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Article

Effectiveness of different fabrics in protecting from ultraviolet rays

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SUMMARY

As the ozone layer depletes and leads to greater exposure to ultraviolet (UV) radiation, a common carcinogen, humankind is increasingly susceptible to skin cancer. Additionally, due to rapid production of fabrics, the quantity is prioritized over the quality. We evaluated the effectiveness of different fabrics in protecting from UV radiation. Nylon is a synthetic, outdoor-activewear fabric, polyester is a multi-purpose durable fabric, linen and cotton are breathable, daily-wear fabrics. Based on the applications of these fabrics rather than their chemical properties, we inferred the most to least protective fabrics would be nylon, polyester, cotton, and then linen. Furthermore, we hypothesized blends of nylon and polyester would be the most protective overall while blends of linen and cotton would be the least. However, our results revealed linen, and subsequently cotton, were the most protective pure fabrics with their blend being the most protective. We concluded that blending two natural fibers, like linen and cotton, in optimum proportions produces the best UV-protective fabric since they contain natural-UV absorber lignin. However, blending synthetic and nonsynthetic fabrics generally produces a more protective fabric than their pure counterparts because their blends contain lignin from the pure counterparts, do not degrade in exposure to UV radiation due to the stabilizing effect of the pure counterpart, and contain the more complex molecular structures of the synthetic fabrics. Using this research, manufacturers can produce garments that maintain UV-protective properties, while consumers can make informed decisions to purchase garments.

INTRODUCTION

Excessive exposure to ultraviolet (UV) radiation poses significant risks to human health which experts group as photodamage, or harm done to the skin caused by the sun (1, 2). UV light damages the skin barrier and causes premature aging, sunspots, and redness (1, 2). Over time, as the skin becomes more damaged, UV radiation also seeps through the skin, causing mutations. As these mutations accumulate, they eventually cause skin cancer, which has become one of the common types of cancer in the United States with about 140 Americans dying from the deadliest form of skin cancer, melanoma, every week (3). In recent years, several factors have contributed to the increased risk of excessive exposure to UV radiation. One such factor is the rapid production and distribution of low quality garments, reducing the lifespan of clothes to one half (4, 5). Therefore, while many people take precautions, such as applying sunscreen to areas directly exposed to the sun, they often wear inexpensive and low-quality clothes that make them more prone to UV radiation (1, 6, 7). The depleting ozone layer is also contributing to this vulnerability leading to increased exposure to UV rays, a common carcinogen (8). Although there are some signs of self-healing in the ozone layer, human activities out-pace this self-healing process, indicating that changes in human behavior must be made to prevent the ozone layer from further depleting (9). Due to this unfortunate combination of ozone layer depletion and rapid production of low quality garments contributing to increased skin cancer cases and other signs of photodamage, it is becoming ever more important to study the effectiveness of various fabric compositions that make up every day clothes in protecting against UV radiation (2).

To give consumers the tools they need to minimize their susceptibility to UV radiation and make informed decisions about their clothing choices, we focused on comparing the protective ability of nylon, polyester, cotton, linen, and various blends of these four fabrics to ultimately find the most protective and least protective fabric compositions. Nylon, a synthetic, versatile fabric made of polymers, is used for outdoor activities with high exposure to the sun's rays. Polyester, a manufactured synthetic fabric, is the most used fiber in the world. In the fiber market, it is roughly 50% of all fibers and about 80% of all synthetic fibers used in the world (10). Polyester is considered strong, durable, crease-resistant, and quick to dry (11). Additionally, it is used for many purposes, such as in clothing, accessories, home furnishings, and footwear (11). Cotton is a natural fabric that is directly taken from *Gossypium* and other types of cotton plants (12). Cotton, a cellulose-based polymer known for its breathability, is the most used fabric worldwide with about 70% of all cotton is used to produce garments (13, 14). Synthetic materials, like polyester, tend to have additives that increase UV absorption (15). Additives include benzotriazole, benzylidene-bis-malonate, and polysorbate 20 (16-19). By chemically bonding into the polymer matrix, these additives absorb UV radiation and prevent the degradation of the chains of polymers (20, 21). However, cotton, a non-synthetic fabric, does not have these additives because it is difficult to supply specifically for cotton, making it expensive to manufacture (22). Linen, a natural fabric made from fibers of flax plant and a polymer of cellulose, is mostly used in loose-fitting clothing made for breathability (21, 22).

