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Functional design as tool for children undergoing chemotherapy treatment

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Abstract:

The present research work envisage the development of paediatric, antimicrobial and sustainable clothing for use in hospital environment. This innovative piece of cloth was devised to offer thermoregulation, physiological comfort and psychological wellbeing for children undergoing chemotherapy. Simultaneously, it is intended to contribute for the prevention of nosocomial infections, particularly, cross-contamination with *Staphylococcus aureus.* For this purpose we built a single knit structure (jersey) with two different raw material compositions. Those knits were submitted to an antimicrobial finishing treatment provided by two different agents: Agiene® and Chitosan, each one individually applied by exhaustion. Several samples of finished knits were tested in order to ascertain which one had the most optimized behaviour in terms of antimicrobial effectiveness and thermophysiological comfort. Antimicrobial activity was analysed by ISO 20743:2007 standard and the major thermo physical properties were studied with Alambeta and Permetest. In the end, it was proved that, chitosan applied by exhaustion revealed to have the best optimized antimicrobial effect combined with maximized comfort. In conclusion, and taking into account this information a technically improved alternative gown, to be used by small children undergoing chemotherapy, was produced.

Keywords: Functional design; Fashion design; Medical textiles; physiological comfort; thermoregulation; chemotherapy.

1. Introdution

1.1. Some sustainability issues

For the environment cotton production is not very viable, since it requires a large area for its cultivation, a great need for water and the fact that the fibre is widely attacked by fungi and bacteria (but resists moths and insects). During its cultivation it's necessary to use various types of anthelmintics, insecticides, agrochemical and other chemical fertilizers, which can weaken the soil making it difficult for subsequently uses and cultivation for other crops.

Researches proved that only in the U.S. annually, are used more than 124.74 million kilograms of pesticides in cultivation of cotton and added to this, there is also the need for massive amounts of fertilizers, growth regulators and biocides in general as methyl bromide. Cotton production requires large quantities of water, which can deplete this resource and even cause deposit of salts in the soil, preventing future crops. The area where cotton plants grows on can cause dry and oxidize soil there, releasing carbon to the atmosphere decreasing fertility of the soil (Naves et al. 2013).

In addition to is highly negative impact over the environment, the cotton demands and therefore its price, is steadily raising in the international market. For all this reasons it is highly recommended that we seek for a fibre, such as hemp, that could successfully replace cotton in the medical clothing market.

The cultivation of hemp has been widely investigated by scientists. It is proven that it is a great fibre for cultivation due to being environmental friendly. For the cultivation of this fibre an authorization is required by law. Depending on the laws of each country in the European community the cultivation is supported and subsidized, in addition to certified seed (which ensures legal THC level), you must have an agreement (purchase and sale) with a transformer authorized by the state, which is only found in France and Spain.

The hemp fibre has a huge potential, it is a natural fibre and biodegradable. The harvest farming is faster, it is good for the soil and uses no chemicals in its cultivation. It provides an environmentally friendly alternative to non-organic cotton which is environmentally destructive. Hemp growing provides soil enrichment by Nitrogen deposits, which can benefited with rotary crops of soybeans and corn for example. In the cultivation of hemp is not used practically any pesticide, and in its cultivation, in the same area, is possible to obtain 250% more hemp fibre then cotton.

In 2006, a study was published by the International Journal of Phytomediation (Campbell et al. 2006), in which scientists have found that Industrial Hemp, can assist in Phytoremediation of contaminated soil, which is an emerging technology to clean up contaminated soil. This technology is very viable and inexpensive. The study showed that industrial hemp (Cannabis sativa) has a very tolerance to benzo-[a]-pyrene and crysene. Hemp would be a prime candidate for remediation of PAH-contaminated soils.

1.2. Medical Clothing for children: Their psycological and protective effect

Quintana et al. (2007), found that “[...] children experience panic situations when placed in front of a person wearing white or with a nurse uniform” (p.414-423). Bocannera et al. (2004), underlined the positive color influence over the patient treatment, "[…] it can help establish balance and contribute to the harmony of body, mind and emotions." (vol.6, no 3.)

