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Woven face mask made from CoolMax fibres with three layers

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In this research, ten fabric samples of CoolMax have been produced for preparing reusable face masks. The first group of five woven fabric samples has been produced with different fabric structures (plain weave 1/1, basket weave in warp direction, basket weave in both directions, satin 8, and twill 3/1) with both warp and weft yarns having 750 twists/m. The other group of five woven fabric samples is produced with the same fabric structures but by using 850 twists/m for warp and weft. The plain weave 1/1 fabric is treated with a water-repellent finish. The fabric properties, such as anti-bacterial, moisture, and air permeability, have been evaluated. It is observed that the fabric samples produced from CoolMax with twill, basket weave, and satin would be suitable for the inner and middle layer of the face mask, as they absorb droplets, and liquids and prevent bacteria, while the treated plain weave 1/1 fabric with water-repellent finish can be used for the outer layer. The woven face mask with three layers has been evaluated by objective and subjective methods, and the results show that the air permeability is 15.8 $cm^3/cm^2/s$, which is good in terms of breathability as compared to a disposable face mask, and withstand 25 cycles of washing for anti-bacterial property. The suggested woven face mask with three layers can reduce the spreading of the infection of COVID-19.

Keywords: CoolMax fibre, Covid-19, Moisture management, Woven face mask

1 Introduction

Due to the increasing global demand for the face mask, the world faced a crisis to cover the required quantities, in addition to environmental problems in the consumption of disposable face masks. This necessitates the search for quick alternatives that prevent the spread of COVID-19 infection and mutations. However, new variants of the virus are expected to occur, and hence there is a need to continue to wear masks in the future in public. Disposable face masks carry both financial and environmental costs. The woven face mask can be used to protect healthy people or to control the sources of infection. The health procedures must be followed personally and socially to prevent the transmission of viruses by wearing a face mask to prevent infection[1-3]. The World Health Organization "WHO" recommended worldwide use of woven masks to cover the face in public to reduce transmission of infection[4].

The outbreak of Coronavirus and its mutations have led to an increase in the demand for face masks globally. Since March 2020 according to the Forbes website, the sales of face masks increased to a maximum in April. Millions of face masks are sold by 10,000 sellers globally[5]. The Center for Disease Control and Prevention (CDC)[6] stated that it encourages the production and use of the face mask from the fabric. The website of CDC[6] shows people how to manufacture face mask at home.

In June 2020, wearing a face mask was mandatory in the world and in the Kingdom of Saudi Arabia. For Saudi citizens and residents, the use of the face mask became a necessary part of their daily clothes. There are many factories in the Kingdom of Saudi Arabia that produce reusable woven face masks to meet the requirements of the market.

Woven face masks became an alternative for many who could not acquire surgical face masks due to the scarcity and hiked price[7]. As compared to strategical face mask, it is less expensive and reusable. Several studies confirmed that wearing medical face masks between healthy family members is important to prevent transmission[8-10]. There is no direct evidence of the efficiency of wearing face masks for healthy people in society to prevent infection with respiratory viruses[11]. The medical mask must prevent and block the spray and droplets of liquids and must be breathable by allowing air passage[12]. It does not prefer to choose elastic fabric to produce mask, because, during use, the materials tightened on the

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face lead to an increase in the size of the pores and a decrease in filtration efficiency during end use[13,14].

In the laboratory setting, the efficacy against bacteriophage has been found to be 50–70% for two-layer fabric face coverings, whereas, for three-ply surgical masks [15] and N95, the efficacy was 95–97%. The number of layers of woven face mask are three layers, depending on the fabric used, including the outer layer water repellent which is exposed to the external environment. For the middle layer and the inner layer that touch the face, the inner layers must have hydrophilic fabric to absorb liquid and drops, but the outer layer must have hydrophobic properties[12]. The selected face mask's fabric must have properties, such as water repellency, breathability and anti-bacterial[12].

CoolMax fibres from polyester have some properties to be recommended for face masks, it is a high-performance fabric that can move moisture away from the body to the outer layer of fabric, where it dries faster than any other fabric[16]. This sweat is expelled from the body. Thanks to the six channels that make up each fibre of our fabric and in this way, garment comfort is achieved[17].

