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Research Article

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The Release of Tacrolimus from a Cotton Biomaterial to Dermis

Oana Parteni[1*], Cezar Doru Radu[1], Ion Sandu[2], Ioan Emil Muresan[3], Lacramioara Ochiuz[4], Eugen Ulea[5] and Cornel Munteanu[6]

Abstract

Objective: The paper describes the creation of a delivery system for a drug with high dimensions, as tacrolimus.

Methods: The achievement of a biomaterial manufactured of alternative layers of chitosan (CS) and sodium alginate (Alg) with the inclusion of tacrolimus (Ta) between layers. By the gradual dissolution of layers, Ta is released.

Results: On a cotton fabric, it has been performed a biomaterial consists of 10 layers of CS and Alg. The biomaterial can sustain and then release Ta according with a specific relase kinetics and by avoiding "burst effect". The following have been evaluated: coated fabric loading degree, the number of charges on the specific surface, the dyeing tests, the Ta kinetic release and the elemental analysis (EDAX). The method proposed describes the advantages of releasing the drug as well as the limits imposed by using other systems for controlled drug release, such as cyclodextrins or hydrogels.

Conclusion: In paper, the proposed biomaterial is a viable alternative for regular treatments of cutaneous diseases with a Ta formulation supported from a textile fabric for psoriasis.

Keywords

Multilayer; Tacrolimus; Chitosan; Sodium alginate; Release kinetics

Introduction

Drug-loaded textiles have certain advantages compared with the conventional routes of administration of various pharmaceutical formulations [1-3]. Although oral administration is characterized by a high degree of therapeutic compliance, it cannot be used in patients who have problems swallowing, who are noncooperative, or are diagnosed with serious mental disorders. In this paper, *compliance* refers to the patients' adhesion to the therapeutic means necessary to improve their medical condition. The topical administration of the drug, while possible, would cause some discomfort for patients due to the repeated procedures entailing interrupted work, dirty hands, time spent dressing and undressing. By using a piece of medical fabric as a drug-loaded support, the drug is administered on a continuous basis in contact with sweat, regardless of the patient's health condition or compliance. There are, however, cases when drugs cannot be included in pharmaceutical formulations due to specific physicochemical and biopharmaceutical properties. Incompatibilities often arise from mismatches between the (hydrophilic/hydrophobic) active principle and the fabric acting as support or the chemical inclusion system. In other cases, there is a disparity between the size of drug molecules and that of the sorption and subsequently release spaces. Inconsistencies have thus been noted in Ta-CD and Ta-hydrogel systems, respectively, determined by the molecular size of Ta (13.99-14.65 Å in length and 10.17-12.29 Å in width), which exceeds the inner diameter of the CD cavity (6.2 Å), or the diameter of pores in case of hydrogel. In this paper, the size of the Ta molecule using ChemAxon software Marvin Space 5.4.0.0. was determined only to explain the failure of experimental tests to include Ta in β-CD or a CS-based hydrogel matrix. This required finding another method of releasing tacrolimus in the treatment for psoriasis supported by a textile fabric worn directly on the dermis. Ta is a calcineurin inhibitor with strong immunodepressive action used in the histopathology of psoriasis, as well as in preventing organ transplant rejection by the body [4,5]. Due to the experimental difficulties encountered in creating a biomaterial able to facilitate the accumulation of Ta on a surface that would subsequently release the drug under a liquid environment (skin perspiration), another drug release method was tested for antipsoriatic therapy. The multilayer alternative deposition of cationic and anionic films is a technique called *layer-by-layer deposition* used to modify the surface of a polymer material. Several studies on obtaining layers of polyelectrolytes forming a new surface with new properties, compared with the initial properties of the substrate, have been conducted. The literature reports attempts to create multilayer polymer systems for various purposes, such as the operation of a polymeric substrate designed to effectively control drug release [6]. According to Martin [6], the first study on the construction of a multilayer system on a cotton substrate was carried out in 2009 [7]. In a further study conducted on cotton fabric, anti-microbial agents were included by means of the multilayer technique, forming a biomaterial with applicative potential in medicine [8]. The multilayer technique applied on cotton fabrics is relatively frequently applied in the specialized literature [9,10]. Multilayer applications on other fiber polymers, use as textile substrates, have also been studied. Thus, in order to change a nonwoven fabric made of polyamide by depositing poly (diallyldimethylammonium chloride) and anionic Scarlet dye films, the conditions for obtaining (concentration and duration of absorption within the solution) multilayer systems have been communicated [11]. Dubas used the layer-by-layer deposition technique in order to cover silk fabrics with thin films for improving color fastness to washing [12]. In another study, the surface of polyester was changed by depositing layers of poly(allylamine hydrochloride) and poly(sodium styrene sulfonate) to characterize the chemical properties of multilayer surface obtained [13]. Moreover, in order to avoid the postoperative infections of implants, an alternative coating with positively charged CS films and negatively charged β-CD films crosslinked with citric acid have been manufactured on a polyesther nonwoven fabric [6]. This was done in view of complexing the inner cavities of β-CD and then releasing an antimicrobial agent to the biological interface of the implant. Therefore, the interest in obtaining performance technical materials is current, focused on creating hybrid layers with mechanical, electrical, optical and

