Improving Appearance and Functional Properties in the Design of Children's Clothes Using NPs Mixtures

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Abstract:
As the children can be unaware by surrounding environment and their weak bodies, they can easily affected by some dangers that can be avoided through multifunction textiles. This research fulfils the requirements for children clothes that provide protection from ultraviolet radiation, exposure to high temperatures, bacteria and wettability. To achieve this aim, this research designed to enhance the appearance and the functionality of cotton fabric by using Nano finishing technology through applying both Zinc Oxide NPs and Silicon Dioxide NPs by pad – dry – cure process on 100% cotton fabrics (Woven fabric, Indian Cotton, and Egyptian Cotton Giza 86). This research focus on 2 to 5 years old girls children clothes in which treated fabric was processed to make different pieces in one design, though each piece could worn separately as a different outfit, and we can exchange the pieces of the design by creating new outfit for spring/summer season. Results show the effectiveness of the treatments can be assessed by using standard test methods and influences of the finishing on some general textile properties such as air permeability, thermal gravimetric analysis, ultraviolet protection factor, anti-bacterial test, and contact angle as well as the durability of the treatments was investigated. The treated samples exhibited very sufficient functional properties even after 25 washing cycles through durability test.

Keywords:
Children clothes
Design
Anti-bacterial
Ultraviolet protection
Cotton fabrics
multifunction properties

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1. Introduction
The primary aim of wearing clothes is for protection, e.g. to keep warm, modesty. Currently, people wear different clothes for different occasions and identities. (Fashion Design Basics, 2011). At the heart of the fashion, industry is the design and manufacture of fashion garments (Dillon, 2011).

Fashion varies from society to society and from region to region. It is a term that is mostly associated with the art of clothing and accessories. In its real sense it is a continuous process of changes in styles in any field, be it clothes, bags, profession, furniture, furnishings etc. (Khurana & Sethi, 2007).

Today we realize that clothing can function as an important component of human safety (Raheel, 1994)1 (Nabil A. Ibrahim, 2018).Clothing design that is fit for purpose should look attractive to the end-user as well as function in relation to their physiological requirements (Faust & Carrier, 2014).

Functional clothing can therefore be defined as a generic term that contains all such types of clothing or assemblies that are specifically engineered to deliver a pre-defined performance or functionality to the user, over and above its normal functions. (Gupta, 2011) (Nabil A Ibrahim, 2017).The kind and type of clothing worn depends on functional considerations (such as the need for warmth or protection from the elements) and social considerations. (Geršak, 2013).

Every single day children are hurt when use the products in their daily routine, even with products made especially for children (Child Product Safety Guide, 2013). When designing children's clothing and accessories, it is essential to take into account the behaviors of the children, whose dependenceon exploration and challenge drives them to use products in different and new ways. (Children's Apparel & Accessories – Product Safety Guidelines, 2015).

Children protection from the sun is essential. Firmly woven fabrics such as t-shirt material, long sleeves and long trousers offer good protection. It is essential that children are not over or under dressed, and that clothing suits the temperature. Younger the child the more easily they can become cold or hot. Natural Children's clothing fibers such as cotton are likely cooler than synthetic fabrics (Children's Clothing in Child Care, 2008).

Children are at high risk from burn injuries that happen from playing with fire (matches, lighters, candles, etc.) in their sleepwear.Children are likely to panic when their sleepwear is on fire and cannot respond quickly to put out the flames as an adult might (Child Product Safety Guide, 2013).

1.1. Statement of problem

- Scarceness of availability for children designs from cotton fabric with multifunctional properties, like anti-bacterial, ultraviolet protection, water/ oil resistance and thermal stability.
- Importance of design clothes to protect children health in preschool stage.

1.2. Significance

- Improve functional properties for children clothes by using nanotechnology.
- Enhance fabric properties like anti-bacterial, ultraviolet protection, water/ oil resistance and thermal stability.

1.3. Objectives

- Apply treatment for fabric to enhance it with new multifunctional properties like anti-bacterial, ultraviolet protection, water/ oil resistance and thermal stability.
- Make new designs applicable for cotton fabric and local market.

2. Experimental

2.1. Materials

Mill-scoured and bleached woven cotton (100%, 240 g/m^2), knitted cotton "EGYPTIAN COTTON GIZA 86" (100%, 76.7 g/m^2), and knitted cotton "Indian cotton" (100%, 140 g/m^2) were used and supplied from Giza Spinning and Weaving Co. Egypt.

