Chapter

Smart and Biofunctional Textiles: An Alternative for Vehiculation of Active Principles

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Introduction

In November 2017, the title of the International Symposium on Materials from Renewables (ISMR) was "Advanced, Smart, and Sustainable Polymers, Fibers and Textiles". Three specific sessions occurred under the denomination of "Smart Fibers and Textiles". That simple fact gives an idea of the importance of this work. However, what really are smart textiles? In the foreword of the book edited by Tao, X. [1], Lewis states clearly that these type of textiles are not only special finished fabrics. The main defining idea of smart textiles is related to the "active character" of them. Smart textiles "react to environmental stimuli, from mechanical, thermal, chemical, magnetic or others", including biotechnology, information technology, microelectronics, wearable computers, nanotechnology, and micromechanical machines.

Biofunctional textiles are fibrous substrates that have been modified to attain new properties and added value. The main idea is to modify their parameters, especially related to comfort, adapting the tissues' reaction to external or internal stimuli. Such textiles constitute appropriate substrates to be used for the delivery of active principles in cosmetic or pharmaceutical applications. Due to their specific response, biofunctional textiles are especially useful when the textile comes into close contact with the skin. As most of the human body is covered with some sort of textile, the potential of this type of textile is considerable. Textiles with functional properties used for delivery to skin have been studied and patented [2,3].

Three cases will be explored in this work as examples of biofunctional systems obtained using vehicles to transport different active principles to a textile substrate: Microcapsules, cyclodextrins, and liposomes.

Microcapsules

Microcapsules may be obtained by a series of techniques that involve liquids, gases, or solids in natural or synthetic polymeric

membranes [4–7]. This process is known as microencapsulation, and requires a layer of an encapsulating agent, generally a polymeric material, that acts as a protective film insulating the active substance [8–10].

According to Souza and collaborators [11], this creates a physical barrier between the core (active principle) and the encapsulating material (shell). This membrane is removed by a specific stimulus, releasing the active substance in the ideal place or moment. In the Figure (Fig 1), it is possible to see this membrane that protects the nucleus

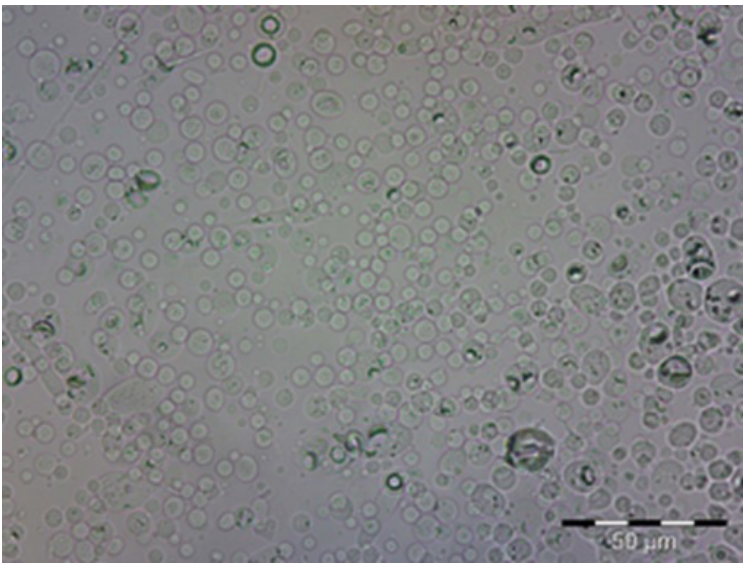


Figure 1: Optical microscopy image of microcapsules formed by complex coacervation.

The encapsulation technique can be used to fulfill diverse objectives, and has the following advantages, as listed by different authors [12–14]. Protection of the encapsulated materials against oxidation or

deactivation due to reaction with the environment (light, oxygen, humidity); masking odors, tastes, and other active principles; insulation of the active principles of undesirable materials; retardation of alterations that might occur in loss of aroma, color, and flavor; separation of reactive or incompatible components; and reduction of the migration rate of the core to the external environment. For this reason, the core and shell should have compatible physical-chemical properties [15].