Patients on chemotherapy treatments tend to be psychologically affected, especially children. They need something to make them feel more confident in their struggle against their illness. They often feel more debilitated by having an outfit that make them feel like “real patients". Hospital clothes should help them feel more confident in themselves and comfortable with the treatment carried out and, simultaneously, improving their self-esteem and demystifying the image associated to the hospital environment.

Their normal routine is modified by the treatment demands. They turn away from school, friends, family and their toys generating feelings of pain, sorrow, anguish and anxiety. The fear of loneliness originated by the separation from family during the treatment can produce dramatic situations, creating fantasies about the hospital environment as mentioned by Cunha et al (2007).
Through play, children can find themselves and rescue their deepest feelings. By their interaction with their games children, can unconsciously, build strategies and communications to confront their treatment and even create tools to resolve a particular conflict, as stated by Fortuna et al (2007).
It is of great importance for children playing in the hospital because it will take away them from where they are, helping them to cope more effectively with the situation which they are facing.

It also known that in hospital environment health staff can contaminate patients with various types of bacteria. When present in hospital textiles, they can generate odour, cross-contaminate patients and in a worst case scenario, lead to death.

Taking these considerations into account, patients need clothes which can help in their protection against bacteria, prevent potential environment contamination and assure the necessary breathability and body thermoregulation.

As this type of patients have a low immune system, they are more vulnerable to contracting diseases. Hence, hospital clothing should be thought as an aid for a disease barrier. In conclusion, medical clothing should cumulate the following functions: Protect the patients' skin against bacteria exposure, allow the skin to breathe; being comfortable, ergonomic and easily allowing their opening and undressing in case of an emergency, so as due care can be performed.

2. Materials and methodology

2.1. Raw-Materials

The selection of the used fibres, can be justified due to their intrinsic properties and their importance in the achievement of our goals. Cotton is already widely applied in the development of hospital medical clothing and hemp was thought to be a possible viable alternative for replacing cotton as more eco-friendly and sustainable fibre.

2.1.1. Cotton

The cotton fibre is a white or whitish natural fibre coming from the cotton plant consisting of approximately 94% cellulose. The material produced is organic and takes around three months to decompose, presents a moderate difficulty regarding their recycling, due to difficult access to the technology to make the recycling process.

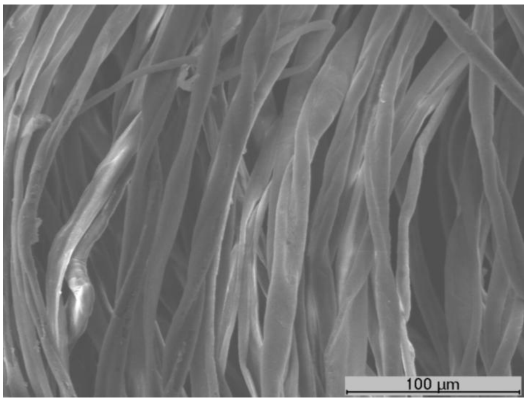


Figure 1: Cotton fibre without any treatment (Magnification: 400)

2.1.2. Hemp

Hemp fibre is also a natural fibre. The common hemp stalk is derived from the Cannabis Sativa it is a mistake to compare the fibre hemp with marijuana, because hemp fibres contains very low levels of the psychoactive chemical tetrahydrocannabinol (THC). The elementary fibres are similar to linen in size and general appearance.

The hemp surface is irregular, smooth, flat to touch, and cold, has a very low elongation due to its high resistance. Nodules may or may not be present depending on the fibre. Note an inner medulla. The fibre is soluble in sulphuric acid. Their burning reaction is very rapid with flashpoints. It leaves very little ash, which is grey-yellow and very thin. When the fibre is burned, its smell is like burned paper. It does not have a melting point, due to the fact that the fibre does not melt.