Due to the properties and applications of each fabric, we hypothesized that the order from most to least UV protective fabrics would be (i) nylon, (ii) polyester, (iii) cotton, and (iv) linen based on real-world uses of these fabrics rather than their chemical composition. We conducted two experiments, one experiment used a colorimeter and the other used a UV lamp and beads, to test our hypothesis. Our results showed that linen was the most protective pure fabric, and of the blended fabrics, 80% cotton and 20% linen was the most protective. Of the pure fabrics, 100% nylon was the least protective fabric, and of the blended fabrics, 45% cotton and 55% linen were the least protective fabric. Future studies should replicate our study using a spectrophotometer to verify our results. In addition, different settings of the spectrophotometer should be used, such as refraction, to better understand the complex properties of the interactions between the fabrics and UV radiation.

RESULTS

We assessed the impact of composition on the protective ability of various fabrics against UV radiation (**Figure 1**). In the first experiment, we utilized a colorimeter at four different wavelengths (430 nm, 470 nm, 565 nm, and 635 nm) to test the absorbency of the fabrics (**Figure 2**). The second experiment utilized a UV lamp to test the change in vibrancy of UV-reactive beads when covered by different fabrics (**Figure 3**).

On the logarithmic scale, high absorbance equates to highest protection. For the pure fabrics, linen had the highest absorbance of 2.327 (**Figure 4**). For blended fabrics, 80% cotton and 20% linen had the highest absorbance with an absorbance of 2.669. Similarly, by the cube root model, linen still had the highest absorption for pure fabrics at 2.329 and 80% cotton and 20% linen still had the highest absorption for blended fabrics at 2.660 (**Figure 4**). The cube-root and the logarithmic models were very similar and on average varied from each other by less than 0.01. Overall, of the pure fabrics, linen had the highest absorption (2.327), followed by cotton (1.351), then polyester (1.119), and finally nylon (0.887). When fabrics were combined, linen and cotton tended to have the highest absorption of all the fabrics when blended in the optimum proportion, while blending synthetic and nonsynthetic fabrics led to the blended fabrics generally doing better than both their pure counterparts (**Table 1, Figure 4**).

Since we could not test UV absorbance directly at 400 nm, which is a part of the UV spectrum, we created two curves of best fit that minimized the residuals in comparison to other common model-types (**Table S1**). The smallest wavelength setting of 430 nm was very close to 400 nm, meaning the models are likely a good approximation of the effects of UV radiation at 400 nm. Using the predicted absorbance values at 400 nm for pure fabrics and the blended fabrics, cubic and logarithmic models were created to predict the protective ability of fabrics with other varying composition percentages of the fabrics not directly tested (as it is impossible to test every possible combination of the fabrics), increasing the scope and real-world applicability of this study (**Figure 1**).

To further test the absorbency of the four fabrics, UV-reactive beads that turned more vibrant green were exposed to more UV radiation from a UV lamp. The color of each of the 20 beads was gathered using an online color eyedropper on a photo taken immediately after the fabric covering was removed from the beads with greater vibrancy (lower value) indicating weaker absorbance. Then, the color was quantified using a self-designed chart, the quantified values were averaged between the three trials (**Figure 5**). The lowest average overall was 100% nylon at 1.5, while the highest average overall was 80% cotton, 20% linen, with an average of 13.0. The highest of the pure fabrics was 100% linen at 12.0. The lowest for blended fabrics was 45% cotton, 55% linen at 4.6 (**Figure 3, Table 2**). We saw that there was a true difference in fabric composition and the UV protective ability of fabrics (95% CI). This conclusion is further supported by the fact that both experiments, which tested the quantitative and qualitative absorbency, organized the fabrics in the same order.

DISCUSSION

Both experiments indicated that linen has the greatest UV protection of the four tested pure fabrics. Originally, we hypothesized that linen would have the least protection because linen clothing is typically loosely woven to make