The materials commonly used as encapsulating agents (shells) are polymers [16,17] and biologic-based materials [18–20]. Bosnea and collaborators [21] highlighted that shell materials based on natural polymers are promising for the formation of microcapsules due to their biodegradability, compatibility with other products, and low toxicity, as well as their wide availability from natural resources. Furthermore, Al Shannaq and collaborators [22] accentuate in their work that the choice of encapsulation material is important to obtain better degradation of the microcapsule. Table 1 shows the main polymers of natural sources used in microencapsulation.

Table 1: Polymers used in microencapsulation [23-27].

Source	Polymer
Natural Polysaccharides	Starch, cellulose, chitosan, gum arabic and alginate
Modified Polysaccharides	Dextrins, carboxymethylcellulose, ethylcellulose, methylcellulose, acetylcellulose and nitrocellulose
Proteins	Gluten, casein, gelatin and albumin
Waxes and lipids	Paraffin, tristearine, stearic acid, monoacyl and diacyl

Besides the inherent parameters of the shell material choice, Santos, Ferreira, and Grosso [28] pointed out that the retention of the active principle is a fundamental factor for the realization of the process. Wang et al. [29] and Yang et al. [30] demonstrated in their works that the efficiency of the encapsulation should be a parameter that is taken into account in the choice of the core. Sharipova et al. [31] showed that the value of the effectiveness of the encapsulation depends on the encapsulating method, the shell material, and the relationship with the core.

Thus, the casing material should relate to the chemical nature (molar mass, polarity, functionality, volatility, and so forth) of the active principle so that a high yield of the process is possible. The thermal analysis technique (DTGA / DSC) can be used to verify the uptake of microencapsulation, as well as its efficiency. The thermogravimetric curves shown in Figure 2 reveal that each component of the system has a different loss of weight when submitted to temperature changes in the oven of the instrument.

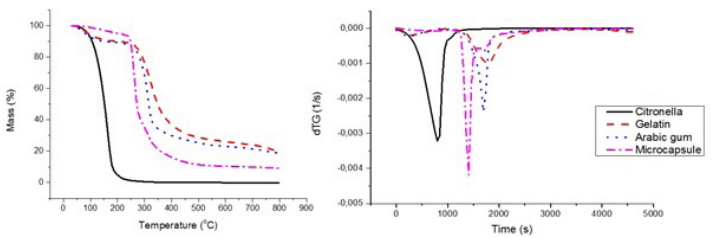


Figure 2: TGA/DTGA thermogram for different components of the system

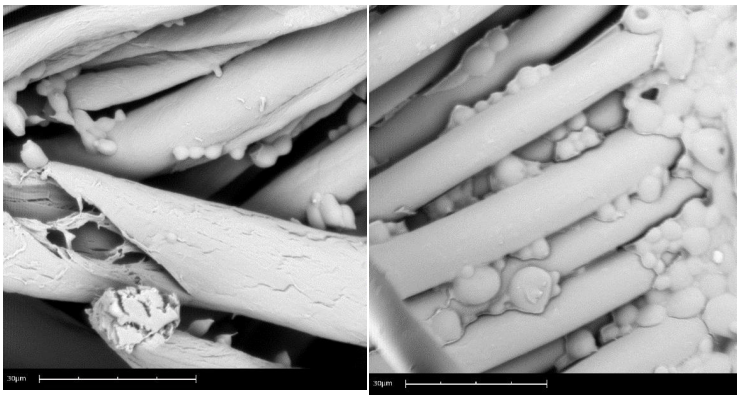
Citronella oil shows a single stage loss of weight, while gelatin and arabic gum show two stages. Formation of the microcapsule gives the new organized system that presents three different stages of thermal rupture. From these thermograms it can be seen that the microcapsule was formed.

There are several techniques for obtaining microcapsules, which can be divided into physical methods (spray drying [32], solvent evaporation [33], pan coating [34]); chemical methods (interfacial polymerization [35], suspension polymerization [36], in situ polymerization [37]); and physical-chemical methods (coacervation [38], ionic gelation [39], sol-gel [40]), among others.

The microencapsulation technique selection depends on the properties of the active principle, the morphology of the desired particle, the nature and capacity of releasing the components, reproducibility, ease of execution of the technique, and the cost/effectiveness ratio [41]. The chosen technique is a determining factor of the characteristics of the formed microcapsule, and will influence the release of the encapsulated agent via one of the following actions: Mechanical, temperature, pH, dissolution, or biodegradation [42].