In addition, We used ZnO NPs (powder) (Sigma Aldrich)[dispersion, 50 wt.% in water, average particle size < 35 nm (APS)], SiO_2 NPs (powder) (Sigma Aldrich) [powder, size 10-20 nm particle size (BET), 99.5% trace metals basis], Polyethylene glycol [PEG 800] (Sisco Research Laboratories, SRL), and textile binder [TUBIFAST AS 4510] (CHT Bezema).

2.2. Method

2.2.1. The Pad – Dry – Cure

Mill-scoured and bleached woven cotton, knitted cotton (Egyptian Cotton Giza 86), knitted cotton (Indian cotton) fabric were immerged in padding liquor at room temperature for 15 minutes and then passed through laboratory padding mangle, which was running at a speed of 15 rpm with a pressure of 1.75 kg/cm^2 using 2-dip 2-nip padding sequence at pick up 80% expression, then the sample padded again for 1 min then squeezed. The padded substrate was dried at 110°C for 5 minutes and curing at 160°C temperature for 3 minutes.

2.3. Testing and Analysis

Air permeability was tested using air permeability tester (21443, FRANK) according to ASTM D737-18 (ASTM D737, 2018). Thermogravimetric analysis was tested according to ASTM E1131 (ASTM E1131 - 08, 2018) and ISO 11358 (ISO 11358-1, 2018). UPF was measured using UV-VIS double beam spectrophotometer (Perkin-Elmer, Lambda 35, diffuse transmission technique) according to the American standard ASTM D6604-2000 (ASTM D6604 - 00, 2018) and AATCC test method AATCC 183-2000 (AATCC 183, 2018). Anti-bacterial was tested according to disc diffusion method for filamentous fungi tested by using approved standard method (M38–A) developed by the National Committee for Clinical Laboratory Standards (**NCCLS**). (CLSI M38, 2018). Contact angle was tested according to ASTM D 5725 (ASTM D5725, 2018): Standard Test Method for Surface Wettability and Absorbency of Sheeted Materials Using an Automated Contact Angle Tester.

3. Design proposal

Developed 20 designs clarifying the idea of how we can make different pieces in one design though each piece could be worn separately as a different outfit, and also we can exchange the pieces of the

design creating new outfit. The designs are suitable for girls from 2 to 5 years old.

Table 1 Different Design Proposals

Design Proposal 1 	**The outer outfit:** Sleeveless short white dress with ruffled fabrics and ribbon in the front, handmade crochet in the curved edge	**The inner outfit:** Sleeveless short baby blue striped dress with fabric gathering, handmade crochet and small handmade embroidery flowers on the top if it
	Suggest fabric: ▪ White woven cotton fabric ▪ Baby blue woven striped cotton fabric ▪ Fuchsia woven cotton fabric Accessories: handmade crochet – plastic zipper – buttons	**Suggested Colors:** 
Design Proposal 2 	**The outer outfit:** Black and white striped short skirt jumpsuit with fuchsia ribbons in the waist	**The inner outfit:** Sleeveless short white dress with printed black dots with fuchsia neck piping
	▪ **Suggest fabric:** ▪ Black and white striped woven cotton fabric ▪ White printed knitted cotton fabric ▪ Fuchsia knitted cotton fabric ▪ Accessories: buttons	**Suggested Colors:** 
Design Proposal 3 	**The outer outfit:** Sleeveless short white dress with printed black dots, handmade crochet, cutline in the waist and curved back hem	**The inner outfit:** Sleeveless white T-shirt with fuchsia neck piping White short with printed black dots with fuchsia pocket piping and elastic waistband
	▪ **Suggest fabric:** ▪ White knitted cotton fabric ▪ White printed knitted cotton fabric ▪ Fuchsia knitted cotton fabric ▪ Accessories: andmade crochet –	**Suggested Colors:** 

