Experimental Research on the Water Repellency Property of Beeswax Treated and Bacterial Cellulosic Material

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ABSTRACT---In the recent years, worldwide and environmental issues have prompted the developers to re-direct their to bio-based resources even in the medical sector. In this context, bacterial cellulose based materials are the upcoming area of research due to its potential medical application in the wound healing field. On the contrary, there are several natural antiseptic materials available out of which the Beeswax, a well-known material which suits requirements for the development of a medical textile material for the purpose of wound healing. Beeswax is a natural animal wax which has various properties in addition to its biocompatible nature. The chemical constituents of beeswax varies according to the geographic region. Beeswax enhances water repellency and emulsifies insoluble particles in textile fabrics. Vitamin A, which is an essential for human cell development is a major composition in the Beeswax. Nata de Coco, a typical bacterial cellulose is the most popular one in the production of nata. Nata is the fermentation product of the bacteria, AcetobacterXylinium referred to as Nata de Coco, Nata de Pina whereby their flavors are controlled by the coconut water based and pineapple based cultures respectively. Nata de Coco marks a remarkable application in the wound healing process for the second degree burns. In this present study, the superficial water-repellency for the beeswax coated fabrics and the artificial developed bacterial cellulose material called Nata de Coco is being compared which will further take the development process to the next stage.

Keywords: Beeswax, Nata, Nata de Coco, Water-repellency.

I. INTRODUCTION

Healthcare sector is the major domain that finds scope in the rapid development in technical textiles. The engineering materials that are used in medical applications such as wound dressings, meshes, bandaging materials to scaffolds for tissue engineering and implantable prostheses, all of which have a very specific requirements which have to meet the medical standards. Wearable Textiles is prevalent in the healthcare applications and through innovation is continuously expanding within the medical sector in both home and hospital environments.

The healthcare sector surpasses a wide historical expectations whereby the new healthcare problems pose new challenges to the ever-changing and quick-responding nature of the health care system. The textile materials find both the in vitro and in vivo applications both in the dressings and regenerative medicine. The materials used of the medical textiles are explored with a focus that its provides barrier for the external parts of the body and for internal parts to support regenerative medicine. The Cellulosic materials has been always an excellent base for many applications such as textile and packaging materials for food industry. And it also finds application in the bio-compatible products. The major restriction in the purpose of the bio-wearable is moisture control where the unmodified cellulosic materials absorb and lose moisture easily , especially due to the climatic conditions and microorganism. This refers to a combination of physical and chemical degradation processes due to combined effects of sunlight, moisture, fungi, bacterial, etc., Due to the excellent applications of the cellulosic structures, they also find applications in the medical industry as it has the natural wound healing properties.

Though there may be various methodologies that that may prevent the degradation of the cellulosic structures, the chemical modification was the methodology that was used to alter the properties of the natural polymeric and textile materials. In this present scenario, water repellent agents are polydimethylsiloxane, silica and fluorine are incorporated over the surface of the materials to make them phobic to mositure. However, the anti-repellent chemicals when comes to direct-contact with human body, there must be toxicity screening test for its biocompatibility nature. The anti-repellent chemicals contain the fluorocarbons that extend the water-repellent nature of the material but still, the perfluorocarbon chains cause biological threats to both the human lives and the environment.[1]

The modified properties of the textile materials in the medical applications are done by the usage of fatty acids that create a top layer dated long time ago. They were know to be used in the sourcing and finishing fabrics. The usage of fatty acids are highly advantageous than the chemical reagents in terms of their ease of use, bio-tolerance, etc., Now a days, the using fatty acids and its derivatives finds a major applications in the textiles industry for its diversified usage.

One of the most conventional and cheapest source of fatty acid form is the wax which are obtained from the various resources such animals, vegetables, minerals and petroleum products. They can be highly used with ease in the coating technologies.[4]. Among with the natural sources of waxes are preferred for the medical oriented applications due to the bio-toxicity and bio-tolerance aspect. Beeswax is the most common wax that can be geographically obtained all over the world but its chemical composition varies according to the geographic region mainly comprising of esters of long

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chain fatty acids, alcohols, hydrocarbons and aliphatic aldehyde. Beeswax, an excellent emulsion stabilizer and water-repellent enhancer is coated over the textile fabrics to remove the surface roughness. The bees wax has a melting point of 61-66 degree Celsius where it remains solid at room temperature. This is the main property supporting its water-repellence concept. [5],[6]

The present experimental study on the properties of the beeswax and bacterial cellulose coated material is being carried out for the purpose of medical application in the field of wound healing. It is well known about the excellent wound healing property of the beeswax. Comparatively, the bacterial cellulose form regenerative cum wound healing material that finds diverse healing application.