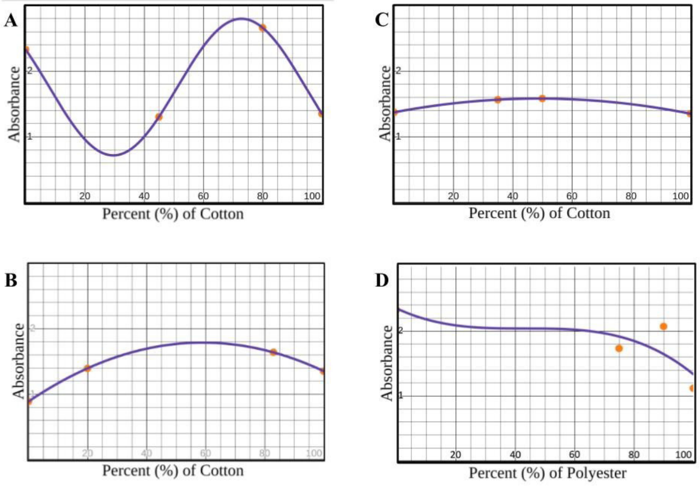

Figure 1: Models of the effect of varying percent composition on absorbance. Based on the predicted absorbance at 400 nm for blends of each fabric type, we determined that sinusoidals graphs most closely fit the shape of the data, as it displayed the highest R2 value out of all common function families. The best curve of fit for each set of data was modeled using Desmos. These graphs can be used to predict the absorbance of other percentages of fabric types that were not tested in our experiment. **A)** Cotton and linen blend **B)** cotton and nylon blend, and **C)** cotton and polyester blend where percentage is based on the percentage of cotton present for all. **D)** Polyester and linen blend where percentage is based on the percentage of polyester present.

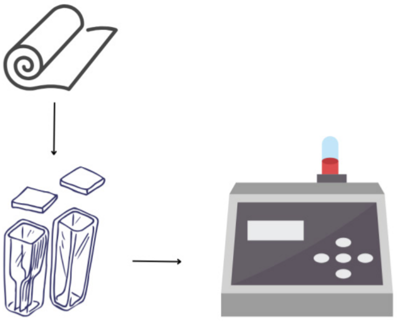

Figure 2: Experiment 1 set-up using a colorimeter to test absorbency. Experiment 1 was conducted using a Vernier colorimeter (right side of figure). The fabrics (top left) were cut to fit the dimensions of the cuvette (bottom left) without any overlap and then the fabric was wrapped around the inner edges of the cuvette. The cuvette was then placed inside of the colorimeter and the absorbance of each fabric was tested at the four wavelength settings: 430 nm, 470 nm, 565 nm, and 635 nm.

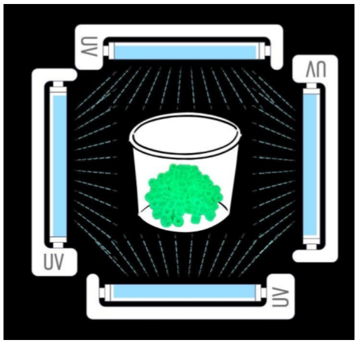

Figure 3: Experiment 2 set-up using UV-reactive beads. Experiment 2 was conducted by placing 20 Korlon UV-reactive plastic beads inside a clear deli container (center of figure). The deli container was fully covered with each type of fabric one at a time, assuring that there was no overlap, and placed under a UV light lamp (blue lights around perimeter of figure). After 30 minutes, the beads (green) were removed from the lamp and a picture of the color change of the beads was taken by a pre-fixed camera to measure UV absorbency.

garments more breathable. Through product analysis on various online platforms and in-person stores, it became apparent that typical linen clothes are made up of less than 50% linen, so the typical properties of linen clothing are not actually representative of the real qualities of linen fabric. Linen is produced using fibers of flax plants, which makes it a cellulose-based material (22). Its components, which include natural UV absorbers, called lignin, are responsible for its resistance to UV light (23). Since lignin has hydroxyl and carboxylic groups within its molecular structure, it is highly capable of absorbing and deflecting UV light because the hydrogen-bonding of the molecules do not let the radiation pass through (23).

Cotton, another cellulose-based fabric that comes from the *Gossypium* plant, had the second-greatest UV protection (23, 24). Cotton, similar to linen, is made from lignin (25). However, linen has a complex weave structure that gives linen a rough exterior, while cotton has a smooth exterior due to its simpler weave structure (26). Cotton's smoother weave reflects more UV light which results in better UV protection compared to rougher weaves which allows more light to pass through.

Polyester, a thermoplastic, often degrades into microplastics when exposed to UV radiation for an extended period of time (>30 minutes). Microplastics become unstable under the exposure to UV radiation (27, 28). Therefore, due to polyester's degradation into microplastics and microplastic's instability under UV radiation, polyester has a relatively low protective ability against UV radiation (28).

Nylon, a synthetic, plastic fabric made of polyamides linked by amide groups, had the poorest UV protection of the four pure fabrics (29). Nylon fibers are created through the process of polymerization in which the polymers are linked together into long chains, giving nylon its durability (29). Since nylon's pure state has poor UV protection, nylon typically has

