Reusable Face Barrier Mask in Cotton: Natural Dye use to Improve Antibacterial Properties

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Abstract: ***Face barrier masks were realized according to AFNOR SPEC S76-001 and ECOSTAND standard 082 2020 (ECOWAS standard). Cotton textile with specific properties according to previous standards was used to make face mask with pertinent barrier parameter after several washing steps. To compare with treated textile with natural dye which is naturally antibacterial properties, we use N'galama" Anogeissusleiocarpus". Masks made with a cotton fabric treated or not and washed or not; showed a barrier effect of 100% efficiency, after spraying with a stream of sodium chloride aerosol and an aerosol based on bacteria. Additional with yellow fabric dying with N'galama there are is a reduction of the number of bacteria on the external surface of the masks by 33%. All of the tests made by CERFITEX on fabric used and mask barrier physical and others properties are compliant with standard.***

Keywords: textile, cotton, face mask, reusable, antibacterial properties, natural dye

1. Introduction

For several months, the world has been battling a disease named COVID 19, with its corollaries of social and economic crises. One of the methods to protect the population against this virus is the use of relevant face barrier masks.

The lack of medical treatment has led public health experts to propose a mandate on "barrier masks," and social distancing rules as protective measures for the general public.

We focus on reusable face masks and study whether some fabrics may provide additional protection. Specifically, we show that some cloth materials enhances the barrier function of face masks as bacteria are less likely to survive in contact with conventionally recommended fabric for face mask

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We build on the AFNOR SPEC S76-001 and ECOSTAND standards (inspired to AFNOR SPEC S76-01), which provide guidelines for testing and producing barrier masks. These guidelines provide a comprehensive set of best practices relative to product, services, methods, processes, and organizations. Consequently, these standards are respected to manufacture the barrier masks described in this article.

We study the well-known antibacterial properties tree (here N'galama) on the efficacy of masks. This tree is remarkable for its beautiful yellow flowers. We use leaves, which are widely used in the artisanal clothing in Mali and West Africa. The tincture is prepared, among other things, by boiling the leaves. It was used at one time, in particular, to color the clothes of the young circumscribed [1]. According to (Tauxier, 1927)[2]N'galama powder is used for healing wounds

Previous literature (Cordon 2007) [3], has shown medicinal values from extracts of dye plants. The chemical groups responsible for pigmentation in plants are known to have bactericidal, fungicidal, and antiparasitic properties. As a consequence, many traditional therapists develop bandages for wounds and fractures with fabrics tinted with plant extracts.

As documented before, cotton textile from Mali Bogolan, which is derived from the bark, roots and leaves of *N'galama(Anogeissusleiocarpus)* are very rich in tannins (17%).[4] Yellow color production is due to theinteraction of flavone glycosides contained in plant extracts with the alkalis in the cotton fabric [5].

2. Materials and Methods

2.1 Textile metrology laboratory of CERFITEX

Depending on the parameter to be characterized, different materials / chemicals were used to apply the standardized methods often adapted to internal test procedures. Thus, we made use of:

- Textile decomposition tools: ISO 7211: 1984 (textile analysis methods adapted to internal procedure);
- Butane gas fitted with a bunsen burner: EN 149: 2001-A1: 2009 (method for determining the flammability of the material of the masks suitable for the internal procedure);
- Method 1 (AFNOR SPEC S76-001: V1.10 04/27/2020, determination of respiratory resistance and air permeability);
- Method to be told by experts (AFNOR SPEC S76-001: V1.10 04/27/2020, determination of the filtration efficiency of the material);
- Method for determining respiratory resistance (AFNOR SPEC S76-001: V1.10 04/27/2020);

Internal procedure for determining the composition of textile materials.

2.2 Finishing workshop of CERFITEX

The materials used are: Water bath, stainless steel cups, precision scales, plastic tubs or buckets, sieve (gauze), spoons, clock, household gloves, rope and clothespins, rod (glass or wood), potash, alum, leaf de n'galama, pH paper, pestle and mortar, kitchen thermometer, calculator, notebook, pens and camera.

2.3 Textile description

The material used is 100% cotton. The texture of the fabric is such that it is woven in plain weave and has 30 threads per cm and 21 picks per cm. It is a poplin fabric having a basis weight of 131 GSM.

2.4 Preparation before dyeing

The fabric being already mercerized must only undergo a wetting operation (water, water + detergent or wetting agent) which facilitates its contact with the treatment bath. This can be done before or during treatment. Thus, it would be preferable to use plain, tape water or, in the case of the primed fabric, water + detergent (soap or soap powder) for better bathing and unison contact at a lower cost.