***Corresponding author:** Oana Parteni, Department of Textiles, Leather and Industrial Management, Gheorghe Asachi Technical University of Iasi, Romania, Tel: +447774683400; Fax: +40 232 230491; E-mail: oanaparteni@yahoo.com

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thermal properties, under strictly controlled conditions [14]. Most studies on multilayer constructions do not have medical purposes, despite the fact that their characteristics could also be useful in evaluating biomaterials for drug delivery [15-17]. The novelty of this paper lies in the release of Ta through the dissolution of the soluble CS and Alg layers applied over the cotton material under the action of an alcoholic solution. The layers acted as coatings, fixing the drug onto the fabric. The aim of this paper is to evaluate the performance and limits of the new Ta release system. The procedure proposes the application of a medical textile in the treatment for psoriasis.

Materials and Methods

The textile substrate used in this study was a 100% cotton woven fabric supplied by SC Iasitex SA company, with yarn fineness Nm = 34/1, in warp and weft, density 225 yarns/10 cm in warp and 185 yarns/10 cm in weft and specific weight 130 g/square meter. The fabric was desized, alkaline boiled and bleached with hydrogen peroxide, washed and dried in industrial conditions. The triplicate samples with dimensions of 10 cm × 50 cm were then subjected to additional preparatory operations in the laboratory, according to protocol 1 presented in the page.3. The CS with a de-acetylating degree of 75-85% and molecular weight ~ 600 kDa was delivered by Fluka, as highly viscous form of CS. The Alg was provided by Sigma Aldrich, as a white powder forming low viscosity solutions. The reagents NaOH, Na_2CO_3, H_2O_2, KCl, HCl and CH_3COOH, purchased from Sigma Aldrich, were used without any alterations. Figure 1 illustrates the chemical structure of Ta. The dyestuffs used (Acid Red 26 and Basic Red 18) were supplied by Bezema. The structures of the dyestuffs are shown in Figure 2. The number of electric charges on the surface of the material was determined by means of conductometric titration (SensION MM-374 conductometer equipped with a bell-type conductivity cell, electrode area=1cm^2), using HCl and NaOH solutions, respectively, $5 \cdot 10^{-3}$ N concentration. The calculation of the number of electric charges was based on the law of equivalents. Dyeing tests were performed on a Mesdan Lab dyeing machine (Italy), 2008. Where the last layer deposited was CS, the multilayer material was dyed using acid dyestuff (CI Acid Red 26) in the following formulation: (2%) Acid Red 26, liquor ratio = 1:200, 5 min. at the boiling point of the solution; cold wash 10 min. In cases in which the last layer was Alg, the material was dyed using basic dyestuff (C.I. Basic Red 18) in the following formulation: (1.2%) Basic Red 18, liquor ratio = 1:150, 5 min. at the boiling point of the solution, cold wash 10 min. The results of these dyeing experiments have been tested on a Data Color 2002 photocolorimeter in order to determine the K/S index measuring color intensity and ΔE color differences, comparing standard samples with color batches, in AN (Adams–Nickerson) units. According to equation (1), ΔE is controlled by: ΔL, lightness difference, Δa, red-green variation, and Δb, yellow-blue variation, between batch and standard samples [18-21]. In this paper, the standard sample was the coatless sample (*witness*). Absorbance measurements for Ta solutions were performed spectroscopically using an UV-VİS spectrophotometer CAMPSEC M501 Single Beam, 2011 at wavelength of 194 nm. A Venticell 55, 2009 oven was used to maintain constant temperatures up to 100° C;

AMETEC EDAX equipment, coupled with SEM Quanta 302D and Genesis Software, were used in elemental analysis. The size of drug molecules was measured using ChemAxon software Marvin Space 5.4.0.0.