The active ingredient in CoolMax fibre is a durable silver-based additive. This additive has proven highly effective in the laboratory against a wide range of bacteria, and the mechanism of action involves the slow release of silver ions from an inorganic 'cage' matrix through an ion-exchange process[18]. The silver ions can interact with bacteria on the fabric to disrupt their cellular functions, thereby inhibiting the growth of bacteria colonies.

The main objectives of this research are to study the effect of yarn twist factors, structures of CoolMax fabric on the performance of face mask and to compare the effectiveness between woven face mask from CoolMax fabric and disposable.

2 Materials and Methods

2.1 Materials

The specifications of woven face mask are critical, when the fabrics are selected carefully. CoolMax fibres give a feeling of great comfort and freshness. The main property of this fabric is its fibre cross-section, with channels that carry sweat and keep the garment completely dry. It is necessary to study the properties of the woven face mask to meet the requirements of a face mask made from smart CoolMax fibres. The smart CoolMax fibres were selected with yarn count for both warp and weft (Nm 40/1), and two levels of yarn twist (750 and 850 TPM) were used to produce ten samples with different fabric structures for the woven face mask.

CoolMax fabrics having different structures, plain weave 1/1, basket weave 4/4 in warp, basket weave 4/4 in both directions, satin 8, and twill 3/1 were prepared separately with 750 TPM and 850 TPM.

2.2 Methods

2.2.1 Sample Preparation and Processes Weaving

All samples were woven in the "Ghazl El-Mahalla for Spinning and Weaving Egypt" factory by using the air-jet weaving machine.

2.2.2 Water Repellent Finish for Plain Weave Samples

Silicon dioxide nanoparticles were used for water repellent finish for two samples of fabrics, plain weave 1/1 with 750 and 850 TPM to be used as the first layer for the woven face to prevent the outside dirt particles or infection from attaching themselves to this layer. At the same time, the fabric remains porous and permits air and moisture transfer.

2.3 Tests Procedure

Some laboratory experiments were conducted to test the CoolMax fabric, for anti-bacterial, liquid absorption, time of absorption, vertical and horizontal wicking test, air permeability, and spray test, according to the standard specifications.

2.3.1 Anti - Bacterial

The American Association of Textile Chemists and Colorists AATCC 100-2004 was used to test CoolMax by preparing different types of bacteria, and organisms incubated in favorable conditions. to provide a clear indication of the antimicrobial properties of the test fabric. The *Staphylococcus aureus* (BCRC 10451, ATCC 6538P), and *Klebsiella pneumoniae* (BCRC 16082, ATCC 4352) bacteria, are the two organisms outlined in the AATCC-100 standard.

2.3.2 Time of Liquid Absorption

The liquid absorption time of fabric was measured in accordance with AATCC-79. A drop of liquid was delivered from a fixed height onto the test fabric (1 cm). The time taken for the disappearance of reflection from the liquid surface was taken as a measure of the wettability of the fabric.

2.3.3 Spray Test

The AATCC 22 was used to test the sample's plain weave with 750 twist/m and 850 twist/m for water

sprayed against the taut surface of a test specimen under controlled conditions producing a wetted pattern whose size depends on the relative repellency of the fabric. Evaluation is accomplished by comparing the wetted pattern with pictures on a standard chart.

2.3.4 Air Permeability

The ASTM D 737 was used to test all fabrics for air permeability under pressure 125 Pascal and area 100 cm^2. The plain weave 1/1 fabrics with 750 TPM and 850 TPM were tested for air permeability before and after the water-repellent finish. The other samples were tested without water water-repellent finish. The control sample for air permeability of the disposable face mask was tested to compare the suggested woven face mask with the disposable face mask for air permeability; the suggested final face mask with three layers was tested also.

3 Results and Discussion

The woven face mask does not require all the specifications mentioned for the medical mask because it is not used in operations or surgery rooms. However, it can be evaluated by many other properties as discussed hereunder.

