haase J., Peltoniemi T., Reina G., Börjesson A., Smallwood J. (2004), Electrostatic testing of ESD-protective clothing for electronics industry, Paper presented at the Electrostatics 2003 Conference, Edinburgh, 23-27 March, 2003 Inst. Phys. Conf. Ser. No. 178 pp. 239-246.

Rah Y. C., Yoo M.H., Choi J., Park S., Park H., Oh K. H., Lee S. H., Kwon S. (2017),In vivo assessment of hair cell damage and developmental toxicity caused by gestational caffeine exposure using zebrafish (Danio rerio) models, Neurotoxicology and Teratology, Volume 64. PP. 1-7, https://doi.org/10.1016/j.ntt.2017.08.003

Ren M., Zhao J., Wang B., An H., Li H., Jia X., Wang J., Wang S., Yan L., Liu X., Pan B., Li Z., Ye R. (2022), Associations between hair levels of trace elements and the risk of preterm birth among pregnant women: A prospective nested case-control study in Beijing Birth Cohort (BBC), China, Environment International, Volume 158, 2022, 106965, https://doi.org/10.1016/j.envint.2021.106965

Sadick N., Arruda S. (2021), Understanding Causes of Hair Loss in Women, Dermatologic Clinics, Volume 39, Issue 3. PP. 371-374, https://doi.org/10.1016/j.det.2021.03.002

Singh A., Sheikh J. (2022), Preparation of mosquito repellent, antibacterial and UV protective cotton using a novel, chitosan-based polymeric dye, Carbohydrate Polymers, Volume 290, 119466, https://doi.org/10.1016/j.carbpol.2022.119466

Stewart-Pinkham S.M. (1989), The effect of ambient cadmium air pollution on the hair mineral content of children- Short communication, The Science of the Total Environment, 78 (1989) 289-296.

Tarrier J, Harland A, Jones R, Lucas T, Price D (2010), Applying Finite Element Analysis to Compression Garment Development, (8th Conference of the International Sports Engineering

Association (ISEA)), Procedia Engineering 2(2). PP. 3349–3354. https://doi.org/10.1016/j.proeng.2010.04.156

Tu Y., Lin S., Chen P., Chou C., Huang C., Ho H, Chen M. (2019), HSD3B1 gene polymorphism and female pattern hair loss in women with polycystic ovary syndrome, Journal of the Formosan Medical Association, Volume 118, Issue 8. PP.1225-1231, https://doi.org/10.1016/j.jfma.2019.04.013

Zhe Wang, Chuchu Zhao, Zhijuan Pan (2015), Porous bead-on-string poly(lactic acid) fibrous membranes for air filtration, Journal of Colloid and Interface Science, Volume 441. PP. 121-129, https://doi.org/10.1016/j.jcis.2014.11.041

Zhen Liu, Da-Ren Chen, Peng Wang, Zhongli Jim (2021) Effect of high pressure on the performance of coalescing filter cartridges for the natural gas purification, Process Safety, and Environmental Protection, Volume 148. PP. 1077-1089, https://doi.org/10.1016/j.psep.2021.02.027

Zhang T, He H, Wei Y, Geng W, Zhai J (2022). Vitamin C supplementation rescued meiotic arrest of spermatocytes in Balb /c mice exposed to BDE-209, Ecotoxicology and Environmental Safety, volume 242, 113846. https://doi.org/10.1016/j.ecoenv.2022.113846