2.5 Dyeing Process

Most natural dyes have no affinity for cellulose (cotton). To create it, an etching treatment (before, simultaneously or after) is necessary.

The process adopted for dyeing is as follows:
Dyeing bath preparation → pre-mordanting → Dying→ Post-mordanting→ Washing→ Drying→ finishing (ironing)

2.5.1Preparation of dyeing bath

The leaves of n'galama (*Anogéissusleiocarpus*) are dissolved in water to extract the coloring molecules.

(a) Composition

Dry powder or n'galama's leaf weighed: 1 to 7 times the dry weight of the fabric to be dyed

(b) Equations

$$bath\ ratio = {}^{1}/_{40} \quad (1)$$

$$Volume\ of\ bath = \frac{Powder\ weight}{bath\ ratio} \quad (2)$$

$$Final\ bath\ (coloring\ solution) = Volume\ of\ bath - weight\ of\ the\ powder\ weighed \quad (3)$$

(c) Procedure (classical method with two extractions)

- Boil the n'galama leaf powder for 30 minutes in a volume of water corresponding to a little more than half of the final bath
- Filter, reserve the juice, and recover the coloring matter
- Repeat the operation with new water
- Gather the juices. It is the final ready-to-use bath

2.5.2Fabric mordanting

(a) Composition

Table 1: Composition of mordanting recipe

Fabric	10 g
Alum	1 g
NaOH	0.5 g
Complete to 200 mL	

(b) Procedure

- Soak the fabric in the mordant bath heated to 60-70 ° C for 30 min, stirring occasionally
- Wring out the fabric and spread it out on the ground without clay or on a rope for at least 30 minutes to promote the oxidation of the bite
- Rinse thoroughly and let dry
- The fabric is ready to dye

2.5.3 Dyeing process

(a) Equations

$$bath\ ratio = {}^{1}/_{30} \quad (4)$$

$$Volume\ of\ bath = \frac{fabric\ weight}{bath\ ratio} \quad (5)$$

$$Volume\ of\ dye\ to\ sampled\ or\ collected = Volume\ of\ bath - fabric\ weight \quad (6)$$

(b) Procedure

- Soak the fabric in the dye bath at room temperature
- Allow the temperature to rise slowly to 60-90 ° C while stirring occasionally for 10-20 minutes at this temperature
- Remove the fabric from the bath by wringing out gently and spread it on the clay-free floor or on a rope until partially dry
- Repeat this process 2 to 3 times if necessary to have the desired color
- Mordanting fabric again with the same recipe and process described above.
- Wash 2 to 5 minutes at 40 ° C with mild soap
- Dry and make finishing (ironing here)

2.6 Face mask conception

The dimensions and shape of the material parts are designed so that after assembly with the set of flanges, the barrier mask can be adjusted to the user's body shape. And thus, ensure a good seal. The pieces are assembled together and with the set of flanges by stitching. The barrier mask consists of three (3) layers of the same material (100% cotton) and a set of flexible elastic straps. Depending on their size, we distinguish between the set of straps adapted to the ears (≈20cm × 2) and the set of straps passing behind the head (≈35cm × 2). These dimensions should make it possible to avoid excessive tightening of the head and to ensure comfort for the user of the mask. The hygiene conditions are impeccable when making the masks. Finally, we recommend cleaning the masks before use while specifying the washing procedure on the labels.

2.7 Washing process for some samples send to LaboRem

2.7.1Preparation of soap solution

- 15 g of usual cleaning soap powder was diluted in 2.5 l of tap water
- Each solution was made for 5 samples.

2.7.2Washing

Operations were made by the same person in order to warranties method and harmonize the mechanical force applied on samples.

Each sample was rubbed with hand 100 (hundred) times. We hypothesize each 10 rubbing was assimilated to one washing. So we can conclude this samples was wash ten (10) times.

Each sample was rinsed four (4) times in 2.5l of tap water in view to eliminate all of the soap or other contaminant particles. During each bath of rinsing operator practice hand rubbing ten (10) times.

After cleaning samples were dry during four (4) hours in intern area away from mainly dust.

Samples were conditioned with cleaned hand in plastics and send to LoboRem for analysis.

2.8 Methods used inLaboRem

2.8.1 Determination of the efficiency of particle filtration (EPF)

Three (3) unwashed beige colored masks and 3 washed beige colored masks were tested for their particle filtration capabilities after spraying with a sodium chloride-based aerosol stream as described in the ASTM F2100 standard. -11. Controls (3 for washed masks and 3 for unwashed masks) were sprayed with an aerosol stream that did not contain sodium chloride.