Table 1 Different Design Proposals

	buttons	
Design Proposal 4 	**The outer outfit:** Yellow shawl with handmade crochet on the whole edge of it	**The inner outfit:** Sleeveless short dress with cutline in the waist
	Suggest fabric: ▪ White knitted cotton fabric ▪ Floral printed woven cotton fabric ▪ yellow woven cotton fabric ▪ Accessories: handmade crochet –buttons	**Suggested Colors:** 
Design Proposal 5 	**The outer outfit:** Black and white striped shawl with piping in the two cut lines in the front of it	**The inner outfit:** White and dark blue striped sleeveless top Fuchsia basic short skirt with elastic waist band
	Suggest fabric: ▪ Black and white striped woven cotton fabric ▪ White and dark blue striped knitted cotton fabric ▪ Fuchsia knitted cotton fabric ▪ white knitted cotton fabric ▪ Accessories: buttons	**Suggested Colors:** 
Design Proposal 6 	**The outer outfit:** Yellow sleeveless pleated blouse with elastic sides	**The inner outfit:** Sleeveless short white dress with printed black dots with two yellow cut lines on the top of it and handmade crochet
	Suggest fabric: ▪ Yellow woven cotton fabric ▪ White printed knitted cotton fabric ▪ Accessories: plastic zipper – handmade crochet	**Suggested Colors:** 

Table 1 Different Design Proposals

Design Proposal 7 	**The outer outfit:** White short skirt jumpsuit printed with black dots with fuchsia piping in the waist and straps	**The inner outfit:** White short dress with fuchsia cut lines in the middle of it and white dotted piping and black neck piping
	Suggest fabric: ▪ White printed knitted cotton fabric ▪ White knitted cotton fabric ▪ Fuchsia woven cotton fabric ▪ Black woven cotton fabric ▪ Accessories: buttons	**Suggested Colors:** 
Design Proposal 8 	**The outer outfit:** White vest dress with white striped collar, ribbons in the two sides of it and curved edges	**The inner outfit:** Sleeveless yellow short dress with blue cut lines
	Suggest fabric: ▪ White woven cotton fabric ▪ White and dark blue striped knitted cotton fabric ▪ yellow woven cotton fabric ▪ dark blue woven cotton fabric ▪ Accessories: buttons	**Suggested Colors:** 
Design Proposal 9 	**The outer outfit:** White and dark blue striped vest with pleats in the middle of it and top fuchsia cut line	**The inner outfit:** Sleeveless dark blue short dress with fuchsia pleats and two white cut lines in the shoulders
	Suggest fabric: ▪ White woven cotton fabric ▪ White and dark blue striped knitted cotton fabric ▪ Fuchsia woven cotton fabric ▪ dark blue woven cotton fabric ▪ Accessories: buttons	**Suggested Colors:** 

Table 1 Different Design Proposals

<table>
<tr><td rowspan="2">Design Proposal 10
  </td><td>The outer outfit:
Half short jumpsuit with cut line ruffles and ribbon</td><td>The inner outfit:
White and black short jumpsuit with cut lines and ruffles and fuchsia collar</td></tr>
<tr><td>Suggest fabric:
▪ White woven cotton fabric
▪ White and black striped knitted cotton fabric
▪ White printed woven cotton fabric
▪ Fuchsia knitted cotton fabric
▪ black woven cotton fabric
▪ Accessories: buttons – plastic zipper</td><td>Suggested Colors:
  </td></tr>
<tr><td rowspan="2">Design Proposal 11
  </td><td>The outer outfit:
White croise vest with fuchsia edge</td><td>The inner outfit:
Floral short dress with fuchsia croise collar</td></tr>
<tr><td>Suggest fabric:
▪ White woven cotton fabric
▪ floral printed woven cotton fabric
▪ Fuchsia woven cotton fabric
▪ Accessories: buttons</td><td>Suggested Colors:
  </td></tr>
<tr><td rowspan="2">Design Proposal 12
  </td><td>The outer outfit:
White sleeveless short dress with fuchsia cut line in the waist and handmade crochet</td><td>The inner outfit:
Sleeveless white short dress with printed fuchsia dots , dark blue cutline in the waist, fuchsia cutline in the shoulders and handmade crochet</td></tr>
<tr><td>Suggest fabric:
▪ White woven cotton fabric
▪ white printed woven cotton fabric
▪ Fuchsia woven cotton fabric
▪ Dark blue woven cotton fabric
▪ Accessories: buttons – plastic zipper – handmade crochet</td><td>Suggested Colors:
  </td></tr>
</table>