Microcapsules in the textile field have been applied in various ways, giving very interesting results and showing very promising applications in several fields, including the use of flame retardant agents [43], protection of atmospheric agents [44–46], and functional finishing [47–50], along with the development of functional fabrics that might have a useful effect on the user and solve problems that conventional processes are not able to [51,52].

Nowadays, microcapsules are applied in textiles to transmit different embedded values, such as the liberation of oils with medicinal effects, protection against disease carriers, and antimicrobials, among others [53–65]. Microencapsulation of citronella oil, to be used as insect repellent and obtained by the coacervation method with the gelatin-arabic gum system, will be detailed as an example [38], is shown in the Figure 3.



(a) (b)

Figure 3: Scanning electron of microcapsules: (a) cotton, and (b) polyester.

In these micrographs it is possible to verify the distribution of the dispersed microcapsules and their reduced size.

Another factor that can be pointed out is the small size of the microcapsules, which facilitates the absorption and penetration of the fabric surface due to the occupation of the interstices of the textile article. Li et al. [23] related the advantages of controlled dosing and increased durability of the textile finish to this small size.

It is also evident that the microcapsules ensure effective protection of the encapsulated material, as already shown by the results of TGA. In short, it can be noted that the encapsulated material is not exposed to the elements, which has been the most serious problem of the application of oils in textiles, as pointed out by Chinta and Pooja [51] and Nelson [42].

Cyclodextrines (CD)

Cyclodextrines (CDs) are used in diverse industrial fields, such as food, drugs, cosmetics, domestic products, agrochemicals, the textile industry, the paper industry, chemical technology, and others [66–68]. This wide range of applications can be attributed to the fact that cyclodextrin shave the capacity to form inclusion complexes with a broad range of substances, allowing the alteration of important properties in the complexed substances [69].

According to Matioli and collaborators [70], CDs are regularly produced from starch by the cyclation of linear chains of glucopyranoses using the enzyme cyclomaltodextrin-glucanotransferase (CGTase). The three widest known natural cyclodextrins are alpha CD (α-CD), beta CD (β-CD), and gamma CD (γ-CD), composed of six, seven, and eight units of D-(+)-glucopyranose, respectively, and united by α-1,4 bonds. Table 2 presents the physical and chemical properties of the most common CDs.

Table 2: Physical-chemical properties of natural CDs [66,69].

Property	α-CD	β-CD	γ-CD
Nº of glucose units	6	7	8
Empirical formula	$C_{36}H_{60}O_{30}$	$C_{42}H_{70}O_{35}$	$C_{48}H_{80}O_{40}$
Solubility in water at 25 ºC (g L^{-1})	145	18.5	232
Inner cavity volume (nm^3)	1740	2620	4720
Nº of water molecules in the cavity	6	11	17
Decomposition temperature (ºC)	278	298	267

These compounds have in their structure primary hydroxyl groups and secondary groups oriented to the exterior [66]. Therefore, present a cavity that allows the hydrophilic external part and a hydrophobic internal cavity. Such cavity allows the cyclodextrins to complex molecules that show compatible dimensions and alter its physical-chemical properties such as water solubility, stability, and bioavailability [70]. An example of complexation is the use of citronella oil (lipophilic) as the host agent, as shown in Figure.

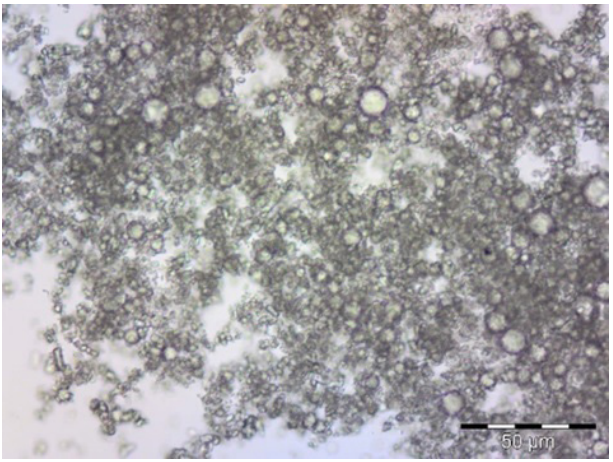


Figure 4: Optical microscopy image of complex. magnification 500*X*

The optical microscopy of the complexes (CD:Oil), shows their shape and distribution (Figure 4). Spherical and small cylinders are seen. The former are free citronella oil and the latter are cyclodextrins like elongated cones. CDs can form inclusion complexes with volatile essential oils, protecting them against oxidation, enhancing their chemical stability, and reducing or eliminating eventual losses by evaporation. These results match those obtained in several other works [59].