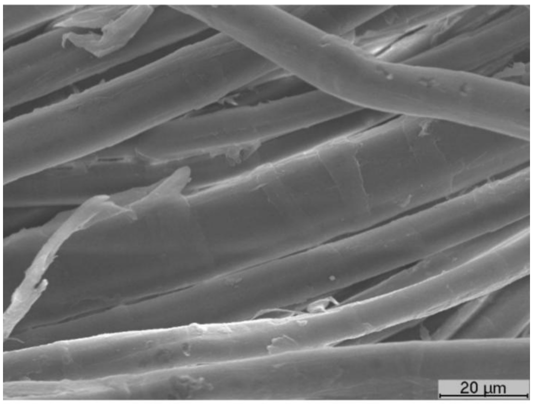


Figure 2: Hemp fibre without any treatment (Magnification:1000)

2.2. Knits Characterization

The yarns used into the knits production were bought and their characteristics are expressed in the table following table 1.

Table 1: **Knits Characterization**

YARN	COMPOSITION	YARN COUNT (Nm)	TWISTING (turns / m)
A	100% Hemp	1/30	500
B	100% Cotton	2/60	520

The knits were made in the Department of Science and Textile Technology at University of Beira Interior. The machine used was a jacquard circular machine - Vanguard Supreme - with a single drum roller and 14 needles per inch. The knits main characteristics are show in the table 2

Table 2: **The knits main characteristics**

SAMPLE	STRUCTURE	MASS/ SURFACE UNIT	YARN COUNT (NM)	TWISTING (TURNS / M)	LOOP LENGTH
A	Jersey	100% Hemp	1/30	500	1.22cm
B	Jersey	100% Cotton	2/60	520	1.13cm

2.3. Antimicrobial agents and its methods of application

The antimicrobial agents used were: Agiene® and Chitosan. Their main features are described as follows:

Agiene

Agiene® is an advanced silver antimicrobial treatment for textiles. Developed by Anovotek, LLC and distributed worldwide by Pulcra Chemicals. Unlike most antimicrobial products, the active ingredients in Agiene® treatments can be recycled by textile manufactures which is another plus for environment. Their particle size can be specifically engineered and it aims to eliminate bacteria present in tissues and simultaneously combating odour caused by them. At a temperature of 250^0C it has a white emulsion appearance, of ionic nature, slightly anionic. pH: 4.3, It is a safe and effective product, sensitive to light.

Chitosan

Chitosan is produced by deacetylation of chitin, which is the structural element in the cell walls of fungi and also in exoskeleton of crustaceans, it is a renewable natural resource (it's a nontoxic natural polymer and biodegradable to natural body components), can be a natural polymer transformable into fibres with wide application fields in medicine, pharmacy, food technology, biochemistry, etc. In medicine it may be used as an antimicrobial agent, and bandages to be used in order to stop bleeding, but it can also be used to deliver certain drugs through the human skin.

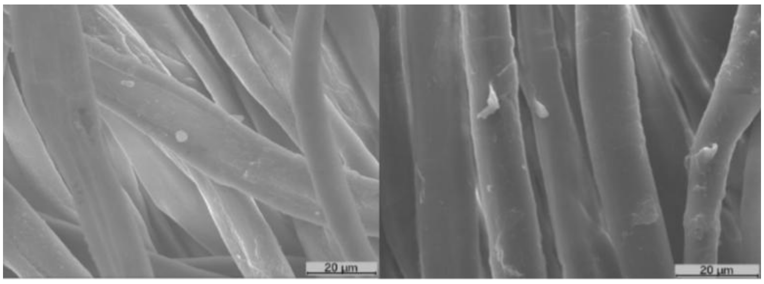
Agiene application method

Initially, the product dissolved in the liquor is absorbed, only on the surface, then penetrates in the core of the fibre and finally migrates thus allowing good uniformity and consistency. The process works by operating temperature and time. While the process is developed, thermodynamic and kinetic reaction interacts.

In this treatment, the samples of knit are cut, so that each sample has a maximum weight of 42 grams, because we have to follow the proportion of 1:7, which means: for each gram of knit, it has 7 ml of anti-bacterial solution. The maximum solution weight added with the weight of the fabric which can be placed in each capsule of the Exhaustion machine is 300 grams or 300ml.

Products concentrations for Exhaustion process: Agiene® 300-A 0.28% w.f = x g/L. Nonax 3009-A 0.1% w.f =x g/L. MgCl2 0.5% w.f= x g/L. Adjust pH 3.8- 4.2.