Table 1 Different Design Proposals

Design Proposal 13 	**The outer outfit:** White and dark blue striped skirt jumpsuit with yellow straps and handmade crochet	**The inner outfit:** Baby blue short dress with dark blue edge, white collar and handmade crochet
	Suggest fabric: ▪ White and dark blue striped woven cotton fabric ▪ Baby blue printed woven cotton fabric ▪ yellow woven cotton fabric ▪ Dark blue woven cotton fabric ▪ Accessories: buttons – plastic zipper	**Suggested Colors:** 
Design Proposal 14 	**The outer outfit:** Black and white striped skirt jumpsuit with fuchsia straps and black ruffles and waistband	**The inner outfit:** White short dress with fuchsia ribbons, collar and hem
	Suggest fabric: ▪ White woven cotton fabric ▪ Black and white striped woven cotton fabric ▪ Fuchsia woven cotton fabric ▪ Black woven cotton fabric ▪ Accessories: buttons – plastic zipper	**Suggested Colors:** 
Design Proposal 15 	**The outer outfit:** White and baby blue striped blouse with fuchsia collar , piping, hem and back ribbons	**The inner outfit:** White and baby blue striped short dress with cut lines, ruffles and ribbon around the neck
	Suggest fabric: ▪ White woven cotton fabric ▪ Baby blue and white striped woven cotton fabric ▪ Fuchsia woven cotton fabric ▪ Accessories: plastic zipper	**Suggested Colors:** 

Table 1 Different Design Proposals

Design Proposal 16 	**The outer outfit:** baby blue short opened skirt with white waistband	**The inner outfit:** White dress with yellow cut lines and ruffles in the neck collar
	Suggest fabric: ▪ White woven cotton fabric ▪ Baby blue woven cotton fabric ▪ yellow woven cotton fabric ▪ Accessories: plastic zipper – buttons	**Suggested Colors:** 
Design Proposal 17 	**The outer outfit:** Double layer floral short skirt with baby blue waistband and ribbon in the back	**The inner outfit:** White short dress with round edge and baby blue , fuchsia collar
	Suggest fabric: ▪ White woven cotton fabric ▪ Baby blue woven cotton fabric ▪ Baby blue knitted cotton fabric ▪ Fuchsia woven cotton fabric ▪ Floral printed woven cotton fabric ▪ Accessories: buttons	**Suggested Colors** 
Design Proposal 18 	**The outer outfit:** Dark blue short skirt jumpsuit with fuchsia straps	**The inner outfit:** Dark blue and white striped short dress with fuchsia collar, cut lines and hem and handmade crochet
	Suggest fabric: ▪ White woven cotton fabric ▪ dark blue woven cotton fabric ▪ Fuchsia woven cotton fabric ▪ White and dark blue striped knitted cotton fabric ▪ Accessories: plastic zipper – buttons- handmade crochet	**Suggested Colors:** 

Table 1 Different Design Proposals

Design Proposal 19 	**The outer outfit:** White and yellow striped shawl can be divided into 4 pieces	**The inner outfit:** White basic tank top with yellow handmade crochet Dark blue leggings
	Suggest fabric: ▪ White woven cotton fabric ▪ dark blue knitted cotton fabric ▪ white knitted cotton fabric ▪ White and yellow striped woven cotton fabric ▪ Accessories: buttons-handmade crochet	**Suggested Colors:** 
Design Proposal 	**The outer outfit:** White shawl with yellow adjustable ribbon and dark blue edges	**The inner outfit:** White and yellow striped short jumpsuit with dark blue ruffles and handmade crochet
	Suggest fabric: ▪ White woven cotton fabric ▪ dark blue woven cotton fabric ▪ yellow woven cotton fabric ▪ White and yellow striped woven cotton fabric ▪ Accessories: buttons-handmade crochet – plastic zipper	**Suggested Colors:** 

4. Implementation of Design

4.1. Implemented No. 1

(a) Outfit 1 (Front) (b) Outfit 1 Back view (c) Outfit 2 Front view (d) Outfit 2 Back view (e) Combination of outfits (Front) (f) Combination of outfits (back)

Figure 1 Implementation No.1

4.2. Implemented No. 2

(a) Outfit 1 Front view (b) Outfit 1 Back view (c) Outfit 2 Front view (d) Outfit 2 Back view (e) Combination of outfits front view (f) Combination of outfits back view