Padding operations were performed on a Benz type foulard; A Mesdan Fabric Lab Dryer 2008 was used for drying and curing, heated from 20 to 300° C with ± 2°C accuracy. Weighting was performed with an analytical balance with 1 ± 10^{-4}g accuracy; After conditioning and weighting, the loading degree of the textile substrate was calculated as a ratio between sample weight and sample surface according to Equation (2).

where M is the weight of the textile fabric on which successive layers of polyelectrolyte were deposited (mg); S is the surface of the textile sample (cm^2) obtained from multiplying the length (cm) by the width (cm) of the sample.

Obtaining the multilayer biomaterial

The cotton samples obtained by courtesy SC Iasitex SA were subjected to additional preparatory operations in the laboratory, according to protocol 1.

Protocol 1

1. Cleaning in distilled water for 8 hours using a Soxhlet; 2. Activating the surface fabric by: a) treatment with a solution containing 12 m/L H_2O_2, 2 g/L NaOH; 2 g/L Na_2SiO_3 at boiling point 1 hour, at liquor ratio 1:10; b) ionization of the carboxylic acid groups in order to form carboxylate groups; the fabric was treated with a solution of 10 g/L Na_2CO_3 at 20°C, 3 hours, then washed with distilled water and rinsed with a solution of 1 g/L CH_3COOH to a pH value = 7; 3. Drying, 10 min at 80°C; 4. Conditioning at 20° C and 65% relative humidity for 6 hours; 5. Weighting. The samples prepared according to protocol 1 were subsequently subjected to coating with alternative layers of CS and Alg in compliance with protocol 2.

Protocol 2

1. Padding on a Benz machine with a 5% solution of CS (reported on fabric weight) dissolved in solution of 2 g/L CH_3COOH; 2. Drying 10 min at 80°C; 3. Curing 30 seconds at 130°C; 4. Padding with a 5% solution of Alg (reported on fabric weight); 5. Drying 10 min. at 80°C; 6. Curing for 30 seconds at 130°C. In creating the biomaterial according to protocol 2, ten alternating layers of CS and Alg were applied, as shown in Figure 3. Ta layers were inserted between the layers, as illustrated in Figure 3.

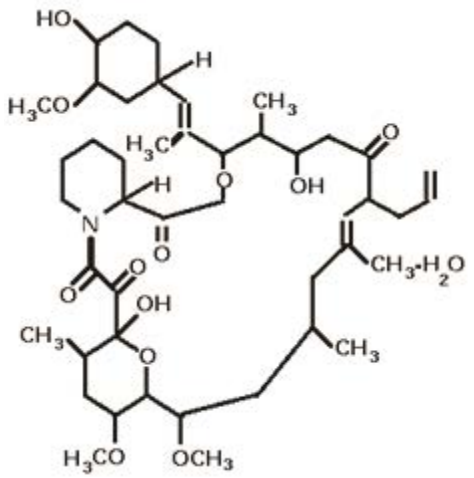
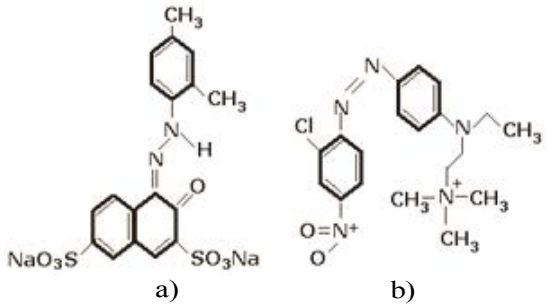


Figure 1: Chemical structure of Ta.



a) b)

a) Acid Red 26 for dyeing the biomaterial with CS as the final layer;
b) Basic Red 18 for dyeing the biomaterial with Alg as the final layer

Figure 2: Structure of dyestuffs.

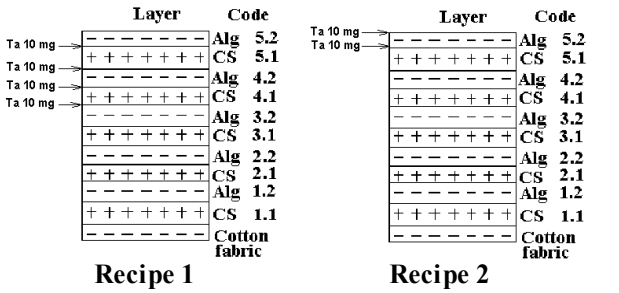


Figure 3: Diagram of CS and Alg layer arrangement with Ta included between the layers of the biomaterial.