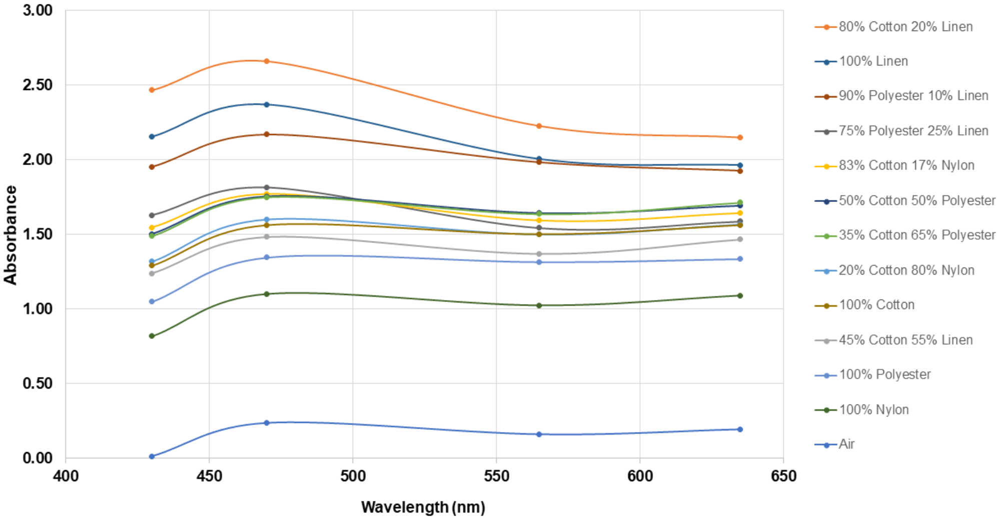

Figure 4: Ranking of fabric protectiveness based on absorbance. All 12 fabric compositions were ranked on the amount of absorbance at every wavelength tested (430 nm, 470 nm, 565 nm, 635 nm), with 80% cotton and 20% linen fabric being the most protective, and 100% nylon being the least protective. We created this graph using Excel based on our established cube-root and logarithmic formulas.

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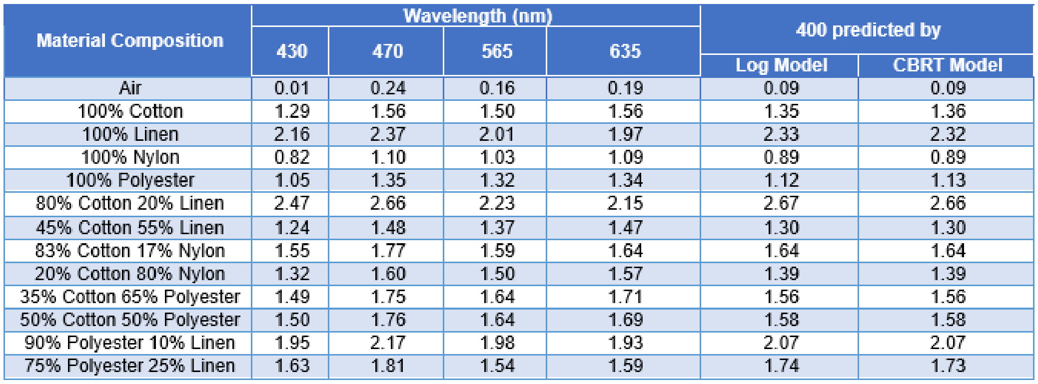

Material Composition	Wavelength (nm)				400 predicted by	
	430	470	565	635	Log Model	CBRT Model
Air	0.01	0.24	0.16	0.19	0.09	0.09
100% Cotton	1.29	1.56	1.50	1.56	1.35	1.36
100% Linen	2.16	2.37	2.01	1.97	2.33	2.32
100% Nylon	0.82	1.10	1.03	1.09	0.89	0.89
100% Polyester	1.05	1.35	1.32	1.34	1.12	1.13
80% Cotton 20% Linen	2.47	2.66	2.23	2.15	2.67	2.66
45% Cotton 55% Linen	1.24	1.48	1.37	1.47	1.30	1.30
83% Cotton 17% Nylon	1.55	1.77	1.59	1.64	1.64	1.64
20% Cotton 80% Nylon	1.32	1.60	1.50	1.57	1.39	1.39
35% Cotton 65% Polyester	1.49	1.75	1.64	1.71	1.56	1.56
50% Cotton 50% Polyester	1.50	1.76	1.64	1.69	1.58	1.58
90% Polyester 10% Linen	1.95	2.17	1.98	1.93	2.07	2.07
75% Polyester 25% Linen	1.63	1.81	1.54	1.59	1.74	1.73

Table 1: Predicted and experimental absorbance values and models for wavelength vs absorbance. For each of the wavelength settings used (430 nm, 470 nm, 565 nm, and 635 nm), the average of the three trials was calculated. Based on the average of the four wavelengths, logarithmic and cube-root models were developed using Desmos Graphing Calculator. Using these models, predictions were generated for the absorbance for each of the compositions at 400 nm.