Figure 2 Implementation No.2

4.3. Implemented No. 3

(a) Outfit 1 Front view (b) Outfit 1 Back view (c) Outfit 2 Front view (d) Outfit 2 Back view (e) Combination of outfits front view (f) Combination of outfits back view

Figure 3 Implementation No.3

4.4. Implemented No. 4

(a) Outfit 1 Front view (b) Outfit 1 Back view (c) Outfit 2 Front view (d) Outfit 2 Back view (e) Combination of outfits front view (f) Combination of outfits back view

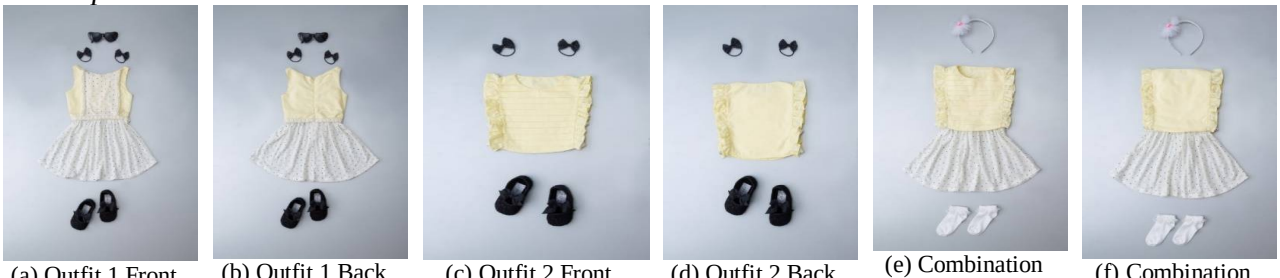
Figure 4 Implementation No.4

4.5. Implemented No. 5

(a) Outfit 1 Front view (b) Outfit 1 Back view (c) Outfit 2 Front view (d) Outfit 2 Back view (e) Combination of outfits front (f) Combination of outfits back

Figure 5 Implementation No.5

4.6. Implemented No. 6



(a) Outfit 1 Front view (b) Outfit 1 Back view (c) Outfit 2 Front view (d) Outfit 2 Back view (e) Combination of outfits front (f) Combination of outfits back