Cellulose is a most abundant, renewable and widely used natural material. During the last few years, the development of the cellulose-based products, with multi dimensional characteristics has gained considerable attention. Cellulose is a major constituent of plants but for this application the cellulosic material is obtained by a process of bio-synthesization. The bacterial cellulose is biosynthesized by certain bacteria, e.g., Rhizobium spp., Agrobacterium spp., Acetobacter spp., and Alcaligenes spp. The cellulose material is chosen as it is protected from degradation because of its close association to a sheath of matrix polymers, which include lignin and hemicellulose. The cellulose structure eases the surface modification ability, eco-friendly processing, enhances bio-toxicity, handling, and health hazards, while synthetic polymers pose significant health risks, such as skin irritation and respiratory disease. Among the various bacteria, the AcetobacterXylinium strain is able to produce cellulose within a temperature range of 25 to 30 degree Celsius and pH range of 4.5 to 7.5.[2],[3]

The obtained bacterial cellulosic material called the Nata is highly pure, hydrophilic in nature and bio-compatible. Also, its excellent structure forming potential and chirality provides a wide range of special applications, e.g. as a food matrix called nata, as dietary fiber, as an acoustic or filter membrane, as ultra- strength paper. It can also serve as a reticulated fine fiber network where it can be used for skin therapy with coating, binding, thickening and suspending characteristics. In addition, thenata also has high mechanical strength in the wet state, substantially permeable for liquids and gases and zero skin irritation revealed that the gelatinous membrane of bacterial cellulose as an excellent skin therapy application.[3],[4]

Combining the excellent antimicrobial nature of both the beeswax treated fabric and an artificially developed bacterial cellulose, anmulti dimensional application can be developed. Depending on the antimicrobial activity of the material, several layers of coating or thickness of the material can be increased. [7]

II. EXPERIMENTAL STUDY

Development of Beeswax Treated Material

The first step of this experimental study is to develop a beeswax treated material. The treatable material should be finely chosen based on the wax pick up property. The beeswax coated material forms the base for many applications.

Development of Bacterial Cellulosic Material

Secondly, the apt bacterial cellulosic material is developed which forms the second functional layer for the medical application. Out of various comparisons, the bacterial cellulosic material (Nata) synthesised by mother cultures with natural media like coconut water was developed using the AcetobacterXylinium. Here in this study, coconut water is chosen a medium due to its excellent healing properties.

Coconut Cellulose

Nata de coco, an edible cellulosic structure developed with coconut water as a media originated from Philippines where it was produced by fermentation of coconut water with a culture called AcetobacterXylinium, a gram negative bacterium. AcetobacterXylinium breaks down the glucose in coconut water and converts it into bacterial cellulose that has high purity, excellent crystalline structure and good mechanical strength. In this experimental study , the water repellent nature and wetting time of both the materials developed are observed. The following figures Fig. 1. and Fig. 2. shows the beeswax bar that is used as a raw material for fabric coating and nata de coco respectively.

Fig 1: Beeswax bar that is used a raw material for fabric coating.

Fig. 2. Nata de coco developed using Acetobacter xylinium

II. DEVELOPMENT METHODOLGIES

The development of the beeswax treated material and the bacterial cellulosic (Nata de coco) material was carried out under laboratory conditions. The following procedures were carried out during the development process.

Beeswax Treated Material

- To develop a material coated with beeswax, a suitable base material should be selected. The fabrics can be either cotton or viscose. The fabric to be coated should be well-sterilised in order to avoid microbial deteriorations.
- A sterilised 100% cotton plain weaved fabric of 5 x 5 cm was taken under study. The purchased beeswax of fine quality was shredded evenly over the surface of the material that was to be modified. The surface of the material is treated with a high temperature through indirect heating so as the wax gets coated over the fabric. Comparing the commercial method, this was one of the convenient method. The commercial method of coating involves a high temperature pour and coat operation because the beeswax solidifies at a room temperature and it reaches its brittle nature when the temperature comes down to 18 degree Celsius. Also, it becomes soft and pliable immediately at around 35-40 degree Celsius.
- The beeswax gets adhered to the treated material once it reaches the room temperature. After processing, beeswax remains a biologically active product retaining anti-bacterial properties. It contains Vitamin A, which is essential for human cell development and wound healing.

