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The Effect of Textile structure on the Comfort and Protection Properties of Clothes (Cloth masks)

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Abstract:

The purpose of the present research is to study the effect of textile structure (Coverage factor and the type of fabrics) on the comfort properties (breathability) and protection properties (resistance to fluid permeability and pores size). Where the problem with this research in lies in the lack or scarcity of research that dealt with the properties of comfort and protection, especially in fabric masks, and the experimental approach was used to reach the best results . Whereas, woven and knitted fabrics were used in the research samples. The Results of air permeability (breathability) showed that the textile structure has a great impact on the breathability property of both woven and knitted fabrics, as the higher the density of the threads at a certain limit in the warp and weft directions in woven fabrics and the number of rows and columns in knitted fabrics, the air permeability and breathability decreased. The results showed that the cloth mask made of knitted fabrics is better than the cloth mask made of woven fabrics in terms of comfort and protection properties. The reason of respect are knitted fabrics better than woven fabrics when used to make cloth masks Based on the results given in the research, the two-layer cloth masks made of knitted fabrics are better in the comfort properties of breathable, expressed in air permeability, according to the technical requirements issued by the Egyptian Ministry of Industry and Trade, as well as according to the standard specification. Also, masks made of knitted fabrics were better than masks made from woven fabrics in terms of protection properties represented in the size of pores as well as resistance to spray permeability, expressed by the fabrics' resistance to fluid permeability under hydrostatic pressure according to the standard specification.

Keywords:
Cloth mask,
Textile structures,
Air Permeability (Breathability),
Spray Resistance,
pores size.

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1. Introduction

The challenges that the world witnessed and is still witnessing as a result of the spread of Coronavirus infection 19. This epidemic that began in Wuhan, China, then spread to all countries of the world which was considered by the World Health Organization (WHO) as a pandemic and a global epidemic, as injuries exceeded nearly 4 million, and deaths nearly 30,000 people, and the numbers are still increasing[i].

The preventive measures that followed are social distancing and wearing personal protective equipment (PPE) such as face masks, As a result, high consumption by medical workers and the general public has led to a severe shortage of surgical masks and made them insufficient to confront the epidemic. Therefore, it was important to find a solution to reduce the search for surgical mask and provide it for workers in the medical field, and this solution was the use of masks made of woven fabrics with certain conditions and specifications to provide the maximum possible protection.

Despite the use of cloth masks, we desperately need scientific evidence of the effectiveness of these masks in preventing the spread of the virus[ii].

Despite the widespread use of cloth masks, especially in developing or developed countries in pandemic situations such as the Corona virus, we note that cloth masks are rarely mentioned in medical policies, and their effectiveness has not been tested in randomised clinical trials (RCT)[iii]. Little as most of the studies that have been done on the effectiveness of a cloth mask has been observational or in vitro[iv].

Historically, it can be said that masks made of fabrics in hospitals in the United States of America during the early twentieth century[v] . After the development of disposable medical masks in the middle of the twentieth century, the use of cloth masks decreased. Nevertheless, cloth masks are still in common use in many Asian countries. An example is the use of masks by health care workers and the general public during the outbreak of severe acute respiratory syndrome in China[vi].

Due to the lack of studies dealing with the effectiveness of cloth masks in preventing the emerging corona virus, because this pandemic is new and spread very quickly around the world. Hence, the aim of this study was to analyze some technical requirements through which it is possible to confirm the effectiveness of cloth masks in preventing COVID-19.

According to the author's background, no work has been published in this field especially in Egypt. On the other hand, and in general, most of the researches were working on the cloth masks as a general specifications without talking about the details of the tests

We have taken into consideration four main factors that contribute to the effectiveness of wearing cloth masks, such as breathability, the intermediate pores size, resistance to spraying, and the treatment of the outer layer to be water repellency, as there are other sub-factors such as mask design, its dimensions and the extent of its tightness on the mouth and nose opening, as well as the number of layers.