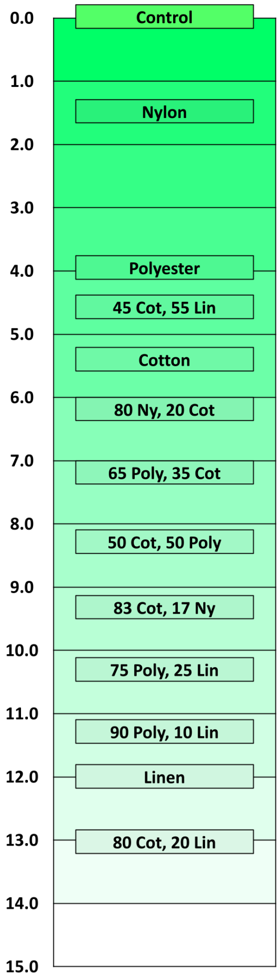

Figure 5: Absorbency chart for UV beads. More vibrant green colors on the chart corresponded with lower numbers, indicating poor absorption of UV light, with 0.0 being the lowest, while higher numbers indicated strong absorption of UV light, with 15.0 being the highest. The color of each of the 20 beads for every fabric was evaluated using an online color eyedropper tool, and the average absorbance for each fabric was found and displayed on the absorbency chart.

additives of other materials to improve its protective ability against UV radiation (30). However, when testing pure nylon under UV radiation, its fibers and chains broke down quicker than the average polyester fiber, weakening nylon's durability and protective properties (31-33).

When blended, the 80% cotton and 20% linen were the most absorbent (**Figure 4**). Both linen and cotton contain lignin; however, the 45% cotton and 55% linen performed the worst out of all the blended fabrics. We believe that the blending of the weave structures of the two fabrics failed to absorb as much UV radiation as it could in the predominantly cotton blend; however, more testing of specific cotton-linen blends would be necessary to make conclusions. Additionally, the linkage of the cellulose fibers may have had the opposite reaction than anticipated, allowing for UV radiation to seep through, performing poorly (34). Cotton and polyester performed at their expected range, towards the middle of all blended fabrics, as both of their pure counterparts performed moderately as well due to their previously mentioned chemical properties. The linen and polyester blends were ranked second and third of all blended fabrics. This indicates that the strong properties of linen fibers, such as natural UV absorbers, were carried onto the blend. The combination of nylon and cotton fabrics was shown to be better than both 100% nylon and 100% cotton. The addition of cotton's lignin to nylon prevents nylon from degrading as quickly, making a blend of nylon and cotton more effective than pure nylon and cotton (34).

A future study could use a spectrophotometer rather than a colorimeter because a colorimeter only measures absorbance within the visible light spectrum. However, a spectrophotometer measures various light properties, such as light reflection and refraction, throughout the UV spectrum from 100-400 nm. Therefore, it would allow us to analyze the impact of the various properties of these fabrics, in a more precise manner for a broader portion of the UV light spectrum, providing a more complete, precise understanding of the protective ability of these fabrics (35, 36).

Another limitation of our experiment was the varying weave structure between the fabrics. Although weave structure plays a significant role in the protectiveness of the fabric (because synthetic and nonsynthetic fabrics have very different weave structures that are often not shared between the fabrics),

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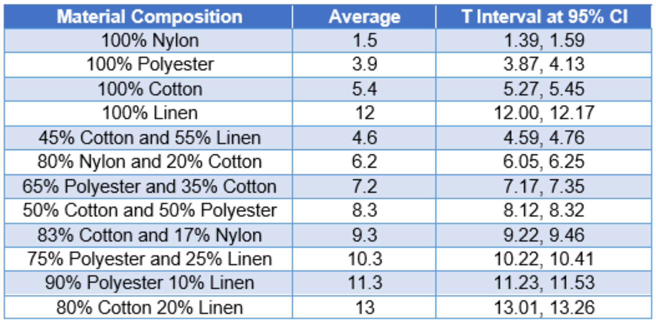


Material Composition	Average	T Interval at 95% CI
100% Nylon	1.5	1.39, 1.59
100% Polyester	3.9	3.87, 4.13
100% Cotton	5.4	5.27, 5.45
100% Linen	12	12.00, 12.17
45% Cotton and 55% Linen	4.6	4.59, 4.76
80% Nylon and 20% Cotton	6.2	6.05, 6.25
65% Polyester and 35% Cotton	7.2	7.17, 7.35
50% Cotton and 50% Polyester	8.3	8.12, 8.32
83% Cotton and 17% Nylon	9.3	9.22, 9.46
75% Polyester and 25% Linen	10.3	10.22, 10.41
90% Polyester 10% Linen	11.3	11.23, 11.53
80% Cotton 20% Linen	13	13.01, 13.26

Table 2: Quantified color values of UV beads. Average quantified vibrancy for 20 beads based on the absorbency chart for UV Beads was calculated for all three trials. Using this average vibrancy, in order to find all plausible values of each fabric's mean absorbance at the 95% confidence interval (CI), four separate calculations of 1-sample t-intervals for means were conducted. Our samples were all randomly selected from the bag of beads. The degrees of freedom for each was 19. As no t-interval overlapped with another t-interval, each of the compositions has a true difference in absorbance.