Bacterial Cellulosic Material

The bacterial cellulosic material, Nata de coco was prepared using the starter culture for Nata with the coconut water media. The culture used for the fermentation to produce bacterial cellulose consists of coconut water (1 litre), sucrose (50 g), urea (10 g), starter culture (also the mother culture) of AcetobacterXylinium (10%) and pH is to be maintained at pH 5 with acetic acid. The media sterilisation was done by autoclaving at 121 degree Celsius for a period of 15 minutes. The Coconut Nata , a bacterial cellulose was cultured at room temperature for 7 days in a Petri dish under static conditions. Once the incubation period is set off, the the harvested bacterial cellulose is boiled in distilled water for 2 hours, and rinsed in running water until the pH becomes neutral. The pH which control the acidity of the cellulose is also an important factor that determines the growth and formation of bacterial cellulose structure. The acidity and brix is the factor that control the thickness of the bacterial cellulose as because sugar is the main carbon source for the bacterial cellulose fermentation process.[8],[9]

1) Tensile Strength

Tensile strength is one of the mechanical properties that determines the strength of the thin film. Tensile strength is the maximum pull force that can be retained by a thin layer. It is the point where the thin layer is disconnected. The tensile strength of the bacterial cellulose is directly proportional to the elongation of the thin layered cellulosic material under test.

2) Elongation

The elongation of the bacterial cellulose is an inverted pattern of tensile strength. The elongation process depends on the incubation period from the date of culture harvest.

3) Swelling ability

The ability of water penetration into the structure of the thin layer of bacterial cellulose is the swelling ability. The more the water content in the structure, more the ability of swelling .Generally, the coconut cellulose is highly crystalline and henceforth, it is hydrophobic in nature .[9] The following figure Fig.3 . shows the schematic representation of Nata de coco development.

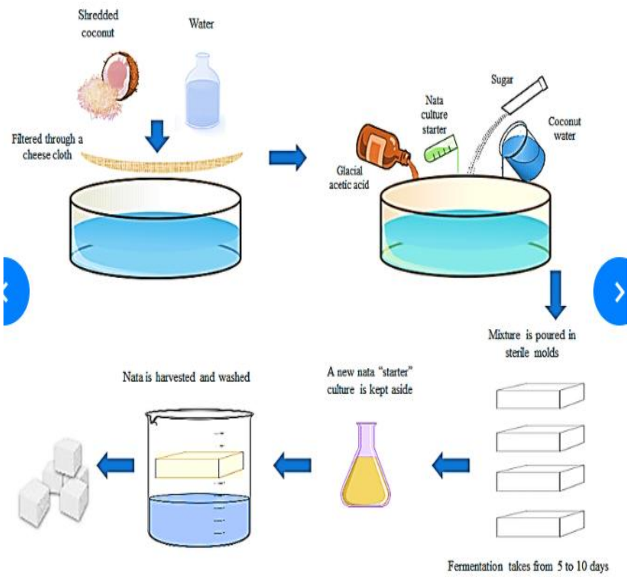

Fig .3 . Schematic Representation of Nata de Coco development

III. RESULTS AND DISCUSSIONS

The tests on water repellency were carried out on both the beeswax coated fabrics and bacterial cellulose material developed via manual method. Both the developed material of 5 x 5 cm were taken and pure distilled water of around 2 ml was measured in a dropper. The water was poured on the surface of both the materials drop by drop with a simultaneous monitor of the time in seconds. The table I shows the wetting time of both the materials.

Table I. Wetting time comparison of the developed materials

TRAIL NO	MATERIAL 1 (BEES WAX TREATED MATERIAL)	MATERIAL 2 (NATA DE COCO - BACTERIAL CELLULOSE)
1	>100 s	>70 s
2	>100 s	> 70 s
3	>100 s	> 70 s

The above table shows the results of the trails conducted for the wettability testsfor both the beeswax treated material and the coconut cellulosic material. It is incurred from the results that the beeswax has a heavy chain of fatty acids compared to the bacterial cellulose developed which results in the high rate of water repellency compared to the harvested nata. The superficial surface of the bacterial cellulose is hydrophilic in nature which absorbs aqueous solutions. The outcome of the experimental study leaves path for the development of a biocompatible, antimicrobial layer that can be used a biomaterial . The bacterial cellulose has various applications in the field of healing wounds up to the second degree and third degree wounds. Also they act as regenerative layer of skin for major wound due to its excellent healing properties.

In the future, our experiment on the nata is to be extended towards the development of a superimposed layer for water repellency with the reverse osmosis property where it locks the moisture on one side and absorbs on the other side. This forms a major base for the development of various biomaterials.

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