2. Material and Methods

A total of 11 different types of cloth face masks (CM) were made of two layers with stretchable ear loops, which were divided into 3 groups depending on the fabric material:

a) The first group: in it the outer layer (treatment against wetness) was made of the weave structure in a plain (1/1) and the inner layer with the same structure ,plain 1/1 (intended in this study the layer in contact with the mouth and nose which is not treated against wetness) Where different densities of warp and weft.

b) The second group: in it the outer layer (treated against wetness) was made of the textile composition (1/1) Where different densities of warp and weft. On the other side the inner layer of knitted fabrics - Jersey - Where different densities of rows and columns.

c) The third group: in it the outer layer (treated against wetness) was made of knitted fabrics - jersey - and the inner layer was made of the same knitted fabrics. Where different densities of rows and columns were used to reach the best materials and samples to reach the best comfort and protection properties.

In this study, woven and knitted fabrics with the following specifications were used:

2.1 woven Fabrics

Water repellency-treated woven fabrics (Plain weave1/1- count number yarn of warp 30/1, count number yarn of weft 30/1) with different weaving structure in the density of the warping thread count, the density of the weft threads, and the weight per meter square . The fabrics were supplied by different companies in Egypt.

2.2 knitted fabrics

Water repellency-treated knitted fabrics (Jersey - count number yarn was 30/1) with different weaving structure in the density of the Number of columns per centimeter, the density of the Number of rows per centimeter, and the weight per meter square . the fabrics was supplied by different companies in Egypt.

2.3 Washing

After the completion of the design and implementation of the various types of cloth mask (woven and knitted), repeated washing was done up to 25 times, with the aim of ensuring the efficiency of the masks during repeated use, which is to ensure the stability of the finishing materials against wetness and the dimensional stability of the mask and the non-expansion of the inter-pores, which negatively affects the filtering efficiency. This processes has been conducted in accordance with BS ISO -16322-3:2005 " Textiles-- Determination of spirality after laundering. Woven and knitted garments "

3. Testing and analysis

3.1- Air Permeability

This test was carried out on cloth mask samples using FX3300 (Textest, Switzerland) with a pressure applied of 30 Pa, according to ASTM D737- 04, and five samples were tested in each case .

3.2- Spray Resistance

This test was carried out using a FX3000 (Hydrostatic Head Tester-Textest, Switzerland) with a pressure applied of 1000 mb and five samples were tested in each case .

3.3- Particle Filtration Efficiency

This test was carried out using pore size measuring device (National Institute of Standards)

4- Result and Discussion

4.1- Air Permeability

There are many factors that affect the comfort properties of fabrics, such as air permeability, fabric structure, thermal insulation, heat transmittance, and permeability of steam and water[vii]. The air permeability feature is a very important comfort feature for fabrics and clothing it maintains thermal balance for its wearer[viii]. It can be defined as "the flow rate of air passing vertically through a particular unit area of the fabric by measuring a certain pressure difference of air across the fabric test area through a specific time period " [ix].

This feature is very important in face masks in

general, as it represents the most important comfort features.
Table.1 and fig.1 shows the factor effect of density of the warp and weft thread count weight per meter square on the air permeability(breathability) for cloth masks.
It is evident from the results that the CM1(61) has less resistance to air permeability than the other two samples (CM2 and CM3), which is better for the inhalation and exhalation process.
It is evident from the results that CM1 sample has a lower resistance to air permeability than the other two samples, which is better for the inhalation and exhalation process. This can be attributed to the fact that the density of the number of threads in both directions is less, and therefore the pores size is larger. This indicates that the cloth masks which have a higher density in the number of threads in the warp and the weft direction were less air permeable (higher resistance to the respiration process) than the cloth masks with a lower numerical density in number Threads and weight per square meter.
Also, the result shows that air permeability (breathability) of cloth mask decreases as specific weight per meter square is increased.