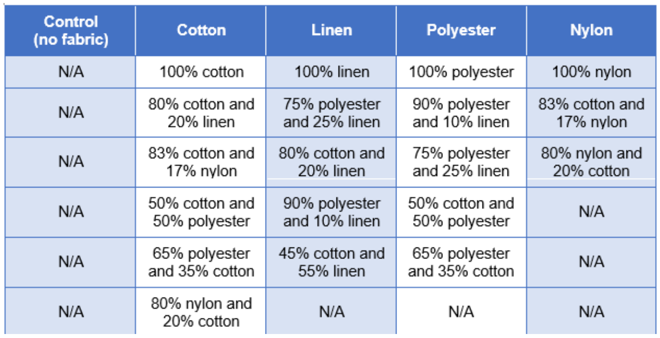
it was difficult to choose a singular weave structure that could be tested using all four pure fabric types. Therefore, instead of trying to find a singular weave structure to test, the applicability of our results was optimized by choosing the most common weave structure for each of the four fabrics.

From this study, blending synthetic fiber with natural fiber was found to generally produce a more protective fabric than their pure counterparts. However, blending two natural fabrics, such as cotton and linen, generally produces the most protective fabrics. The influx of low-quality garments that often contain solely synthetic fabrics or natural fabrics in non-optimum blends makes it difficult to protect the skin from photodamage. Garment tags often include properties such as the country of manufacturing, laundry directions, and materials utilized. However, these labels do not allow consumers to fully grasp the implications of the fabrics in their clothes, as well as the chemicals in those fabrics, which may affect their skin. Without proper labels and access to fashionable clothing made from quality materials which effectively absorb UV radiation, consumers are not able to take appropriate actions to protect their skin from UV radiation. This study serves to add awareness to the impact of these fabrics on UV protection and, more importantly, bringing attention to the need for further information about the issue that leads to skin cancer and other consequences of photodamage.

MATERIALS AND METHODS

Experiment 1: Absorbency based on colorimetry

All 12 pure and synthetic fabric samples (**Table 3**) were cut into pieces measuring 4.5cm x 4 cm. Pure fabrics were chosen due to their commonality in garments and accessibility. They were all obtained from Amazon, and they all had the same color, thickness. Proportions of blended fabrics were chosen based on the most common blends seen in online retailers and local stores. In general, cotton has a greater variety of compositions with other fabrics as it is widely used in garments worldwide. Though we tried to find the two most common blends of each fabric, we were unable to find a blend of nylon and polyester; since they have similar properties in real-world applications, and it is not practical for companies to produce the two fabrics blended. Additionally, as nylon and linen typically have very different uses, we were unable to find a blend of nylon and linen (**Table 3**). Using a magnifying glass and a ruler, we counted the number of threads in one square inch of each fabric, finding that all 12 fabrics had a thread count of roughly 200 (plus or minus 10) threads, meaning that all the fabrics had roughly the same density. The color of every fabric was kept constant to prevent any changes in color having an impact on the absorbance; we chose to use white fabrics for our experiments, so we also made sure that the colorimeter could detect changes in absorbance (as the color white itself does not absorb much UV radiation) (37).



Control (no fabric)	Cotton	Linen	Polyester	Nylon
N/A	100% cotton	100% linen	100% polyester	100% nylon
N/A	80% cotton and 20% linen	75% polyester and 25% linen	90% polyester and 10% linen	83% cotton and 17% nylon
N/A	83% cotton and 17% nylon	80% cotton and 20% linen	75% polyester and 25% linen	80% nylon and 20% cotton
N/A	50% cotton and 50% polyester	90% polyester and 10% linen	50% cotton and 50% polyester	N/A
N/A	65% polyester and 35% cotton	45% cotton and 55% linen	65% polyester and 35% cotton	N/A
N/A	80% nylon and 20% cotton	N/A	N/A	N/A

Table 3: List of all fabrics and compositions tested. The four pure fabrics types tested were 100% cotton, 100% linen, 100% polyester, and 100% nylon. Additionally, varying compositions of these four main fabrics were tested.