Six (6) other masks treated with a plant extract (yellow colored masks), 3 of which were washed, were also tested for their particle filtration efficiency according to the method described in the ASTM F2100-11 standard. As with the untreated masks, controls (3 for washed masks and 3 for unwashed masks) were sprayed with an aerosol stream that did not contain sodium chloride.

2.8.2 Determination of the efficiency of bacterial filtration (EBF)

The same treatment plan and method described in the ASTM F2100-11 standard for determining the effectiveness of masks in filtering out bacteria were used. Twelve (12) masks (including 3 untreated unwashed, 3 untreated but washed, 3 treated unwashed and 3 treated and washed) were sprayed with an aerosol stream containing bacteria. For each category of mask, we set up 3 controls treated with an aerosol stream that did not contain bacteria. Efficacy of treatment on bacteria deposited on the external surface of the masks was evaluated.

2.8.3 Effectiveness of the treatment on bacteria deposited on the external surface of the masks

The quantity of mask bacteria treated or not and washed or not was determined by taking the bacteria from 1 cm2 of the mask using a sterile swab. After 30 minutes and 1 hour of incubation, samples were taken. Decimal dilution series were performed for each sample and 100 µl of each dilution were plated on solid TSA medium. After 24 hours, the bacterial microflora was determined for each type of mask.

3. Results and discussions

3.1. Characterizations in CERFITEX

In accordance with document AFNOR SPEC S76-001: V1.10 27/04/2020, a conformity assessment of barrier masks was carried out by the textile metrology laboratory of CERFITEX. The tests concerned: the type of material (composition and texture), visual inspection, the filtration efficiency of 3µm particles (According to experts following the specification of the material), respiratory resistance and permeability to water air (method 1), the resistance of the flange set and the flammability of the material (EN 149: 2001-A1:2009).

The barrier masks have thus been declared compliant with AFNOR SPEC S76-001: V1.10 27/04/2020 documents (see figure 1) and therefore with ECOSTAND standard 082 2020.

To characterize the filtration capacity of smaller particles (<3µm) per test, other tests were carried out at LaboRem (FST). Thus, the masks are classified category 1 (filtration capacity > 90%).

Table 2 : Result of the conformity assessment carried out at CERFITEX barrier masks

	Type of test	Observation	Standard/ specification	Decision
1	Material	Plain weave woven fabric with a basis weight of 131 GSM (Poplin). Fabric comprising 30 threads per cm and 21 picks per cm.	AFNOR SPEC S76-001: 2020	Compliant
2	Visual inspection	Pleated barrier mask in mercerized cotton fabric respecting the folds and technical dimensions. Mask surface free from apparent defects. Face piece mask made of three layers of the same material and covering the nose, mouth and chin tightly. Pleated barrier masks with different parts assembled by stitching with flexible elastic head harness passing behind the ears or the head.	AFNOR SPEC S76-001: 2020	Compliant
3	Penetration of filter material 3µm particles	Contexture similar to material 689 (compliant with category 2) from the list of materials available on the website www.afnor.org	AFNOR SPEC S76-001: 2020	Compliant at least with category 2
4	Breathing resistance	Contexture similar to material 689 (compliant with category 2) from the list of materials available on the site www.afnor.org	AFNOR SPEC S76-001: 2020	Compliant
5	Resistance of the head harness	Very elastic material making the mask easy to adjust, wear and remove. Insignificant plastic deformation after the test carried out by three subjects of different morphology: put on and take off the mask 5 times in a row. Head harness fixed by sewing. Head harness designed so that the mask can be put on and taken off easily and so as to avoid	AFNOR SPEC S76-001: 2020	Compliant

		discomfort while wearing it.		
6	Flammability	Will not burn after exposure for 15 seconds to 20 mm of a 40 ± 2mm flame (temperature ≈ 800 ± 50 ° C).	Test adapted according to standard EN 149: 2001 + A1: 2009	Compliant

All of the tests made by CERFITEX on fabric used and mask barrier physical and others properties are compliant with standard.

3.2. Characterizations in LaboRem (FST)

3.2.1Determination of the efficiency of particle filtration (EPF)

100% of the masks tested are effective and the rest even after washing and therefore are of very good quality according to the ASTM F2100-11 standard. And those after 10 washings.

3.2.2Determination of the efficiency of bacterial filtration (EBF)

100% of the masks tested effectively filter bacteria and the rest even after washing. They are therefore of very good quality according to the ASTM F2100-11 standard.