Table.1. the Air permeability (breathability) of cloth masks. (*Two layers from woven fabrics*)

No.	Fabric type	Structure type	Number of layer	Number of warp threads	Number of weft threads	weight per meter square (gm)	Air permeability (pa)
CM 1	Cotton	Plain(1/1)	2	24	18	127.7	61
				24	18		
CM 2	Cotton	Plain(1/1)	2	29	26	162,5	52
				29	26		
CM 3	Cotton	Plain(1/1)	2	35	20	155	55
				35	20		

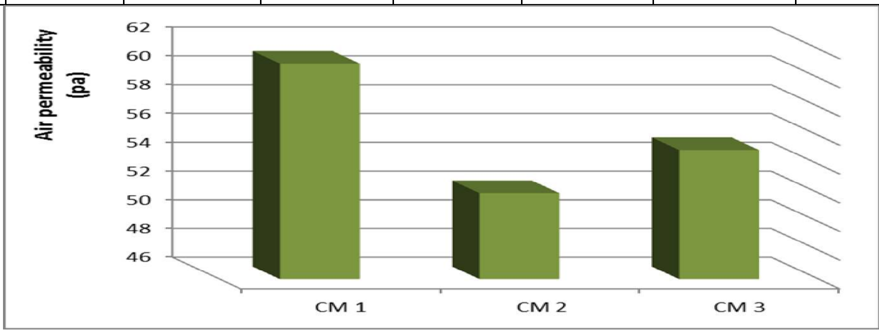

Fig.1 the Air permeability (breathability) of cloth mask. (Two layers from woven fabrics)

The results in Table 2 and Fig. 2 indicate that the best samples of this group in the respiratory process are CM6 (57 pa), followed by CM5 (39.5 pa), followed by CM4 (35pa). This indicates that the number of rows and columns has a great impact on the breathing process as the CM6 sample is the least sample in the number of rows and columns and the weight of a square meter and therefore it is the least resistant to air permeability. It appears that the air permeability resistance is inversely proportional to the coverage coefficient

Table.2. the Air permeability (breathability) of cloth masks. *(Two layers from knitted fabrics)*

No.	Structure type	Number of layer	Number of columns	Number of rows	weight per meter square (gm)	Air permeability (pa)
CM 4	Jersey	2	19	29	198	35
CM 5	Jersey	2	16	27	187,7	39,5
CM 6	Jersey	2	14	21	182,3	57

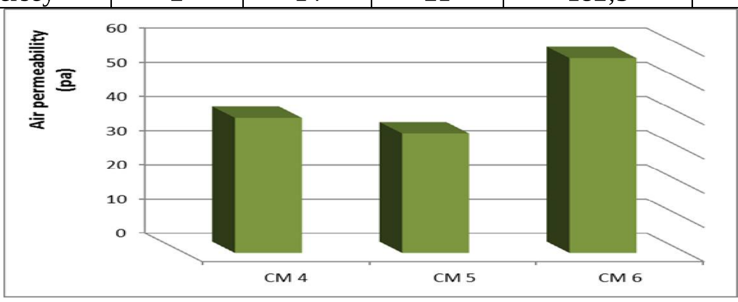

Fig.2. the Air permeability (breathability) of cloth masks. (Two layers from knitted fabrics)

Table No. 3 and Fig. 3 refer to the results of the air permeability resistance of the cloth masks made of two layers, one of which is woven fabrics and the other layer of knitted fabrics. It is evident through the results that the best samples in the breathing process (the least resistant to air permeability) are CM9 (55 pa), followed by CM7 (28 pa), followed by CM8 (25 pa).

From the foregoing, the results indicate that the reason for the difference between the three samples in the resistance to air permeability can be attributed to the difference in the coefficient of coverage, as well as the result of the superposition of the pores of each layer during use.

Through all the results shown in the previous three tables, it is clear that the lowest resistance to air permeability is CM1 (61 pa), while CM8 (25 pa) has the largest resistance to air permeability, while CM4 (35 pa) has an average state of resistance to air permeability. If we take the best samples, the sample will be CM4, as it will represent a protection factor greater than the other two samples, and this will become clear later.