Loading the drug onto the multilayered biomaterial

In order to incorporate the drug between the CS and Alg layers, a solution containing Ta 0.010 g / 20 ml ethanol was used. The alcoholic solution based on Ta was sprayed onto the surface of the biomaterial. The material was dried for 4 hours at 20° C, after which the following layer of CS or Alg was deposited according to the procedure described above. Two Ta inclusion procedures were used, as presented in recipe **1** and **2** (from left to right), shown schematically in Figure 3 above. According to recipe 1, the drug was introduced in four batches containing 10 mg Ta, with a total amount of 40 mg. According to formulation 2, a first portion of the product (10 mg) was inserted between the last and the last but one layer of polymer and a second portion (10 mg) was laid onto the outer surface. A total amount of Ta 20 mg was inserted. There are various ways in which the drug can be loaded into the biomaterial. This study used 10 layers in order to be able to observe the multilayer behavior based on a considerable number of layers. On the other hand, the drug was inserted on the surface, and between the 6th and 10th layers, with the purpose of determining the release profile. As no specific therapy was targeted in this study, we did not attempt to establish a therapeutic dose. The number of biomaterial layers depends on the required therapeutic dose to be released to the dermis.

Tests of dimensional size of Ta

The measurements used the Marvin Space software 5.4.0.0., courtesy of Prof. E. Dumitriu. The data show that the Ta molecule presents maximum dimensional values (length=13.99-14.65 Å and width=10.17-12.29 Å) compared to hydrocortisone acetate and Advantan, medicines used in allergic dermatitis. For β-CD, the size of 6.2 Å is the value of the internal diameter of the molecule, and 7.8 Å is cavity height. By comparing Ta sizes with β-CD sizes, it becomes clear that the drug molecule size significantly exceeds the dimensions of the CD inner cavity. This is the reason why Ta cannot be complexed in β-CD. This detail has been verified experimentally. Furthermore, under the experimental conditions tested by the authors, Ta cannot be adsorbed in the interstices of the CS-based hydrogel deposited on a cotton fabric and ionically crosslinked with Na_2SO_4. Under the experimental conditions of our research, as Ta has a large molecule, it probably forms associates with dimensions that do not allow inclusion and drug release from the hydrogel mass, respectively.

Drug release from the multilayered material

In order to release the drug, the textile samples (each weighting approximately 9 g) containing the drug (20 or 40 mg) at 20° C were immersed in 200 ml of 50% ethyl alcohol solution (Ta is insoluble in water but soluble in ethyl alcohol) at 400 rpm on magnetic stirring. Samples were collected from this solution after 24 hours, and the multilayer samples containing the drug were later introduced in a fresh aqueous solution based on ethyl alcohol (50%). The procedure was repeated every 24 hours. The Ta concentration was determined through photocolorimetration at a wavelength of 194 nm. The calibration curve and the straight line equation y = 0.0606x + 1.4307, where y is absorbance and x the Ta concentration (mg/mL) was calculated by introducing the experimentally determined absorbance values, obtaining the value of the Ta concentration.

Results

This study presents the results obtained in developing a multi-layer system consisting of 10 alternating layers of biocompatible CS and Alg and water-soluble polymers. In the first stage of research, we studied the formation and features of the layers deposited onto a 100% cotton fabric. In the second we tested the characteristics of the Ta release.

Coated fabric loading degree

After padding with CS or Alg, drying and curing, the samples were conditioned and weighted in order to determine the degree of loading. The results are shown in Table 1.

Table 1 shows the specific mass values (mg/cm^2) based on the number of layers. Prior to the application of the CS and Alg layers, the fabric had a specific weight of 12.9 mg/cm^2. According to Table 1, the correspondence between the number of layers provided (2, 4, 6, 8 and 10) and the layers is as follows: in the case of 2 layers, the 1st layer - CS and the 2nd layer - Alg; in case of 4 layers, the 1st layer - CS, the 2nd layer - Alg, the 3rd layer - CS and the 4th layer – Alg and so on for other values. The values of loading degree illustrated show only the contribution of the CS and Alg layers without Ta. The loading degree depends on the number of layers adding a new amount of polymer to the next layer. The specific pressure on the contact line, as squeezing parameter, was maintained constant at 1.1 N/cm.

