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Mini Review

Biofunctional Textiles using β-Cyclodextrins

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ABSTRACT

With the new environmental-friendly developments surrounding the industry and society, the use of new materials as carriers is becoming more important. In the case of essential oils and organic chemical substances, the role that cyclodextrins play is very important. The use of the Guest-host structures in the cone structure of β-Cyclodextrins is very frequent in Pharmacy and Biochemical systems related to biomedical applications. In this work, we present a mini-review work suggesting possibilities of the application of the cyclodextrins characteristics to be used in the textile industry to achieve antibacterial, antimicrobial, or simply, aromatic properties longed in time.

Keywords: β-cyclodextrins; Carriers; Textile substrate; Biofunctional textiles

INTRODUCTION

Cotton accounts for more than 50% of the global fiber market and has intrinsic properties such as high tensile strength, hydrophilicity, high moisture absorption, and comfort [1-3]. In addition to all these properties, new properties can be added to the fabric through innovative methods [4], with great industrial appeal. Thus, there is a need to add properties to cotton fabric so that it can be consumed even more widely and serve a more demanding public that requires materials that release active ingredients [5]. One of the ways to produce these biofunctional textiles is to apply Cyclodextrins (CD) to the material. Thus, the CD will be responsible for changing the surface of the fabric to receive the active ingredient, making the material biofunctional [6,7]. The use of β-Cyclodextrines offers a very interesting complementary option; cyclodextrines can be fixed on the substrate using cross-linkers (usually bifunctional carboxylic acids), maintaining their capability to absorb organic molecules which makes the whole surface of cotton tissues a whole carrier system for molecules that show a lot of difficulties to be carried out in different forms.

LITERATURE REVIEW

Biofunctional textiles

With a growing trend in technology, the global textile industry has recently found modern applications in various fields. The production of high-value-added textile structures and functional products such as smart textiles, protective textiles, medical textiles, and especially cosmetic textiles or cosmetotextiles are examples of modern applications in this field [8,9].

Historically, the term "biofunctional textiles" has been, usually referred only to antimicrobial textiles, but with the growing needs of people and technological advances, this scientific field has developed and new functions in textiles are spreading. The term is currently used as a substitute for cosmetotextiles as it is more comprehensive.

When it comes to new technologies and innovative methodologies, there is a growth in the functionalization of bioactives. Currently, the term "biofunctional textiles" includes cell development and growth, biodetection, cosmetic benefits [10,11], as well as medical [12], catalyst carriers and sutures, leading to the promotion of human health and improved quality of life.

Thus, these modified textile materials, when in contact with the human body and skin, are designed to directly transfer an active material for cosmetic and medical purposes. The operating principle of biofunctional textiles is the controlled release of bioactive compounds, most of which are complex in the textile substrate. The mechanisms of the delivery are still under study and are a part of complex research. When the carrier structures have been applied, there is a strong influence of the mutual chemical characteristics between the carrier external structure, the trigger mechanism, and

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the chemical affinity of the active molecule with the own structure of the tissue. On average, every step influences the global transport mechanism from the carrier towards the surface of the tissue, and from here to the skin.

Characteristics of bioactive compounds commonly present in biofunctional textiles include gradually perfumed, moisturized, wrinkle-free, refreshed, relaxed, revitalized, UV-protected, insect-protected, improved healing and antimicrobial skin.

For these properties to play a role in the skin, the agents applied to the surface of the fabric must complex, or retain to a certain extent, the bioactive agent and release it into the skin to benefit the user. Examples of these agents include microcapsules [13], nanoparticles [14], Metal-Organic Frameworks (MOFs) [15,16], liposomes [17], and cyclodextrins [18].

Among these, Cyclodextrins (CDs) are an important class of oligosaccharides with a truncated cone shape and sustainable compounds from renewable sources [19]. CDs are widely used in the pharmaceutical, cosmetic, and food industries and are increasingly used in the textile industry due to their ability to encapsulate bioactive substances, allowing the development of new finishes and the production of fabrics with new applications [20].

Cyclodextrins

The application of CDs in industry is very diverse and they have been used in the pharmaceutical, textile, food, and even cosmetic industries. CDs play an important role in the textile industry as they can be used to: Remove surfactants from washed textile material [21], as leveling agents in dyeing and in textile finishing [22], and can be considered as a new class of auxiliaries in the textile industry [23].

The variety of natural or semisynthetic cyclic oligosaccharides is limited and the most important DCs are α-, β- and γ-CDs with 6, 7, and 8 glucose monomers, respectively. Among the natural DCs, β-CD is the most widely used due to its ability to complex a large number of hydrophobic drugs and its availability in high quantities [24].

When it comes to the stoichiometry of the inclusion complex, there are four most common types of complexes in CDs: A substrate with 1:1, 1:2, 2:1, and 2:2, depending on the size and structural aspect of the substrate concerning the cavity of the CD [25]. This allows the formation of stable inclusion complexes, which are widely used in the pharmaceutical, agrochemistry [26], food, and cosmetic industries, as well as in the textile industry.