Table.3. the Air permeability (breathability) of cloth mask. ***(Different Two layers (outer woven and internal knitted fabrics)***

No.	Layer type	Structure type	Number of warp/ columns threads	Number of weft/rows threads	weight per meter square (gm)	Air permeability (pa)
CM 7	Outer	Plain(1/1)	41	20	165,6	28
	internal	Jersey	18	22	158,4	
CM 8	Outer	Plain(1/1)	30	17	125,8	25
	internal	Jersey	15	20	235	
CM 9	Outer	Plain(1/1)	22	28	138	55
	internal	Jersey	15	21	202	

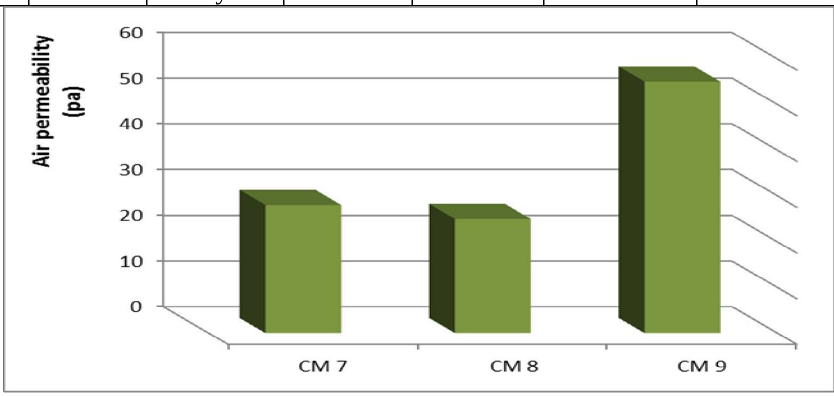

Fig.3. the Air permeability (breathability) of cloth masks. (Different Two layers (outer woven and internal knitted fabrics)

4.2- Spray Resistance

Most of the studies and research of cloth masks have dealt with the filtration feature, and little of this research deals with the importance of treating fabric masks against wetness and their resistance to fluid permeability, especially water. As one of the characteristics of the surgical mask is its resistance to fluid permeability, as well as the mask must be woven[x].

Resistant to fluid permeability under hydrostatic pressure or spray resistance is one of the most important tests that must be performed on cloth masks. As most of the studies have shown that the Corona virus is transmitted through droplets and direct contact. These studies assumed that the droplets of the droplets may be transported for a distance of from one to 2 meters, and sometimes they may reach 8 meters.[xi].

From the table 4 and fig.4, It is evident that the three samples in this group have an acceptable degree of resistance to the liquids permeability under hydrostatic pressure, which simulates the permeability resistance to spray, where the results were as follows: 19, 25 and 22 for samples CM1, CM2 and CM3, respectively.

From the previous results, it was found that CM2 was higher in the spray resistance than CM1 and CM3. It can be due to increase overlaps between warp threads and weft threads . Which indicates that this sample is the best in this group in protecting the person who wears it from the spray coming from the outside, as well as protecting the surrounding people from the spray that may fly from the person who wears this cloth mask, especially in the case of sneezing.

Table.4. the Spray Resistance of cloth masks. ***(Two layers from woven fabrics)***

No.	Structure type	Number of layer	Number of warp threads	Number of weft threads	weight per meter square (gm)	Spray Resistance (mb)
CM 1	Plain(1/1)	2	24	18	127.7	19
			24	18		
CM 2	Plain(1/1)	2	29	26	162,5	25
			29	26		
CM 3	Plain(1/1)	2	35	20	155	22
			35	20		

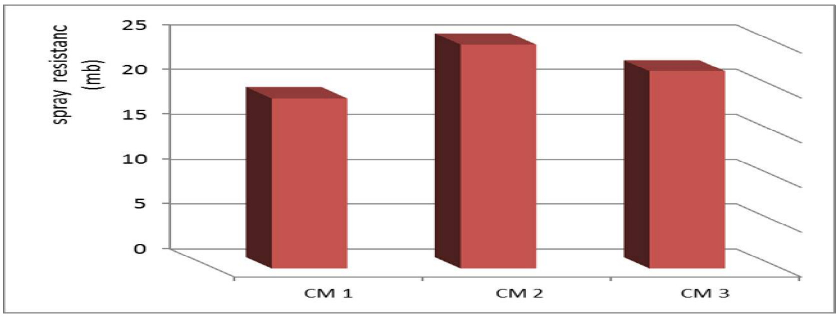

Fig.4. the Spray Resistance of cloth masks. (Two layers from woven fabrics)

Likewise, We find that the results in Table No. 5 and fig.5 also indicate acceptable degrees of protection from liquids permeability under hydrostatic pressure, and they were as follows: 22, 20 and 17 mbar for samples CM4, CM5 and CM6, respectively.