Since the first publication regarding cyclodextrins in 1891, and the first patent in 1953, these molecules have been a source of great interest to researchers [71]. Nowadays, the widest use of cyclodextrins is their complexation with many classes of drugs [72–76], flavors [77–79], and aromas [80–82].

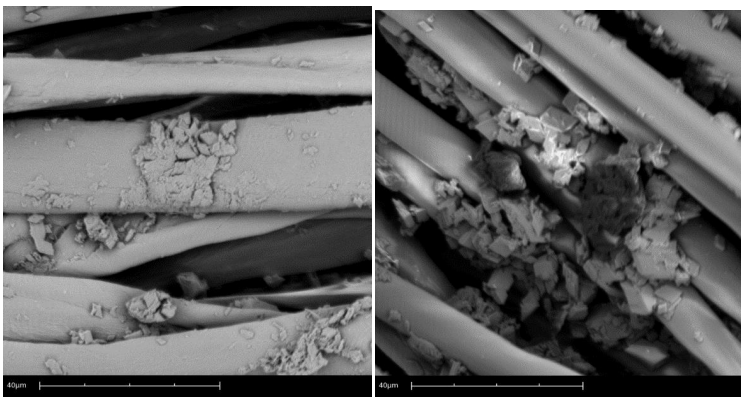
According to Table 2, it is verified that the number of glucose units determines the dimension and the size of the cavity. Hydrogen atoms and glucosidic oxygen bonds delimit the cavity. The non-bind-

ing electron pairs in the glucosidic oxygen bonds are directed to the interior of the cavity, being responsible for the hydrophobic internal effect and producing a high electron density that allows to the interior of the CD cavity a Lewis base character [66,70].

In textiles, the CDs may be applied in different ways and with many end-uses. Bhaskara-Amrit, Pramod, and Warmoeskerken [71], highlight that the CDs have an important role in the processing and textile innovation. Their use fosters immediate opportunities to the development of products that are less harmful to the environment, besides having a great potential in many applications.

The highest employability of the CDs in the textile field is related to the field of finishing, showing an excellent potential to be applied in dyeing and finishing [69,66, 71,81,82]

In the field of textile finishing, the cyclodextrin might have many applications, being able to absorb unpleasant odors, release essential oil, vitamins, caffeine, menthol, and biocides [81]. The great interest in the essential oil application is also observed in the encapsulation of these compounds in cyclic oligosaccharides such as cyclodextrins (CDs). An example of cyclodextrin application in the textile area is shown in Figure 5. The application of the complexes on the cotton (a) and polyester (b) surface can be seen.



(a) **(b)**

Figure 5: Scanning electron of complex: (a) cotton, and (b) polyester.

CDs can form inclusion complexes with volatile essential oils protecting them against oxidation, enhancing the chemical stability and reducing or eliminating eventual losses by evaporation [82].

The CDs in textiles can create interactions according to two different mechanisms: physical bonding without strong chemical interactions or covalent bonding [71,82]. In the first case, the cyclodextrin is physically bonded to the textile substrate via a resin; in the second, CDs are permanently fixed in the substrate via covalent bonds [81].

Liposomes

Liposomes are vesicles prepared with lipids that can encapsulate different ingredients; one of their applications could be onto textiles. Due to the liposome bilayer structure, liposomes have been applied as models for biological membranes in medical research. Another im-

portant use of this type of vesicleis as microcapsules for drug delivery in the cosmetic field [83–86]. The textile industry has used liposomes in the wool dyeing process as an auxiliary [87,88]. Liposomes could have different properties depending on the lipidic base used during their formulation.

In this study, phosphatidylcholine (PC) and internal wool lipids (IWL) were used to form liposomes structures.