Surface charges

In order to acquire additional information on surface behavior, the number of charges on the surface of the samples was determined with the addition of each layer. The variation in the number of charges on the surface of the biomaterial samples depended on the number of layers applied to the cotton surface. The values obtained show a general variation from 10^{22} positive charges/25 square cm up to 85.10^{21} negative charges/25 square cm of the biomaterial as was

Table 1: Values of loading degree with CS and Alg.

Number of layers	0	2	4	6	8	10
	(mg/cm^2)					
Cotton fabric	12.9	13.1	13.4	13.5	13.7	14.0

illustrated in Figure 4. The latter shows the variation in the number of charges on the surface of the biomaterial samples depending on the number of layers applied to the cotton surface, for the confirmation of the zeta potential variation for each biomaterial, observed in evolution after the application of each layer. The number and nature of electric charges on the surface of the biomaterial depends on the nature of the polymer deposited and on the number of layers. Thus, after depositing the Alg layers, the surface charge of the material becomes negative. The portion between the 4th and 5th layers suggests a possible surface saturation of the material. On the other hand, the deposition of CS on the fabric changes the sign of the surface charge to positive. This occurs, however, only in the 1st and 3rd layers. Beyond the 4th layer, the deposition of CS makes the surface charge negative, maintaining the sign of electric charges for the upper deposition cycles. This change in the sign of the electric charge on the surface of the material is most likely due to the involvement of the (protonated) amino groups in the CS molecule by hydrogen bonding with the hydroxyl groups in the Alg molecule. The hydrogen bonding formed achieves the "adherence" of the successively deposited layers (CS/Alg). At the same time, hydrogen bonding is also responsible for the "compaction" of the substance layers (CS/Alg) deposited in successive cycles, by reducing the intermolecular space. This enables the negatively charged marginal dissociated carboxyl groups in the Alg molecule to reach a higher plane than that of the deposited molecules, making the fabric surface negative.

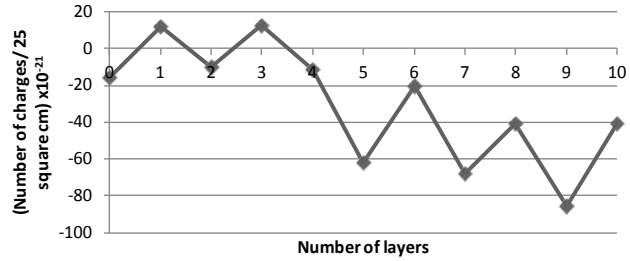
Dyeing tests

Dyeing tests were carried out in order to be able to qualitatively appreciate the influence of the outer coating charge. As previously mentioned in "Methods", tests were conducted to explore the influence of the electrical surface charge of the biomaterial on the electrostatic attraction of the acid and basic dyestuff, as well as of its active centers (CS ammonium and Alg carboxylate groups). The color aesthetics of the biomaterial was disregarded, given the fact that the fabric was only used as a carrier for the release of bulky molecules, having no wear value. The color strength values of dyeing with Basic Red 18 dye, as the biomaterial was coated with an outermost layer of Alg determined the following descending order for Alg42>Alg2.2=Alg3.2>Alg5.2> Witness> Alg 1.2, as a result of the compromise reached between the outer surface charge and the availability of the cationic dyestuff groups in approaching the anionic surface centers. This confirms the hypothesis according to which the fabric acquires a greater negative potential following the treatments to which it was subjected, compared with the potential obtained by depositing the Alg layer. ΔE stands for the colour difference between batch and standard samples [18-21]. The colour differences determined for the samples dyed with Basic Red 18 dyestuff had the following values: $\Delta E_{Alg\ 1.2}$= 1.678 AN; $\Delta E_{Alg\ 2.2}$=5.881 AN; $\Delta E_{Alg\ 3.2}$=5.093 AN; $\Delta E_{Alg\ 4.2}$=8.089 AN; $\Delta E_{Alg\ 5.2}$= 5.334 AN follows the descending order $\Delta E_{Alg4.2}>\Delta E_{Alg2.2}>\Delta E_{Alg5.2}>\Delta E_{Alg3.2}$>witness>$\Delta E_{Alg1.2.}$ Thus, the values determined reveal a certain degree of matching to K/S rating. The difference between the order of K/S and the ΔE color might be due to some steric hindrance. As regards the CS-coated biomaterial, the K/S values of dyeing with Acid Red 26 dyestuff determined the following order: $K/S_{CS1.1}>K/S_{CS2.1}>K/S_{CS5.1}=K/S_{CS3.1}>K/S_{CS4.1}>K/S_{Witness}$.