Figure 6 Implementation No.6

5. Result and discussion

5.1. Air Permeability

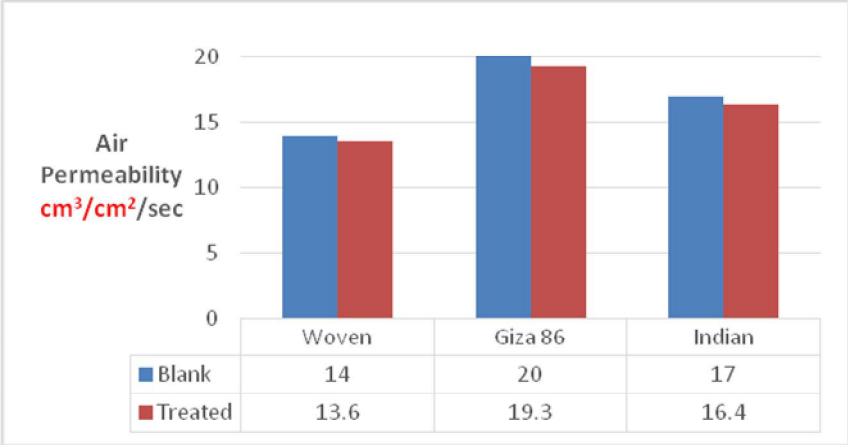
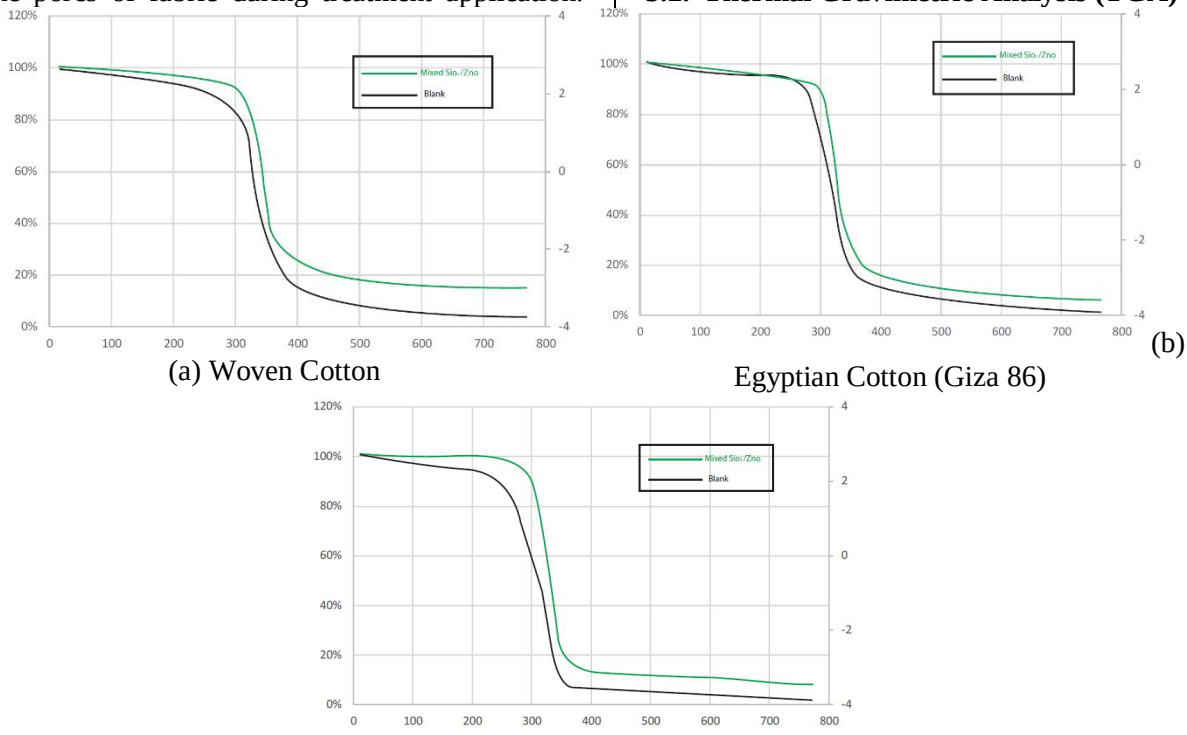


Figure 7 Effect of treatment application on Air Permeability for the different types of cotton fabric

There was a slight decrease in air permeability results in the different fabrics from the blank samples, and this occurs because the NPs got into the pores of fabric during treatment application. This indicates a good treatment occurred and the NPs got successfully into the fabrics, and this slight difference doesn't affect the fabric comfort.

5.2. Thermal Gravimetric Analysis (TGA)



(a) Woven Cotton (b) Egyptian Cotton (Giza 86)

(c) Indian Cotton

Figure 8Effect of treatment application on TGA for the different types of cotton fabric

The TGA effect fordifferent types of cotton fabric shows weight loss in fabric until 100°C is due to water evaporation while is thermally stable until 240-280°C. Sharp decomposition stage between 240°C to 370°C was very fast and significant. At temperature 370°C - 600°C the loss is mainly due to pyrolysis of the char rest. In woven fabric blank sample sharp decomposition loss was 69.63% and started at 230°C compared to after treatment application result loss was 53.15% started at 300°C.While in Egyptian cotton Giza 86 blank sample sharp decomposition loss was 68.24% and started at 260°C compared to treated samples where loss was 55.85% started at 310°C. Finally in Indian Cotton blank sample sharp decomposition loss was 67.63% and started at 260°C compared to best treatment application result of SiO_2 high concentration treatment where loss was 55.72% started at 300°C. And this indicates the treatment was successful and improved the thermal stability of the treated cotton fabrics much higher that of the untreated cotton fabrics.

5.3. Ultraviolet Protection Factor

Figure 9 Effect of treatment application on Ultraviolet Protection Factor for the different types of cotton fabric

The UPF results got better with treatment; the best UPF result was especially for the woven cotton fabric resulted from the presence of ZnO and the woven fabric structure, which is tight and provide better protection.