Internal wool lipids are a mix of cholesterol, free fatty acids, cholesterol sulphate, and ceramides, similar to those found in membranes of other keratinized tissues such as human hair or stratum corneum (SC) from skin. Wool is a fiber which is mainly keratinic but with a small amount of internal lipids [89,90]. Due to the IWL liposome bilayer structure's similarity to stratum corneum lipids, their application onto human skin has been assessed in previous studies. The results obtained have demonstrated the beneficial effect of this type of liposome when used with ceramides, topically applied onto intact skin in aging populations or in individuals with dry skin [91–93]. Therefore, we could consider IWL liposomes an optimal encapsulation route for cosmetic or dermopharmacy applications [94].

Using a solar filter as a tracer, ethyl hexyl methoxycinnamate (EHMC), PC-based, and IWL-based liposomes were prepared. The influence of the type of lipid in the vesicle on skin penetration has been demonstrated in previous studies. In particular, the crystalline liquid state of PC liposomes seems to play an important role in this characteristic. On the other hand, when using IWL liposomes, penetration into the skin is delayed—a fact that suggests some reinforcement of the barrier function of the skin's stratum corneum [95]. These two types of liposomes, with IWL and PC, were chosen to be applied to cotton and polyamide fabrics to design biofunctional textiles.

To evaluate the effectiveness of the textile in contact with the skin, a series of methodologies in vivo were used and an in vitro process were optimized to determine the penetration of the encapsulated active principle.

For the evaluation of the biofunctional textiles' beneficial capacity on skin, the transepidermal water loss change (TEWL) was used as an indicator of the barrier function state. TEWL measures water-holding capacity as changes in skin capacitance [95]. An in vitro methodology based on percutaneous absorption [96] was used to determine the amount of encapsulated principle that passed into the different skin layers (stratum corneum, epidermis, or dermis) from the textile.

An in vivo stripping was used as a minimally invasive methodology, where a series of strippings allowed quantification of the amount of active principal in the outermost layers of the SC [97].

These methodologies have shown that liposomes, especially IWL liposomes, are suitable for applying active principles onto biofunctional textiles. In this study, Liposomes, alone or as mixed micelles, form a very stable microstructure that allows the vehiculization of active principles for application into different textiles. The chemical and physico-chemical interactions between them and the textile substrate are translated to an adequate substantivity for most of the studied cases.

However, the high desorption of most synthetic acrylic and polyester fibers confirmed the preferential application of cotton and polyamide as cosmetic biofunctional textiles. Moreover, this study showed that polyamide always presented high substantivity for the two phospholipid structures and also for the antioxidant [98].

The in vitro percutaneous absorption tests of different cosmetotextiles (CO and PA with GA vehiculised with Liposomes and mixed micelles) have been performed to demonstrate GA penetration within the layers of the skin [99].

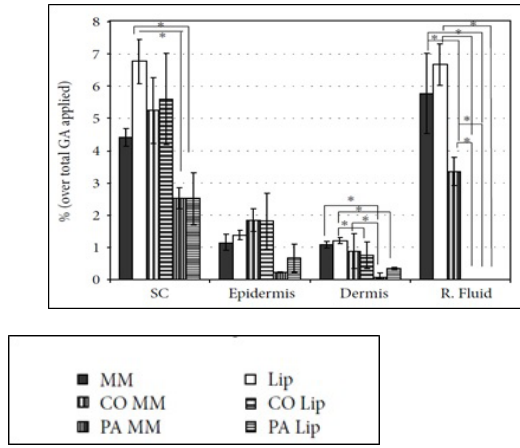


Figure 6: In vitro percutaneous absorption of gallic acid (GA) in liposome and mixed micelle formulations and the polyamide and cotton cosmeto-textiles (SC: stratum corneum, R. Fluid: receptor fluid) (significant level accepted *P<0.01)

When GA was embedded into the cosmeto-textiles, it always promoted a reservoir effect that was much more marked for PA. Similar penetration was observed in the textiles treated with GA in MM or Lip in such compartments of the skin as the stratum corneum, epidermis and even the dermis. GA detected in receptor fluid only when CO was treated with mixed micelles. This methodology may be useful in verifying how encapsulated substances incorporated into textile materials penetrate human skin. Indeed, such materials can be considered strategic delivery systems that release a given active compound into the skin at specific doses.