Each fabric was placed in a cuvette, with dimensions of 1.2 cm x 4.35 cm x 1.2 cm (**Figure 2**). The fabric was wrapped in the cuvette with no overlap. The cuvettes only had the fabric in them (i.e., no water was added). Additionally, a cuvette without any fabric was also utilized as a control to test the typical absorbance at each tested wavelength without any coverings to block the light. A Vernier Colorimeter was utilized with a range of 0-3 absorbance. We tested four wavelengths: 430 nm, 470 nm, 565 nm, and 635 nm. The typical resolution of this type of colorimeter is 0.035 percent transmittance (%T) which is the ratio of transmitted light to the incident light. A resolution of 0.035 %T means the colorimeter can detect changes in transmittance as small as 0.035 percent. The transfer function is V_{out} = 0.035 x (%T) + 0. The colorimeter was calibrated before the trials (**Figure 2**).

Each of the four wavelengths was tested for each fabric three times and then averaged. Based on the general shape of the data and an attempt to reduce the residuals for the control where wavelength was on the x-axis and absorbance was on the y-axis, logarithmic and cube-root functions were determined to be the most appropriate mathematical models for the experimental data (**Table S1, Figure 4**). To predict the absorbance in the UV light spectrum, each of the tested wavelengths were used for each fabric and a curve of best fit was created using Desmos Online Graphing Calculator. The models were then used to predict the absorbance at 400 nm, which is a part of the UV light spectrum.

Based on the predicted absorbance at 400 nm, new models were created using Desmos Online Graphing Calculator to predict the absorbance of varying percentage compositions not directly tested by this study. These models were created using curves of best fit of varying family functions to ensure that the predictions for each fabric were as accurate as possible. The R2 values of each of these curves of best fit were greater than 0.5 with most equal or greater than 0.98, meaning that most of the variation in the absorbance was accounted for in the variation in the composition, validating the predictions (**Table S1**).

Experiment 2: UV-bead absorbency under UV lamps

We measured all 12 pure and synthetic fabrics and cut them into a standardized size of 25cm x 25cm. Then, we placed 20 Korlon UV-reactive plastic beads (8mm in diameter, 6mm in height, and with a 4mm aperture in the middle), that change into a more vibrant green based on the amount of UV light they are exposed to, in 16 oz clear plastic deli containers. We wrapped each of the deli containers in the fabric, assuring that no overlap was present in the folding method. We gave one container of beads no fabric covering to act as the control group because it would serve as a baseline for the vibrancy of the beads with full exposure to UV light. Then, we completely sealed the fabric covering using tape. Each bead was labeled from 1-20 and placed under a Beetles Gel Polish UV LED Nail Lamp with 18 long-lasting LED bead lights for 30 minutes (**Figure 3**). As we removed the beads, the vibrancy of the beads was immediately captured by a pre-fixed camera before giving the beads time to “cool-off”.

Because color is a subjective, qualitative variable, a chart was made to quantify the vibrancy of the beads for data analysis (**Figure 5**). This semi-quantitative chart ranges from 0.0 to 15.0; more vibrant green colors corresponded with lower numbers on the chart, indicating poor absorption of UV light, while less vibrant green colors corresponded with higher numbers, indicating strong absorption of UV light (**Figure 5**). Utilizing an online color eyedropper, which evaluates the specific amounts of RGB (red, green, and blue), CMYK (cyan, magenta, yellow, and key (black)), HSV (hue, saturation, and value), and HLS (hue, lightness, and saturation) color models to find the specific hex of each bead, to accurately match the bead color to the absorbance chart, we gathered the color of each of the 20 beads and tabulated them (**Table S2**) (37). We repeated the process of placing 20 beads under the lamp and determining the vibrancy of the beads 3 times. Then, the average vibrancy of each bead for the three trials was calculated. Using this average vibrancy, in order to find all plausible values of each fabric’s mean absorbance at the 95% confidence interval, we conducted four separate calculations of 1-sample t-intervals for means using a TI-84 Graphing Calculator (**Table 2**). Our samples were all randomly selected from the bag of beads, so, the independence condition was met for all four, so, the independence condition was met for all four. The normal condition was met since there was no extreme skew or outliers with 1,000 beads total, so all four sampling distributions were approximately normal by the Central Limit Theorem. The degree of freedom for each was 19.