After the calculations and preparation of solutions, each sample of Knit was placed in a capsule separately, adds up the antimicrobial solution. The exhaust treatment is made for 20 minutes at 50^0C, using 40 RPM (rotations per minute), and a gradient of 2.5, which means that the temperature of the exhaustion chamber will increase gradually every minute 2.5^0C until the temperature of 50^0C which is the temperature suitable for the process. After this time the knits are drawn from inside the capsules and taken to kiln, in order to completely dry the fabric at a temperature of 110^0C for 14 minutes. The fabric is cured for 45 seconds at a temperature of 180^0C. Figure 3, represents cotton and hemp fibers, both treated with agiene by exhaustion.



(a) (b)

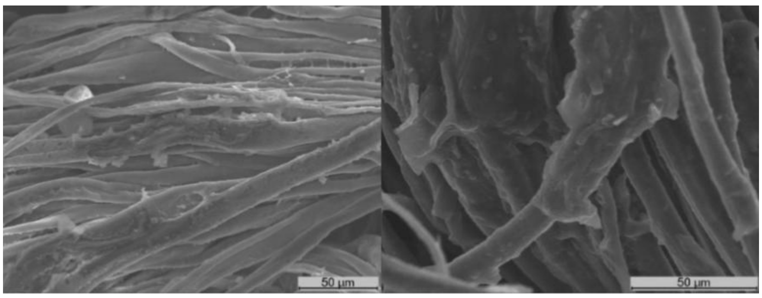
Figure 3- SEM - Fibers treated with Agiene® by Exhaustion (Magnification: 1100) (a) Cotton fibre (b) Hemp fibre. (Source: Optic Center of UBI)

Chitosan application method

The Chitosan treatment consisted primarily on a pre-treatment of knit samples with citric acid (99%) 100g/L add Na2HPO4.12H2O or NaH2Po42H2O 60g/L. After performing the treatment, by Pad-batch, had to dry the fabric 90^0C for 5 minutes and then curing at a temperature of 180^0C for 5 minutes.

After performing the pre-treatment with acid began the treatment with Chitosan. The method was performed by Exhaustion, where we had to prepare a solution of Chitosan 1% v/v, 0,1M Acetic acid, stirring it for 1 h at 60^0C. The emulsion ready to place the emulsion within the knit and capsules into Ugolini equipment, expose the fabrics to a temperature of 60^0C for two hours.

After completing treatment, samples were washed with distilled water and left to dry at room temperature. In figure 4, we can observe cotton and hemp fiber treated with chitosan by exhaustion.



(a) (b)

Figure 4- SEM - Fibres treated with Chitosan by Exhaustion (Magnification: 500) (a) Cotton fibre (b) Hemp fibre. (Source: Optic Center of UBI).

3. RESULTS AND DISCUSSION

3.1 - Antimicrobial Tests

This International Standard specifies quantitative test methods to determine the antibacterial activity of antibacterial finished textile products including nonwovens. ISO 20743:2007 is applicable to all textile products, including cloth, wadding, thread and material for clothing, home furnishings and miscellaneous goods regardless of the type of antibacterial agent used (organic, inorganic, natural or man-made) or the method of application (built-in, after- treatment or grafting).

After treatment of knits with antimicrobial agents, their characteristics were slightly modified as regards the absorptivity of water. It was noticed during the test that the amount of antimicrobial activity made necessary to make two different tests, one facing the knitting treated by Agiene® agent, which has hydrophilic characteristics, the method to verify the antimicrobial activity was carried out by absorption method. The knits that have been treated by Chitosan became hydrophobic after the treatment, so the inoculation of bacteria was done by transfer method.

The absorption method test (an evaluation method in which test bacterial suspension is inoculated directly onto samples), was carried out under the following conditions: the weight of the specimens was 0.4 ± 0.05 grams, with 6 negative control and 6 treated samples of textile knits. The bacteria used for the test was Staphylococcus aureus ATCC 6538P, in a concentration of: 1.5 - 5 x 10^5 cfu/ml, during 24 hours and with agitation.