3.1 Anti-Bacteria Activity

The result shows that the CoolMax for the inner and middle layers of the face mask fulfils the first clause of the ASTM F2100 standard, because the active ingredient in CoolMax fibres is a durable, non-migratory silver-based antimicrobial additive. This additive has been proven to be highly effective in the laboratory against a wide range of micro-organisms, including bacteria up to 99%, when incorporated into fabrics, such as polyester staple and filament; it is bacteriostatic. It is observed that that all samples of new materials of CoolMax and after 25 cycles after washing, are found to be excellent (3 rating) and thus are suitable to be used in the middle or in the inner layer of the face mask to prevent bacteria and infection.

3.2 Moisture Results

3.2.1 Assessment of Liquid Absorption Rate

The liquid absorption ratio can be calculated as:

$$\text{Liquid absorption ratio (\%)} = \frac{(\text{Wet weight} - \text{Dry weight})}{\text{Dry weight}}$$

It is clear from Table 1 that all samples made from CoolMax can absorb at least twice the fabric weight, and some samples can absorb four times the weight. The fabrics made with 750 TPM yarns absorb more water quantity than those made from 850 TPM yarns, and hence they can be used as the inner layer of the face mask for a long time to absorb the droplets and prevent infection. It seems that samples with fabric structure of satin weave 8 and twill 3/1 with 750 and 850 TPM are the best in terms of water absorption and can be used for the inner layer of the mask.

3.2.2 Estimation of Time of Liquid Absorption

Figure 1 shows that the time of the liquid absorption has a wide variation range among the

Table 1 — Moisture test results, liquid absorption (%), and time of absorption for CoolMax

Fabric structure	Yarn T.P.M.	Liquid absorption rate %	Absorption time, s
Plain weave 1/1	750	2.62	24
Basket weave 4/4 in warp direction	750	3.12	9
Basket weave 4/4 in both directions	750	3.37	14
Satin weave 8	750	4.62	10
Twill weave 3/1	750	3.62	12
Plain weave 1/1	850	2.22	39
Basket weave 4/4 in warp direction	850	2.47	14
Basket weave 4/4 in both directions	850	2.72	15
Satin weave 8	850	3.97	12
Twill weave 3/1	850	2.97	13

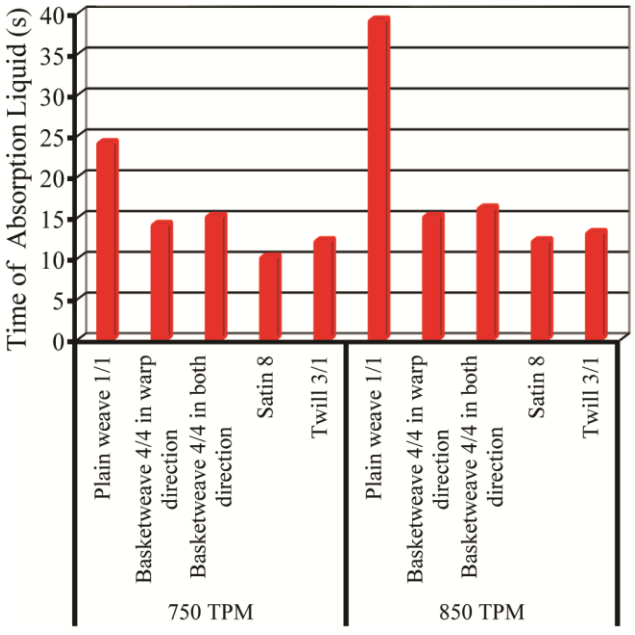

Fig. 1 — Time of liquid absorption for CoolMax with different yarn twists and fabric structures