The colour differences determined for the same samples dyed with Acid Red 26 had the following values: $\Delta E_{CS1.1}$=21.991 AN; $\Delta E_{CS2.1}$=19.191 AN; $\Delta E_{CS5.1}$= 17.828 AN; $\Delta E_{CS\ 31}$=17.488 AN; ΔE_{CS41}=16.247 AN. The rating values obtained ($\Delta E_{CS1.1}>\Delta E_{CS\ 2.1}>\Delta E_{CS5.1}>\Delta E_{CS3.1}>$ $>\Delta E_{CS4.1}$>Witness) are overlapped with the K/S rating. In cases in which other methods are unavailable (Zeta potential, Number of surface charges, etc.) dyeing tests are a qualitative method that can be used to evaluate the behavior of ionic interactions between a dyestuff and a polymer layer having opposite charges. Even in this case, the interactions between layers form a system that is too complex for an accurate characterization.

Biomaterial Ta release

As Ta is insoluble in water but soluble in ethyl alcohol, it was dissolved in ethyl alcohol for spray application between CS and Alg layers. In order to determine the kinetics of Ta release, the drug was deposited in two variants by inserting it between the layers without monitoring the therapeutic dose. Water soluble polymers were chosen in order to activate the drug substance through solubilization (one has in view to mime the perspiration action). The results of this study reveal the load capacity of Ta on CS and Alg layered textile materials. Based on the results obtained, the drug load of a biocompatible system with topical application and transcutaneous release of Ta can be modulated, depending on the required therapeutic dose. Furthermore, the choice of the two polysaccharides (CS and Alg) was justified by their polyelectrolyte character with opposite electric charges, as well as by their biocompatible, biodegradable and non-toxic nature, given that the final material is meant to act by direct skin contact. Another argument was the hydrogel nature of the multilayer deposited onto the fabric allowing the gradual release of the included Ta by diffusion, triggered by the swelling of the material in contact with the perspiration drawn from the skin. The data on Ta release kinetics, for recipe 1 and 2, are illustrated in Figure 5. The drug release was determined for ten-day observation. The efficacy of drug release in case of formulation 1, calculated as the amount of drug released relative to the total amount of Ta introduced in the biomaterial, is (27.95/40)*100, namely 69.8%, while in the case of formulation 2, it is (18.43/20)*100 = 92.15%. It follows that the more dispersed the drug is among multiple layers, the lower its release. In recipe 1, four doses were introduced between the last 5 layers, while in recipe 2, two doses were released, the first on the outer layer and the second between the last and the last but one layers. The kinetics revealed a similar general profile, except for the fact that the release in case of the first formulation started after the first day of



Layer 1 = CS 1.1; Layer 2 = Alg 1.2; Layer 3= CS 2.1; Layer 4 = Alg 2.2; Layer 5 = CS 3.1;
Layer 6= Alg 3.2; Layer 7= CS 4.1; Layer 8 = Alg 4.2; Layer 9 =CS 5.1; Layer 10 = Alg 5.2.

Figure 4: Values of the number of surface electric charges obtained on each layer of biomaterial.

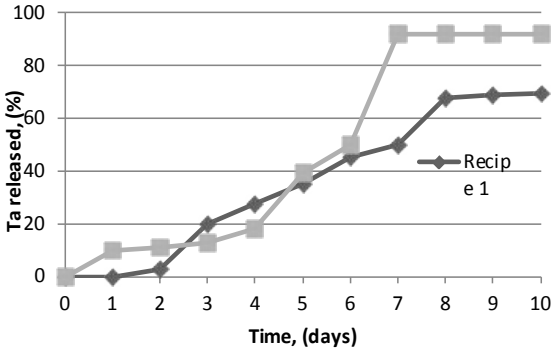


Figure 5: Ta release kinetics from biomaterial.