Application of cyclodextrin in textile substrate

The interactions between β-CD and the cotton fabric that represents the work in question can be chemically fixed, through a catalyzed esterification process [27]. Esterification reactions are widely used in a variety of chemical industries, it is a mineral acid-catalyzed nucleophilic substitution reaction of the acyl group involving a carboxylic acid and an alcohol [28]. The process typically uses mineral acids as catalysts, so the catalyst must be removed at the end of the reaction by aqueous alkaline washing for neutralization.

The mineral acid protonates the oxygen atom of the carbonyl group, making the carboxylic acid much more reactive to nucleophilic attack by the alcohol and forming a tetrahedral intermediate. This is followed by the transfer of a proton from one oxygen to another, resulting in a second tetrahedral intermediate and the conversion of the -OH group to a leaving group, culminating in the loss of a proton that regenerates the acid catalyst, resulting in the ester [29].

According to Zhao, et al. [30], it can be seen in Figure 1, that the Carboxylic groups (-COOH) of citric acid can form ester bonds (-COO-) with the Hydroxyl groups (-OH) of both cotton cloth and β-CD through the esterification reaction.

In this way, the CDs are applied to the surface of the cotton fabric through a direct synthesis process known as textile finishing. The substrate undergoes a surface modification that, after the complexation of the CDs, can transform it into functionalized fabrics in the future. Functionalized fabrics contain additional functions compared to unfinished textiles. When using the β-Cyclodextrins esterification process, their structure allows to use of the whole tissue as a selective absorbent for active molecules. That specific property generates a huge amount of possible applications because the textile substrate acts as a "reservoir system" that can control the delivery of different molecules in quantities under a constant dosage rate [31,32].

Therefore, for the fabric to obtain a new function, it is necessary to complex the β-CD with agents such as vitamin E, citronella [33], silver [34], and Erythrosin B [35], which transform the fabric into a biofunctional one.

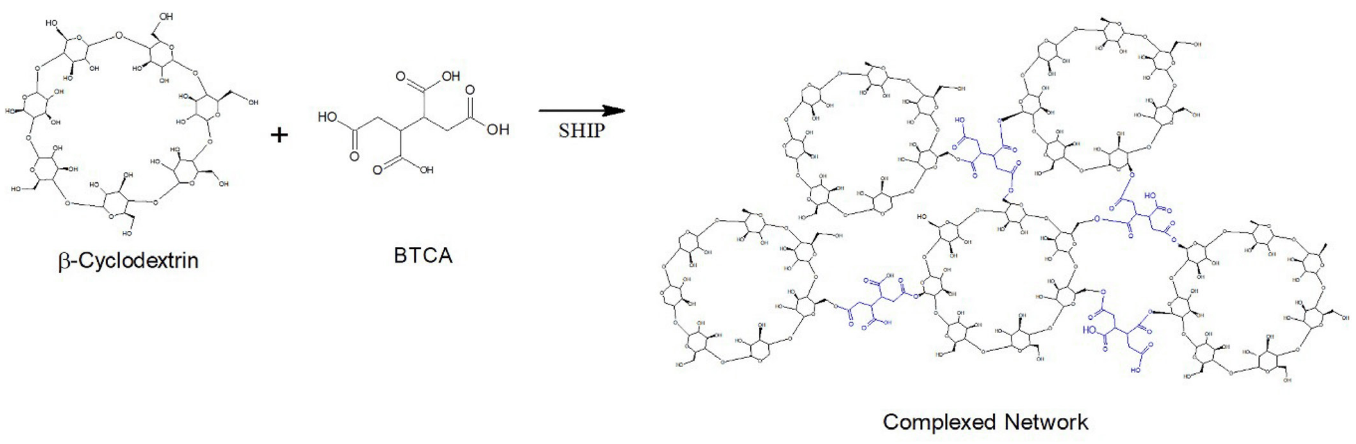

Figure 1: Network formation with β-Cyclodextrines esterification reaction, LIS et al. [32].

CONCLUSION

Textiles are essential to everyone's daily life, and the application of science and technology is evolving every day to meet the most diverse needs. The majority of our skin is covered by clothes which makes it possible to use the reservoir effect of the functionalized textiles to act as delivery systems to the skin.

As has been demonstrated, cyclodextrins can be applied to textiles with covalent bonds, giving to the material new properties and making it functional. These new properties allow the textile to be used as a cosmetic, a release matrix, in other words, a product that can help its user in a different way than conventional textiles. The study of new textile materials and new ways to functionalize them is increasing every year, showing the importance of the interdisciplinary and transversal nature of the textile field. In this field of study, several topics are involved as biophysics, chemical reactions, and transport mechanisms. In every case, the final product can be evaluated and the dosage calculated which allows to model, mathematically the final result of the substrate modification, as well as to design the intensity of modification required for a specific final effect. New finishes will always be necessary according to the needs of society and the evolution of materials. Textiles will always be present in people's lives.

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