Similarly, a sun filter was encapsulated in different kind of liposomes and in microcapsules to form biofunctional textiles which can break as the fabric rubs the skin, releasing the active agents [98]. Moreover, Ethyl hexyl methoxycinnamate (EHMC) used also as a tracer, was vehiculized with two different liposomes made up of internal wool lipids (IWL) or phosphatidylcholine (PC) [99]. They were applied onto cotton and polyamide fabrics by exhaustion treatments.

After topical applications of textiles on human volunteers, skin properties were evaluated by non-invasive biophysical techniques. Two methodologies based on percutaneous absorption were used to determine the content of the active principle penetration into the skin.

An adequate absorption of both liposomes over the fabrics between 10 and 15% was found presenting PC liposomes a higher affinity than for IWL liposomes. Furthermore, cotton fabrics yielded a slightly lower percentage of liposomes than synthetic textile polyamide. Skin properties, after 24 h of fabric applications were evaluated by non-invasive biophysical techniques. The TEWL decrease is more marked for IWL liposome treated fabrics and even more marked for liposome treated polyamide. Significant differences were found with non-treated polyamide when compared with PC treated polyamide, which can promote drug permeation [99].

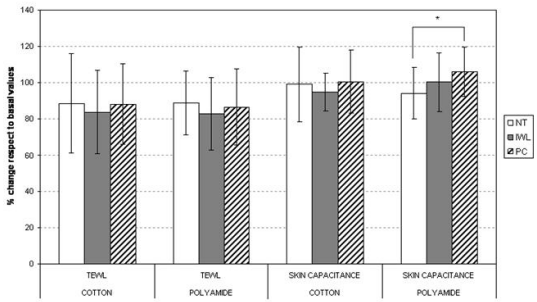


Figure 7: Variation of TEWL and skin capacitance (hydration) between initial and 24h of skin application of cotton and polyamide fabrics. NT: non-treated fabric. IWL: fabric treated with IWL liposomes. PC: fabric treated with PC liposomes (*$p<0.05$ corresponds to significant difference between the marked columns).

EHMC penetration in vivo into the outermost layers of the skin indicated a higher percentage of EHMC when polyamide fabrics were

applied. This is consistent with the higher effect found in the decrease in TEWL for IWL liposomes and in the increase of hydration for PC liposomes when absorbed into polyamide fabrics.

Therefore, polyamide was the fibre which presented the highest absorption and the greatest release to the skin when these two PC and IWL liposomes were applied with encapsulated EHMC. This was corroborated by the greater effect of skin barrier reinforcement due to IWL treated polyamide and the greater hydration increase due to PC treated polyamide. This resulted in a marked in vivo and in vitro EHMC release enhancement. The methodologies presented in this paper could serve to confirm penetration in human skin of encapsulated substances that can exert a marked influence on specific doses of active agents released to the skin [99].

Summarizing, antioxidants vehiculized through liposomes can be better applied to cotton and moreover polyamide due to their lower desorption in front of the other fibres assayed such as acrylic or polyester. The two in vitro and in vivo methodologies used to determine the content of active principle penetration into the skin when in contact with the smart textiles indicates the great influence of the physicochemical properties of the drugs. When GA is vehiculized in liposomes into the textile, there is a clear reservoir effect much marked with PA [98].

However when a clear lipophilic compound such as EHMC is also vehiculized in liposomes in the textile, a significant higher release of the active to the skin was found, being the polyamide the fibres with higher desorption [100]. This was corroborate by the in vivo results of percutaneous penetration and the greater skin barrier reinforcement and hydration of polyamide smart textiles [101].

Therefore, it can be concluded the different release behavior of hydrophilic drugs which may be much retained in the hydrophilic core of the liposome in front of lipophilic drugs which are embedded in the surface lipidic bilayer of the liposomes favouring their release [102].

Vehiculation of Active Principles

A variety of textile fibers was already studied as support for biopolymers in the absorption of active molecules in the field of controlled releases such as cotton [37, 103-106] polyester [37, 107-109] wool [110-112] and nylon [107,113,114]. These many possibilities of fabric modification allow the textile combination with the controlled release system, enabling the capacity of absorbing therapeutic or cosmetic compounds and releasing them to the skin [48,103, 115-117].