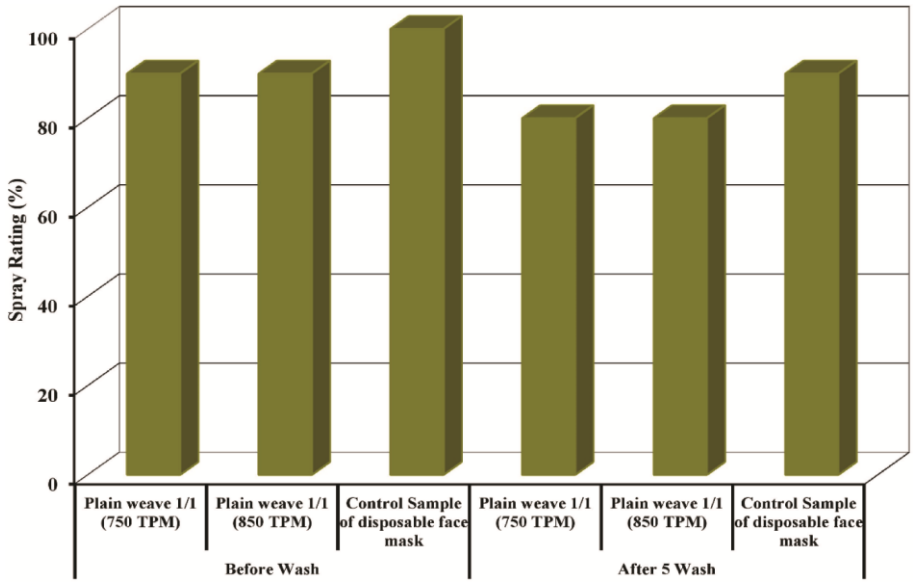

Fig. 2 — Water repellency of plain weave fabric 1/1 with 750 and 850 TPM and control sample of first layer of disposable face mask, before washing and after five washing cycles

samples. The shorter the time of absorption, the easier the fabric wets. The plain weave is not suitable for the inner layer of the face mask, because it takes a long time to absorb the droplets and the liquid. The satin weave 8, twill weave 3/1, and basket weave in both directions with 750 TPM and 850 TPM respectively are suitable to absorb liquid and droplets quickly, and hence they can be used for the inner layer of the face mask.

3.3 Comparison of Spray of Water Repellent

Figure 2 compares the spray rate of the samples after finishing before washing and after five times of washing. It is clear that the values of spray rating before washing plain weave 1/1 and the first layer of the control disposable sample are 90-90-100 respectively, and the values of spray rating after washing of plain weave 1/1 and the first layer of control disposable sample are 80-80-90 respectively. It means that these samples after water repellent finish can withstand water for several cycles of washing and can protect the face against external influences.

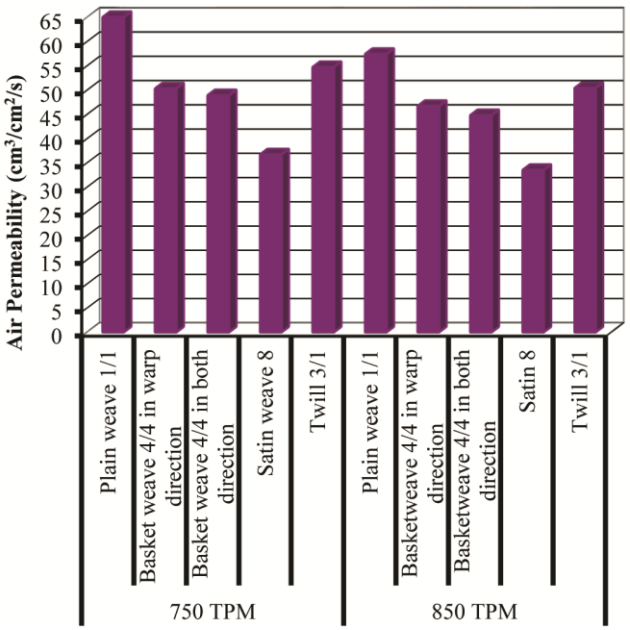

Fig. 3 — Air permeability of one layer of CoolMax fabric without water-repellent finish, having different yarn twists and fabric structures

3.4 Interpretation of Air Permeability

Breathability is a very important property of face mask fabric. The breathability can be evaluated by testing fabric air permeability after water-repellent finishing. Figure 3 shows that the maximum air permeability is achieved by the plain weave 1/1 for both yarn twists, followed by twill 3/1 for both twist levels and basket weave, although air permeability is an important requirement for the comfort of the face mask. It must be kept at a certain limit to avoid the transmission of the COVID-19 infection. The test results for air permeability of all samples produced from CoolMax are in the range of 35-65. $cm^3/cm^2/s$ for one layer only.

Figure 4 shows that the air permeability for plain weave 1/1 decreases after treatments of water repellent

finish and the values are in the range of 42-45 $cm^3/cm^2/s$. These values must be considered during selecting and arranging the layers of the face mask.