The transfer method test (an evaluation method in which test bacteria are placed on an agar plate and transferred onto samples), was carried out under the following conditions: diameter of the specimens was 3,8 cm; with 6 negative control and 6 treated samples of textile knits. The bacteria used for the test was Staphylococcus aureus ATCC 6538P, in a concentration of: 1.5 - 3 x 10^6 cfu/ml, during 24 hours and with agitation. The attained results are as depicted in table 3:

Table 3: **Result of antimicrobial activity for cotton and Hemp fibre treated by Agiene and Chitosan.**

	Agiene Treatment				**Chitosan Treatment**			
	Cotton		Hemp		Cotton		Hemp	
	Negative control	**Sample 1**	**Negative control**	**Sample 2**	**Negative control**	**Sample 3**	**Negative control**	**Sample 4**
Concentration of inoculum	1.6 x 10^5 cfu/ml	1.6 x 10^5 cfu/ml	1.6 x 10^5 cfu/ml	1.6 x 10^5 cfu/ml	3.6 x 10^6 cfu/ml	3.6 x 10^6 cfu/ml	3.6 x 10^6 cfu/ml	3.6 x 10^6 cfu/ml
Average concentration of bacteria (t=0h)	6 x 10^3 cfu	6.2 x 10^3 cfu	4.6 x 10^3 cfu	5.4 x 10^3 cfu	8.2 x 10^4 cfu	4.2 x 10^4 cfu	3.9 x 10^4 cfu	4.4 x 10^4 cfu
Average concentration of bacteria (t=24h)	5.8 x 10^8 cfu	1.1 x 10^8 cfu	4.2 x 10^7 cfu	4.04 x 10^4 cfu	3.4 x 10^8 cfu	1.5 x 10^7 cfu	3.2 x 10^8 cfu	2.7 x 10^7 cfu
Antimicrobial activity in percentage	**81%**		**99.90 %**		**95.5 %**		**91 %**	

The analysis of the antimicrobial activity denotes that the best result of all is obtained by Hemp with Agiene. Which is greater than the one we got with the same agent on cotton. Regarding the agent Chitosan the highest value is achieved with cotton while hemp decreases its performance when compared to the other agent. However the difference between those values is not as significant, due to the fact that antimicrobial activity above 90% is considered to be high.

3.2. Thermal Properties Analysis

The main thermal properties were evaluated with the Alambeta apparatus, in accordance with the guidelines recommended by the manufacturer and under a conditioned atmosphere. Those properties were assessed in the dry and wet state. The conclusions obtained will be far based on the wet state, as this represents the state that most closely matches the conditions of use of a particular piece of clothing, the dry state corresponding to time zero, which is the time when user dresses the cloth on. The tests were carried out on 30 specimens and the final results are sown in table 4

Table 4: **Thermal Properties of Cotton and Hemp fibre**.

	DRY STATE			WET STATE		
	b ($W.m^{-2}.K^{-1}.s^{½}$)	λ ($W/m.K$)	r (m^2K/W)	b ($W.m^{-2}.K^{-1}.s^{½}$)	λ ($W/m.K$)	r (m^2K/W)
Cotton untreated	176	50.4	38.8	178	83.5	28.6
Cotton Chitosan Exhaustion	172	70	10.7	211	114	6.6
Cotton Agiene Exhaustion	162	62.7	18.6	221	131.3	8.1
Hemp untreated	188	56.4	16.9	216	105.8	15.7
Hemp Agiene Exhaustion	173	58.4	15.9	184	114	10.4
Hemp Chitosan Exhaustion	166	55.5	11.5	151	132	5.5

According to the analysis of the thermal properties, we can say, that hemp treated with chitosan had the lowest thermal resistance and the highest thermal absorptivity. Although the thermal conductivity is not the highest. When analyzing cotton, we also point out that the sample treated with chitosan had low thermal resistance and high thermal conductivity as intended. The absorptivity is not the highest, but the differences are not significant.

3.3. Physiological Properties Analysis

The study of the physiological properties was made with the Permetest device. The tests were performed according to recommendations given by the manufacturer and under a conditioned atmosphere. The tests were carried out on 30 samples and the final results are displayed in table 5.