3.2.3Effectiveness of the treatment on bacteria deposited on the external surface of the masks

After 30 minutes, the external surface of treated masks contains 33% less bacteria than that of untreated masks. Even after washing, the treatment remains 33% effective.

After 1 hour of time we did not notice any statically significant differences although we observed a slight decrease in the number of bacteria.

Likewise, after 1 day no change is noticed.

Table 3: Result of the conformity assessment of LaboRem on barrier masks

Type of test	Observation	Standard/ specification	Decision
Efficiency of particle filtration (EPF)*	Masks made with a cotton fabric treated or not and washed or not; showed a barrier effect of 100% efficiency, after spraying with a stream of sodium chloride aerosol.	ASTM F2100-11	Compliant (EPF□ 98%)
Determination of the efficiency of bacterial filtration (EBF)**	The masks made with a cotton fabric treated or not and washed or not showed a barrier effect of 100% effectiveness, after spraying a stream of aerosol based on bacteria.	ASTM F2100-11	Compliant (EFB □ 98%)

* Represents the percentage of bacteria from 1 to 5 micrometers filtered

** Represents the percentage of particles 0.1 to 1.0 micrometers filtered

4. Conclusion and perspectives

All of the tests made by CERFITEX on fabric used and mask barrier physical and others properties are compliant with standard.

Samples of untreated cotton barrier masks of beige color (washed or unwashed) and treated of yellow color (washed or unwashed) respectively registered under the numbers 003/04 / FST LaboREM-Biotech2020 and 013/04 / FST LaboREM-Biotech2020 have shown high filtration efficiency of particles and bacteria and have therefore been declared to comply with ASTM F2100 (ASTM = American Society of Testing and Materials) for face mask materials according to the level of performance.

EFP and EFB were determined after 10 washes to determine. Masks are always effective. However from the perspective of research, the number of washes from which the efficiency decreases should be determined.

The treatment of the mask fabric with *N'galama* made it possible to reduce the number of bacteria on the external surface of the masks by 33%. In the perspectives, the determination of the Minimum Inhibitory Concentration (MIC) of the product on a mixture of Gram + and Gram- bacteria, we will be able to determine the amount of *N'galama*to be applied on each mask to minimize the risk of contamination with bacteria that can long survive on masks

References

[1] R. Pageard, "plantes à brûler chez les Bambara", Journal of "Africanistes", 37-1, pp. 87-130, 1967.
[2] L Tauxier, la religion Bambara, Geuthner, Paris,p.298, 1927
[3] D. Cordon, Natural Dyes, Tradition, technology and Science, Archetype Publications, p.778, 2007
[4] P. Duponchel, Textile de coton : bogolan du Mali. Teinture de plantes et de terre, Annuaire, Tome 106, P.605, 1997-1998
[5] J.B.Donne, "Bogolanfini : A mud –Painted Cloth from Mali", Man.8 (1), JSTOR 2800615, 1973

Author Profile

Dr Awa S DOUMBIA received Engineering School Diploma Textile Chemistry Engineering (2008 at ENSAIT, France) and she obtained PhD degree in Materials Science (2012 at USTL1, France). She works in ISPA and GEMTEX (France) as researcher in textile, polymeric and composites fields. She is already been technical manager in textile and soft materials for URGO laboratories. When she arrived in Mali in 2016, she became studies Manager in CERFITEX. In 2017 she had the honor to having the confidence of the state to appoint her as the first person in charge of CERFITEX (GENERAL MANAGER)

Author's Speech

Currently General Manager of CERFITEX, I am in charge of defining, coordinating and developing the activities of this educational institute.

I represent the school at different events with national and international institutions. I am actively involved in projects related to cotton and textile development in the West Africa regional area.

As a teacher and researcher, the research and development of high-performance polymeric materials and technical textiles has always deeply interested me.

In 2014-2015, thanks to my expertise in materials field, I participated to innovation, conception and development of advanced wound dressings (for the treatment of patients with major burns, pressure sores, diabetic foot ulcer, etc…). Previously, always in the relation with materials R&D, I worked as researcher in the field of thermoplastic composites, essentially in thermoplastic material weight reduction issues in automotive sector.

Before these experiences, I cut my teeth as researcher during a PhD thesis in the development of filaments/textiles from biopolymer (PLA) with specific functionalities (especially **antibacterial** and UV protection properties).

In addition to the scientific and technical expertise obtained from these works, I have also acquired several types of transferable skills such as: project and business unit management .I had in 2019 a certificat to business unit management at HEC paris. This certificate will more complete my technical background in wiew to improve my management skills for CERFITEX. My personal strengths are: good team working abilities, strong organizational skills and appeal to challenges.