3.5 Suggested Face Mask Made from Woven CoolMax

Selecting and arranging face mask fabrics are very important because some materials may have better performance than others and may be suitable for the outer layer, whereas some materials are suitable for the inner and middle layers. The fabrics made from low twisted yarns have more water absorption than the fabric made from high yarn twists, but the satin fabrics in both cases of yarn twist have more water absorption. Hence, these fabrics of low yarn twists may be suitable for face masks. It is observed from the results, that the woven fabrics from CoolMax, are anti-bacterial, suitable for the inner and middle layers of the face mask, and absorb droplets and liquids.

3.5.1 Selecting Inner and Middle Layers of Face Mask

The fabric twill 3/1, satin 8, and basketweave with 750 TPM in both directions can be used in the inner and middle layers of the face mask. They have a short time of absorption, good vertical wicking, and horizontal distribution of liquid to outside, which will help to dry the droplets and liquids.

3.5.2 Selecting Outer Layer of Face Mask

The outer layer of the face mask must meet the requirements of the face mask to prevent infection from outside. So, the plain weave 1/1 with 750 and 850 TPM treated to be water repellent will be suitable for outer layer of face mask, the selection depends on the breathability and air permeability.

3.5.3 Air Permeability of Three-Layer Fabric for Face Mask

Plain weave 1/1 is selected for the outer layer, and the twill 3/1 fabric is used for inner and middle layers, because it has better air permeability than satin fabric. The three layers are tested for air permeability together. The results show that the air permeability is 15.5 $cm^3/cm^2/s$, while the air permeability of the disposable face mask made from polypropylene, is 17.2 $cm^3/cm^2/s$.

3.5.4 Arrangement of Three Layers of Face Mask

The three layers of face mask can be arranged as shown in Fig. 5; the first layer is water repellent finished hydrophobic plain weave 1/1.

The second layer is anti-bacterial and it can be chosen from twill 3/1, satin weave, or basket weave. The third layer is hydrophilic, and it can be chosen from twill 3/1, satin, and basket weave. The final woven CoolMax face mask can achieve the requirements for a face mask, which prevents the infection from spreading.

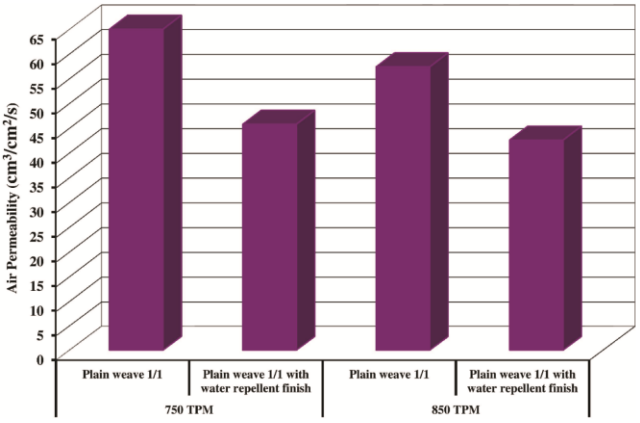

Fig. 4 — Air permeability for one layer of CoolMax fabric plain weave 1/1 (750 and 850 TPM), with and without a water-repellent finish

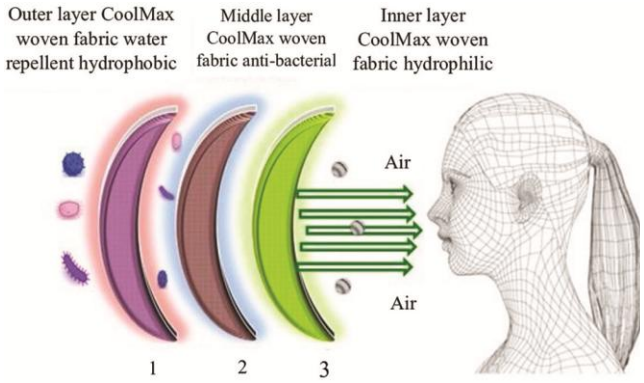

Fig. 5 — Arrangement of three layers of woven face mask CoolMax fibres

3.5.5 Evaluation of Woven CoolMax Fibres Face Mask (Three Layers)

The face mask is evaluated by objective and subjective methods. The objective method is antimicrobial, which is a major factor for evaluation mechanisms commonly for woven face mask[19]. Standard tests evaluate bacteriostatic or bactericidal activity over the course of several hours where a face covering has to contend with viral particles[20]. The CoolMax yarn, which is used to produce the face mask is an inherent anti-bacterial and can be washed and reused up to 25 washes, according to the manufacturer of yarn, as mentioned in section **3.1**.