That is, the CM1 sample is the highest resistance to liquid permeability, and this can be attributed to its having a coverage coefficient (number of rows and columns) higher than the other two samples. This makes that the best specimen in this group for splash protection.

Table.5. The Spray Resistance of cloth mask. ***(Two layers from knitted fabrics)***

No.	Structure type	Number of layer	Number of columns	Number of rows	weight per meter square (gm)	Spray Resistance (mb)
CM 4	Jersey	2	19	29	198	22
CM 5	Jersey	2	16	27	187,7	20
CM 6	Jersey	2	14	21	182,3	17

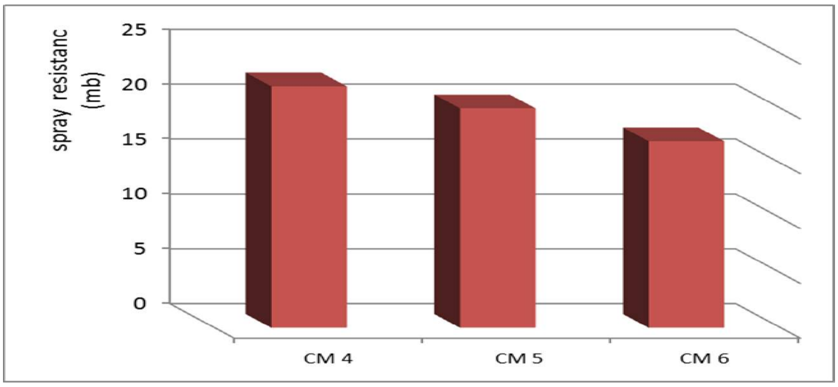

Fig.5. the Spray Resistance of cloth mask. (Two layers from knitted fabrics)

It is clear from the data of table 6 and fig.6 that all samples had a high resistance to fluid permeability under hydrostatic pressure, as the results were as follows: 29, 27 and 22 mbar for samples CM7, CM8 and CM9, respectively. It is also noted that the samples of this group have higher resistance to fluid permeability than the previous two groups, and this may be due to the difference in the textural composition of the outer layer and the inner layer. Through the results, it is also clear that the CM7 sample is the best resistance to fluid permeability, due to its having a higher coverage coefficient and an increase in the proportion of interactions between the fibers.

Table.6. the Spray Resistance of cloth masks. ***(Different Two layers (outer woven and internal knitted fabrics)***

No.	Layer type	Structure type	Number of warp/ columns threads	Number of weft/rows threads	weight per meter square (gm)	Spray Resistance (mb)
CM 7	Outer	Plain(1/1)	41	20	165,6	29
	internal	Jersey	18	22	158,4	
CM 8	Outer	Plain(1/1)	30	17	125,8	27
	internal	Jersey	15	20	235	
CM 9	Outer	Plain(1/1)	22	28	138	22
	internal	Jersey	15	21	202	

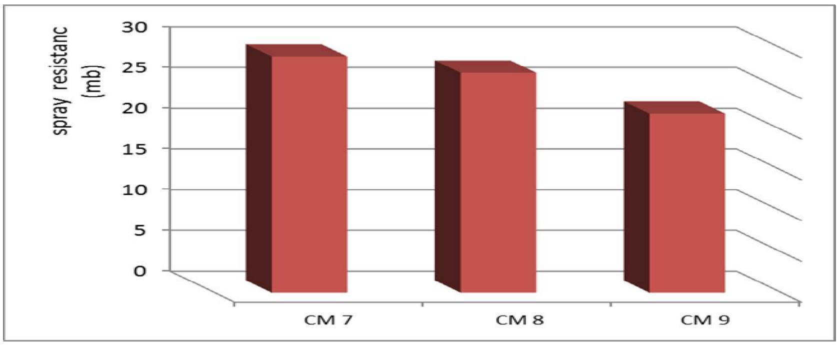

Fig.6. the Spray Resistance of cloth masks. (Different Two layers (outer woven and internal knitted fabrics)