Table 5: **Water vapour permeability (%)**

Standart Textile					
Initial Weight	Final Weight	Difference	Area	WVP=24M/At	Rate %
137.772	131.946	5.826	0.005408	1077.319	0

Reference sample	Initial Weight	Final Weight	Difference	Area	WVP=24M/At	Rate %
Hemp Natural	140.809	134.888	5.921	0.005408	1090.325	101.21
Hemp Chitosan Exhaustion	141.928	135.961	5.967	0.005408	1090.081	101.18
Hemp Agiene Exhaustion	140.440	135.223	5.217	0.005408	964.706	89.55
Cotton Natural	139.899	134.068	5.831	0.005408	1078.244	100.09
Cotton Chitosan Exhaustion	140.085	134.098	5.987	0.005408	1076.433	99.92
Cotton Agiene Exhaustion	140.663	135.038	5.625	0.005408	1040.152	96.55

According to the attained results of water vapor permeability it is possible to conclude that the both fibers, cotton and hemp, without treatment, have the highest values of water vapor permeability.

When analyzing the finished samples, we can clearly observe tha hemp sample treated with chitosan applied by exhaustion, had the best permeability. This is of great importance for our prototype due to its excellent ability to maximize the evaporation of the body transpirationand, therefore, the physiological comfort. It is also possible to see that the cotton samples treated with chitosan had also the highest permeability values.

3.4. Prototype of the developed gown

During the conception and development of the gown we seek to provide easy medication access and, also to promote sensory, psychic and ergonomic comfort to the patient. Another important feature is its antimicrobial behaviour, and especially to avoid cross infection among workers and patients that have a very weak immune system. Other considered issue in the development of the prototype was sustainability and the environmental concern.

The prototype has in the chest part an opening for easier application and handling of the chemotherapy catheter. The prototype sleeves are in Velcro designed to facilitate opening the gown for the serum medication. In the lower front part, there is a cut-out all around its circumference, so that the children can interact with their clothes, increasing or decreasing the length.

The prototype development entailed the following guidelines:

DESIGN: we sought to create a product aesthetically viable, meeting the needs of a functional product for application in hospital environment. Comfort and functionality were the key words of the prototype. Avoiding chemicals, colours was worked out the hemp natural colour (greyish) mostly. Small and colourful details has been applied through digital printing.

SHAPE: It was developed in order to obtain the greatest ergonomic comfort possible and to facilitate the movements of the patient´s while being dressed/undressed in case of needing urgent/emergency care.

MATERIALS: The selected materials are thought to provide an optimal antimicrobial activity, being environment friendly, and assist in thermoregulation and patient comfort.

With the conclusion of the experimental tests, it was possible to ascertain the best optimized combination of the fiber and antimicrobial agent. In accordance to our conclusions, we developed a gown prototype. The following images give us a visual description of the final outcome and underlines the best characteristics that we sought to impart in our prototype.

(a) **(b)**

Figure 5- (a)Providing psychological comfort for the patient; (b)Easiness in handling and application of catheters;

4. Conclusions

Accordingly to the aforementioned assumptions, we conceive and developed a gown prototype suitable to be used in healthcare facilities by male children aged 2-8 years old, when submitted to chemotherapy treatment.

For this purpose we sought to develop a gown with a set of characteristics that met the necessary requirements, namely, great antimicrobial effectiveness, maximized thermophysiological comfort and ergonomic shape combined with an appealing appearance, so as children may be led to interact with it, improving their psychological wellbeing during treatments.

It was also our intention to develop a gown based upon sustainable fibres in order to attain a more eco-friendly piece of cloth. Moreover, we aim at the replacement of the usually used woven fabrics by knits.

Several samples of finished knits were put to test in order to ascertain which one had the most optimized behaviour in terms of antimicrobial effectiveness and thermophysiological comfort. In the end, as proven, hemp knits treated with chitosan applied by exhaustion revealed to have the best optimized antimicrobial effect combined with maximized comfort.

In conclusion, this research work proposed, conceived, developed and tested a new viable and, technically improved, alternative gown, to be used by small children undergoing chemotherapy.

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