The subjective method is applied by the wearer; to evaluate the comfort of a face mask. Thirty persons wear the face mask for two months to evaluate the comfort of face mask, and at least 90% agree with the comfort of the face mask.

3.5.6 Comparison in Cost between Disposable and Woven Face Mask

This study is not for comparing the prices between different kinds of masks, because the prices of the masks are not steady, and depend on many factors, such as situation of spreading the infection, brand name, materials, and performance for end use. At the same time, the consumption of textile materials of woven face mask is less than the disposable mask, and the less consumption of textile materials is an advantage for cheap price of woven mask and also for environment compared with the disposable face mask.

4 Conclusion

The fabric made from yarn twist 750 TPM twill 3/1, satin 8, and basket weave in both directions can be used as inner and middle layers due to their absorbency. On the other hand, the plain weave 1/1 treated with a water-repellent finish is suitable for the outer layer of the face mask. The suggested face mask from woven CoolMax fabrics made with three layers can be used to reduce the spreading and transmission of infections of Covid-19, due to its anti-bacterial activity, breathability, comfort, and reusability for several times. It can achieve the requirements to protect non-infected person, reducing the virus spreading and the consumption of disposable face mask and maintaining the safety of the environment.

References

1 *Infection Prevention and Control during Health Care when COVID-19 is Suspected: Interim Guidance* (World Health Organization), 19 March 2020.

2 *Infection Prevention and Control Guidance for Long-Term Care Facilities in the Context of COVID-19: Interim Guidance* (World Health Organization), 8 January 2021.

3 *Home Care for Patients with COVID-19 Presenting with Mild Symptoms and Management of their Contacts: Interim Guidance* (World Health Organization), 17 March 2020.

4 Chu D K, Akl E A, Duda S, Solo K, Yaacoub S & Schünemann H J, *The Lancet*, 395 (10242) (2020) 1973.

5 https**://**www.forbes.com, (accessed on 20 May 2020).

6 https://www.cdc.gov/, (accessed on 10 September 2020).

7 Mueller A & Fernandez L, *Med Rxiv*, 4(2020).

8 Jefferson T, Dooley L, Ferroni E, Al-Ansary L A, van Driel M L & Bawazeer G A, *Cochrane Database of Systematic Reviews*, 1(2023).

9 Cowling B J, Chan K H, Fang V J, Cheng C K Y, Fung R O P & Wai W, *Ann Intern Med*, 151 (7) (2009) 437.

10 Barasheed O, Almasri N, Badahdah A M , Heron L, Taylor J & McPhee K, *Infectious Disorders-Drug Targets (Formerly Current Drug Targets-Infectious Disorders)*, 14 (2) (2014) 110.

11 *Information Note COVID-19 and NCDs* (World Health Organization), 2020.

12 *Advice on the use of Masks in the Context of COVID-19: Interim Guidance* (World Health Organization), 6 April 2020.

13 Jung H, Kim J K, Lee S, Lee J, Kim J & Tsai P, *Aerosol Air Qual Res*, 14 (3) (2014) 991.

14 Zhao M, Liao L, Xiao W, Yu X, Wang H, Wang Q, *Nano Lett*, 20 (7) (2020) 5544.

15 Neupane B B, Mainali S, Sharma A & Giri B, *Peer J*, 7(2019) 1-14.

16 www.invista.com. (accessed on 3 March 2021)

17 https://cpaluart.com/en/coolmax-extreme-fresh-2/. (2021).

18 www.advansa.com. (accessed on 10 December 2020).

19 *TSI Mechanisms of Filtration for High Efficiency Fibrous Filters* (ITI–041, TSI Incorporated), 2005.

20 *Advice on the use of Masks in the Community, during Home Care and in Health care Settings in the Context of the Novel Coronavirus (2019-nCoV) Outbreak: Interim Guidance* (World Health Organization) 29 January 2020.