4.3- Pores size (Particle Filtration Efficiency (PFE)

One of the important tests is to measure the pores size, as this test is considered an indication of the ability of fabrics or cloth masks to block various particles or allow them to pass. As the pores size is the main factor affecting the respiration process and the particulate filtration efficiency. Filtration efficiency of cloth masks depends on many factors, such as thread count, number of layers, type of fabric, and weaving structure.

Through table No. 7 and fig 7, we find that the CM2 sample is the smallest of the three samples in porosity (41 µm), while we find that the two samples are CM1 and CM3 are similar in pore size (44 µm and 43.7 µm) and the larger in the porosity than the sample CM2. This can be explained by the fact when the number of warp threads is close to the number of weft threads in the unit area, this led to an increase in correlations and which lead to decrease in the porosity hence, higher protection, and this is what happened in the CM2 sample.

Table.7. the Pore size of cloth masks. ***(Two layers from woven fabrics)***

No.	Structure type	Number of layer	Number of warp threads	Number of weft threads	weight per meter square (gm)	Pore size (µm)
CM 1	Plain(1/1)	2	24	18	127.7	43.7
			24	18		
CM 2	Plain(1/1)	2	29	26	162,5	41
			29	26		
CM 3	Plain(1/1)	2	35	20	155	44
			35	20		

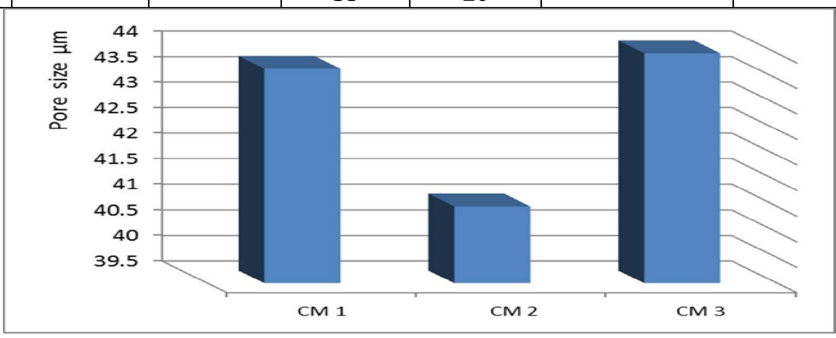

Fig.7. The Pore size of cloth mask. (Two layers from woven fabrics)

From the table 8and fig.8 , also it is obvious that the CM4 sample is the least porous (16 µm), followed by the CM5 sample (38 µm) and CM6 sample (40.5 µm) . This can be attributed to the fact that the cm4 sample has more rows and columns (with a higher coverage coefficient) than the other two samples(CM5 and CM6), which causes a smaller pore size and hence, higher particle filtration efficiency.

Table.8. Pore size of cloth mask. (*Two layers from knitted fabrics)*

No.	Structure type	Number of layer	Number of columns	Number of rows	weight per meter square(gm)	Pore size (µm)
CM 4	Jersey	2	19	29	198	16
CM 5	Jersey	2	16	27	187,7	38
CM 6	Jersey	2	14	21	182,3	40.5

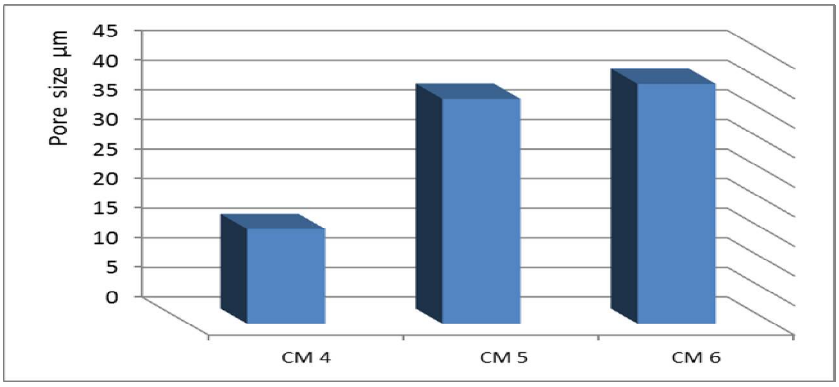

Fig.8. the Pore size of cloth masks. (Two layers from knitted fabrics)