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APPENDIX

Material Composition	Logarithmic (Log) Model	R^2 values	Cube Root (CBRT) Model	R^2 values
Air	$0.634\log(x) - 1.56$	0.49	$0.101\sqrt[3]{x}-1.57$	0.48
100% Cotton	$1.129\log(x) - 1.59$	0.68	$0.181\sqrt[3]{x}+0.03$	0.67
100% Linen	$-1.790\,log\,(x) + 6.985$	0.75	$-0.291\sqrt[3]{x} + 4.46$	0.75
100% Nylon	$0.175\,log\,(x) - 0.40$	0.65	$0.175\sqrt[3]{x} - 0.40$	0.63
100% Polyester	$1.258\,log\,(x) - 2.15$	0.68	$0.201\sqrt[3]{x} - 0.35$	0.67
80% Cotton 20% Linen	$-2.567\,log\,(x) + 9.348$	0.85	$-0.417\sqrt[3]{x} + 5.73$	0.85
45% Cotton 55% Linen	$0.834\,log\,(x) - 0.875$	0.57	$0.134\sqrt[3]{x} + 0.31$	0.57
83% Cotton 17% Nylon	$-0.005\,log\,(x) + 1.651$	0.1	$-0.002\sqrt[3]{x} + 1.65$	0.1
20% Cotton 80% Nylon	$0.941\,log\,(x) - 1.06$	0.58	$0.150\sqrt[3]{x} + 0.29$	0.57
35% Cotton 65% Polyester	$0.777\,log\,(x) - 0.46$	0.52	$0.124\sqrt[3]{x} + 0.65$	0.51
50% Cotton 50% Polyester	$0.606\,log\,(x) - 0.001$	0.42	$0.096\sqrt[3]{x} + 0.87$	0.42
90% Polyester 10% Linen	$-0.575\,log\,(x) + 3.569$	-0.4	$-0.095\sqrt[3]{x} + 2.78$	0.41
75% Polyester 25% Linen	$-0.830\,log\,(x) + 3.895$	-0.53	$-0.135\sqrt[3]{x} + 2.72$	0.54

Table S1: Logarithmic and Cube Root Models for wavelength vs absorbance. Based on the average of the four wavelengths used, logarithmic and cube-root models were developed using Desmos Graphing Calculator. Using these models, predictions were generated for the absorbance for each of the compositions at 400 nm and placed in Table 1.

Material Composition	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
100% Nylon	1.3	1.6	1.9	1.5	1.2	1.2	1.5	1.6	1.8	1.5	1.1	1.4	1.6	1.5	1.3	1.4	1.7	1.5	1.5	1.7
100% Polyester	3.5	3.9	4	3.7	4.4	3.7	4.3	4.1	4.6	3.7	4	4	4.3	3.6	4.2	3.8	3.9	4.1	4	4.2
100% Cotton	5.4	5.5	5.6	5.2	5.6	5.3	5.6	5.2	5.2	5.4	5.7	5.3	5.1	5.1	5.3	5.6	5.3	5.2	5.4	5.2
100% Linen	12	12	12	12	12	12	12	12	12	12	12	13	12	12	12	12	12	12	12	12
45% Cotton and 55% Linen	4.5	4.6	4.7	4.3	4.5	4.9	5	4.8	4.6	4.5	4.7	4.9	4.4	4.7	4.9	4.5	4.6	4.8	4.9	4.7
80% Nylon and 20% Cotton	5.8	5.7	6	6.3	6.4	6.2	6.5	6.4	6.2	6	6.1	6.3	6.1	6	6.3	6.5	5.9	6	6.1	6.2
65% Polyester and 35% Cotton	7.6	7.2	7	7.3	7.2	7.3	7.2	7.6	7.5	7	7.1	7.3	7.2	7.5	7.3	7	7.2	7.4	7.3	7
50% Cotton and 50% Polyester	8.2	8.3	8.1	8	7.9	8	8.6	8.7	8.3	8.2	8.1	8.5	7.9	8.2	8.3	8.4	8.1	8.3	8.2	8.1
83% Cotton and 17% Nylon	9.2	9.3	9.1	9	9.1	9.4	9.7	9.5	9.1	9.1	9	9.4	9.7	9.8	9.4	9.3	9.1	9.7	9.4	9.5
75% Polyester and 25% Linen	10	11	11	10	10	11	10	10	10	10	10	11	11	10	10	10	10	10	10	10
90% Polyester 10% Linen	11	11	11	11	12	12	12	11	11	11	12	12	12	11	11	11	11	11	11	12
80% Cotton 20% Linen	13	13	14	13	13	13	13	13	13	14	13	13	13	13	14	13	13	13	13	13

Table S2: Trial values of experiment. The quantified values of the absorbance based on the absorbency chart for each of the beads during our trials is recorded, which we then used to calculate our average quantified color values of UV beads.