5.4. Anti-Bacterial Test

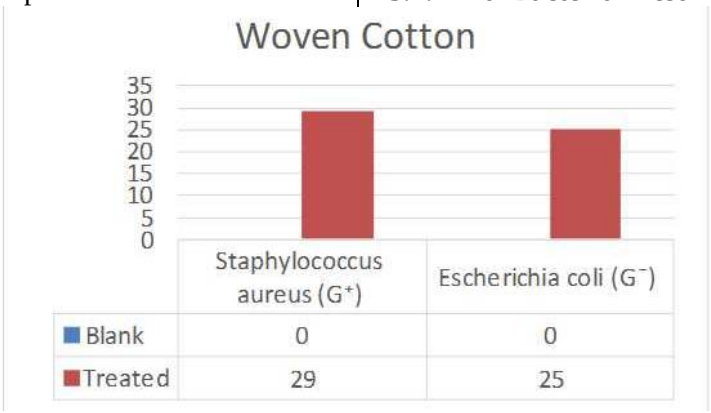


Figure 10 Effect of Treatment Applications on Anti-bacterial for Woven Cotton Fabric

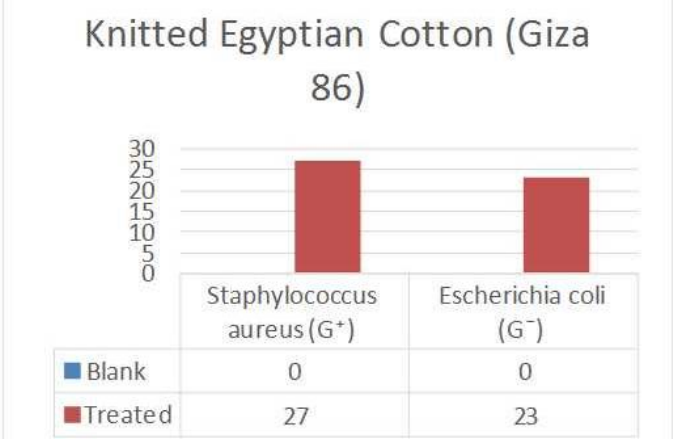


Figure 11 Effect of Treatment Applications on Anti-bacterial for Knitted EgyptianCotton(Giza 86) Fabric

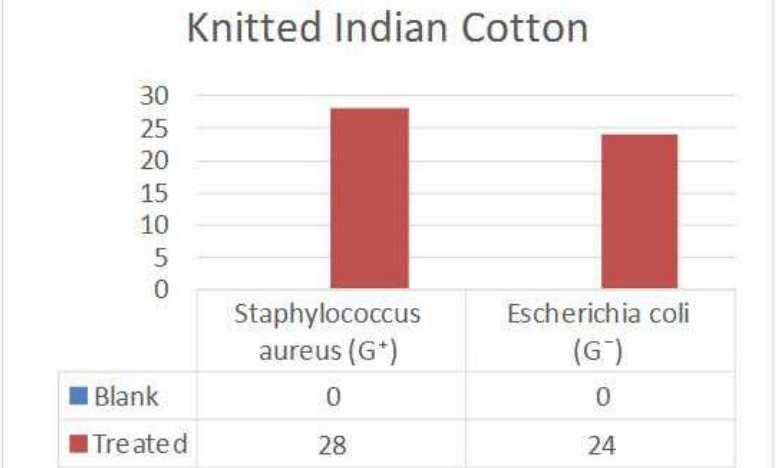


Figure 12 Effect of Treatment Applications on Anti-bacterial for Knitted Indian Cotton Fabric

There was improvement in the treated samples compared to blank samples in all fabrics tested, and this can be noticed through the improvement happened in the inhibition zone as the blank samples was zero and treated samples have a range from 23 to 29 mm.