From the data obtained and shown in Table 9 and fig.9 .The data mean that CM7 is the least of the three in terms of pore size. It is also clear that there is a convergence in the pores size between the two samples CM7 and CM8 (25 µm and 26 µm), which have a pores size less than CM9 (33 µm). This can be explained by the fact that the CM7 sample contains an outer layer of woven fabrics with a higher coverage coefficient than the other two samples. It also contains an inner layer in contact with the mouth made of knitted fabrics with a large coverage coefficient (the high number of rows and columns per unit area)

Table.9. the Pore size of cloth masks. *(Different Two layers (outer woven and internal knitted fabrics)*

No.	Layer type	Structure type	Number of warp/ columns threads	Number of weft/rows threads	weight per meter square (gm)	Pore size (µm)
CM 7	Outer	Plain(1/1)	41	20	165,6	25
	internal	Jersey	18	22	158,4	
CM 8	Outer	Plain(1/1)	30	17	125,8	26
	internal	Jersey	15	20	235	
CM 9	Outer	Plain(1/1)	22	28	138	33
	internal	Jersey	15	21	202	

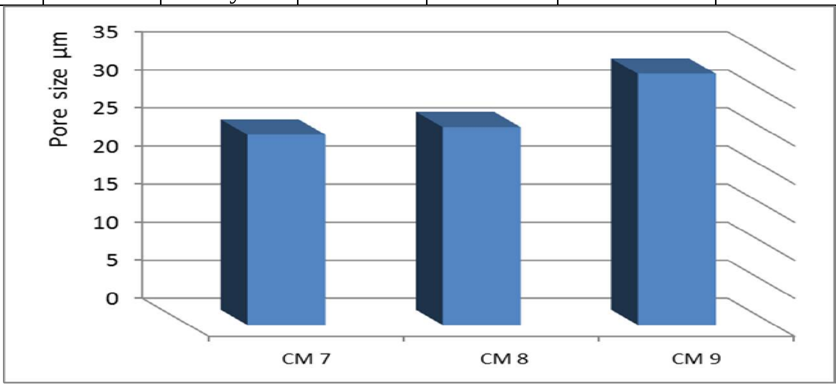

Fig.9. the Pore size of cloth masks. (Different Two layers (outer woven and internal knitted fabrics)

Generally, It is very obvious from the result shown in tables No.7,8 and 9 that pores size of view were very different for all the cloth masks. Where it is clear from the tables that, CM3 has the smallest pores and CM2 has largest pores, CM9 has medium pores.

From the above, it can be said that cloth masks can provide part of the protection if they are designed according to scientific studies, as the pores size of the cloth masks in this study ranged from 16 to 44 µm, while the size of respiratory droplets ranges between 5-100 µm .

Therefore, it can be said that the best cloth masks is the CM4, which is designed from two layers, both of which are knitted fabrics, as it was less in pores size than the other study samples, which means higher filtration efficiency and thus higher protection.

Conclusion

In conclusion, The protective properties of a cloth mask are affected by the appropriate use of the mask, as well as by choosing the type of fabric fiber used, the masks design, and the size of the pores (particle filtration efficiency), as the protection rate increases as the pore size is smaller. Also, the number of mask layers and the number of threads per area, Where the protection rate increases with the increase in the density of the threads, in addition to the fabric's resistance to water permeability (splash resistance), but provided that all of the above does not severely affect the ability to breathe.

We believe that the findings of this study will be helpful for increasing public awareness among populations of developing countries where such masks are very common, and for policy makers to make and implement basic guidelines for face masks for public use.

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