Table 2: Percentage values of the main elements of the biomaterial

Elements	C	N	O
Layer	Weight (%)	Weight (%)	Weight (%)
Alg/Ta outer	43.45	3.61	35.15
CS/ Ta inner	38.45	4.97	56.58

immersion into the alcoholic solution, while in the case of the second formulation, the release started before the first day. The explanation lies in the fact that a 1/2 of Ta was deposited onto the outer surface of the biomaterial, in second case, being more exposed to the action of the ethyl alcohol solution in which it was released. While not all the details that are necessary to explain the form of release kinetics are known, its diffusion takes place in both directions – to the dermis and to the deeper layers of the biomaterial. The aspect of the release curves is the drug's diffusion response to the variation of the profile for electric interactions at various depths. The Ta release method is due to the erosion of CS and Alg layers by dissolution in an aqueous solution, which release the drug into the dermis. In terms of therapeutic dose, the drug release control depends on the amount of Ta deposited between the layers, as well as on the thickness and number of CS/Alg layers. As the water molecules penetrate the biomaterial, determining the hydration, dissolution and erosion of CS and Alg, the drug is released onto the dermis surface. Even if curing temperature and duration can contribute to the adjustment of layer solubility (higher curing temperatures and duration lead to cross-linking reactions, which affect solubility), and consequently to the control of drug release, the action margin is still limited. Depending on the application method and on the amount of drug deposited between the CS and Alg layers, drug release can be obtained in accordance with medical prescriptions, thus avoiding the "burst effect". In both release kinetics, a drug accumulation proceeding the eighth day, in which a maximum of Ta is released, was present. The drug inclusion process presented in this paper can constitute a more effective method than other standard delivery systems (cyclodextrins, hydrogels). The biomaterial developed in this study has considerable potential for the cutaneous route of administration. Moreover, if the cellulosic material were replaced by a polymer support easily soluble in physiological fluids or water, the biomaterial could potentially be used as an implant.

Elemental analysis (EDAX)

Table 2 illustrates the elemental weight values (%) for carbon, nitrogen and oxygen in both outer and inner layers.

The nitrogen content (4.97%) in the inner layer of the biomaterial is higher than that in the outer layer (3.61%). As illustrated in Table 2, Ta contains a certain amount of nitrogen in its structure, while in CS, an amino group is present. It follows that there is a higher nitrogen level in the inner surface, where both Ta and CS are present. In the outer layer of the biomaterial, however, Ta is the only source of nitrogen, determining a lower nitrogen content. The nitrogen content, therefore, confirms the presence of Ta on the structure of the biomaterial. On the other hand, concerning textile support, either a piece of 100% cotton knitted or woven fabric can be used as substrate. In our case, the latter was preferred in order to fulfill the need to maintain a flat structure, which would have been difficult to obtain had we used knitted fabric due to its tendency to bend or roll. When designing a textile fabric, the number of layers deposited onto the fabric surface can be adjusted depending on the amount of drug used for therapeutic purposes, an issue that was not taken into consideration in this study. The ten layers used in this paper allowed us to obtain a general characterization of a multilayer biomaterial. As noted in Figure 4, the multilayer system forms a complex system of electrostatic interactions. CS and Alg were chosen due to their good solubility properties as well as to their biocompatibility with the skin, being produced from natural materials. While, after depositing the first 4 layers of CS and Alg, the biomaterial obtained still retained the flexibility specific to textiles, after depositing the additional layers, the biomaterial became rigid.

Conclusion

The alternative deposition of polyelectrolyte layers of opposite electric charges can be a viable and attractive option in creating a drug reservoir on a textile substrate. Ta, a water-insoluble drug, can be included in the multilayered material obtained to be gradually released by diffusion under the action of the perspiration. The system proposed in this paper can be an alternative to existing treatments of cutaneous diseases, especially of psoriasis.

Acknowledgements

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Author Affiliations

Top

[1]*Department of Textiles, Leather and Industrial Management, Gheorghe Asachi Technical University of Iasi, Romania*

[2]*Alexandru Ioan Cuza University of Iasi, ARHEOINVEST Interdisciplinary Platform, Iasi Romania*

[3]*Department of Chemical Engineering and Environmental Protection, Gheorghe Asachi Technical University of Iasi, Iasi, Romania*

[4]*Department of Pharmacy, Department of Pharmaceutical Technology, Gr.T.Popa University of Medicine and Iasi, Romania*

[5]*Department of Plant Science, I.Ionescu Brazi University of Agricultural Science and Veterinary medicine, Iasi, Romania*

[6]*Department of Mechanical Engineering, Gheorghe Asachi Technical University of Iasi, Romania*