5.5. Contact Angle

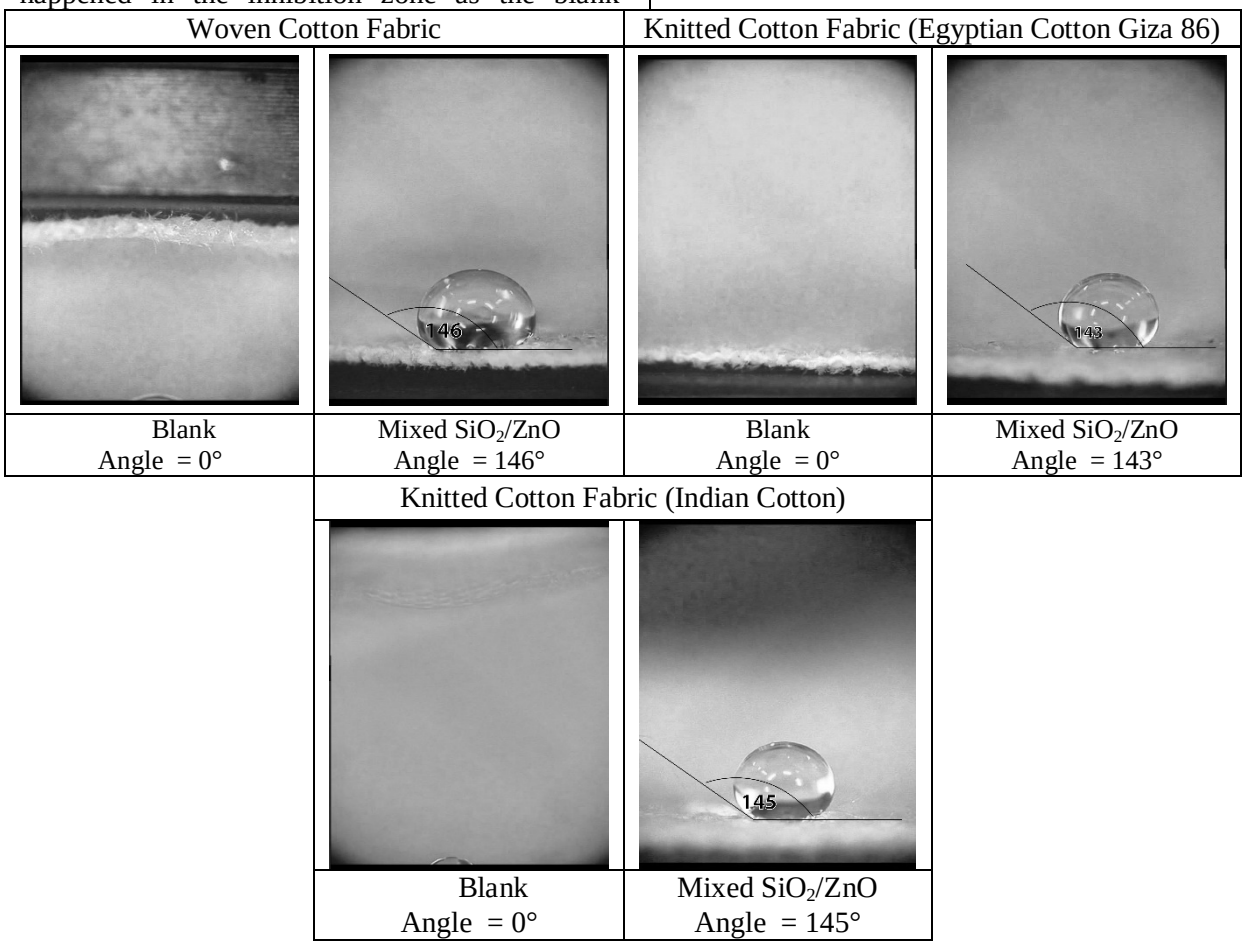


Figure 13 Effect of treatment application on Contact Angle for the different types of cotton fabric

Drops of water form spherical shape on the fabric while cellulosic materials famously known by their super wettability characteristic that indicates hydrophobic effect modification of the fabric after treatment with SiO_2 NPs; that its crystal surface structure was responsible for the hydrophobic effect. Contact angle results recorded indicates that all of samples are above 90° and this proves that the treatment was effective.

6. Conclusion

This research shows that the ability to create different designs, that each piece could be worn separately as a different outfit and the pieces can be exchanged to create new outfit that achieve the designs variety with minimum piece number. Six designs were implemented to prove the applicability of the idea, suitable for children, and give good appearance.

These outfits are made from 100% cotton fabric which has enhanced functional properties like UV-Blocking, hydrophobic, thermal stability, and antibacterial which are required for children clothes safety. These functional properties have successfully achieved by applying SiO_2 NPs and ZnO NPs treatment application on the surface of cotton fabrics, The effect of these treatments were tested for functional properties of 100% cotton fabrics (Woven fabric, Indian Cotton, and Egyptian Cotton Giza 86), these properties are enhanced after NPs treatment by the pad-dry-cure process.

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