The combination of these effects results in the development of biofunctional textiles [48,107,113]. The use of textile articles as supports for the controlled release presents as properties to emphasize the high contact area with the skin, drug-carrier capacity, ease of application, low cost, release via stimulus, biocompatibility, non-allergenicity, non-toxicity, among others [105,106,114]. The Figure 8 shows the controlled release profile of two microencapsulated substances applied in different textile matrix.

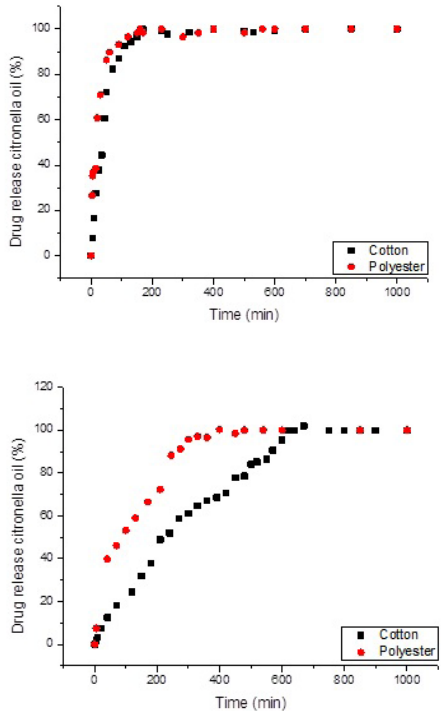


Figure 8: In vitro controlled release profiles in water at 37 °C for: (a) microencapsulated and (b) complexed (cyclodextrin) applied on textiles.

The incorporation of these systems allows the implementation of specific properties in the textile fibers, being possible to perform the application of microcapsules [37,48,107], cyclodextrins [109,117], lipossomus [98-102],formed by softeners.

The controlled release allows the delivery of the active principle under the desired conditions. The transference textile-dermis occurs without the necessity of conscious interference of the user. The diffusion of the drug might happen by the temperature, pH, friction with

the skin, among others. These conditions enhance the effectiveness of the compound when compared to traditional release methods [118]. Costa & Lobo [119] point out that the discharge of these encapsulated substances follows, generally, three mechanisms: diffusion, liberation via activation, polymeric disaggregation/ erosion. The predominance of a release mechanism depends invariably on the properties of the polymer employed in the system, the matrix geometry, and the active principle [105].

The active principle dispersed in the polymeric matrix, or involved in a porous or non-porous membrane is present in the liberation by diffusion. Figure 9 shows this type of release.

Figure 9: Schematic representation of the diffusion of an active and system with the polymeric membrane, adapted from BEZERRA, et al. [120]

In the diffusion process, the matter is transported to the core of the system resulting in molecular random movements that occur in small distances. Adolf Fick, in 1855 [121[, quantified the diffusion process adopting the mathematic equation proposed by Fourier (Heat Exchange Transfer Phenomenon)[122]. The proposed equation (1) is the following:

$$\frac{dQ}{dt} = -D\frac{dC}{dx}$$

Where:

$\frac{dQ}{dt}$ = diffusion speed of the asset transported in a given time;

D= diffusion coefficient;

$\frac{dC}{dx}$ = concentration of the substance diffusing in the spatial coordinate.

In the erosion mechanism, the polymer that protects the active principle will disintegrate and liberate it. According to Lopes, Lobo, and Costa [123] there are two important processes that involve this system: time dependent, first it occurs the diffusion from the middle to the interior of the polymer, making the dry core hydrated (dilation), and the second, when the exterior layer becomes jellified and suffers erosion.

Controlled Release Models

The analysis of the controlled in vitro release of active substances entrapped in polymers may offer important information, Manadas, Pina, and Veiga [122] point out that there is a necessity of a quantitative analysis of the obtained values in the tests of dissolution. Then, for this reason, generic equations are used, and these equations may be deduced by a theoretical analysis, as, for example, the zero order kinetics [119], or by empiric equations. Table 3 presents a summary of some models that were developed aiming to describe the discharge of an active principle, although the most commonly used are from Higuchi [124] and Korsmeyer et al. [125] since they describe the release by diffusion.

Table 3: Mathematical models used to describe dissolution profiles.

MODEL	EQUATION	APPLIED	REFERENCE
Order zero	$\frac{M_t}{M_\infty} = K_0$	Erradible systems, controlled diffusion with constant concentration gradient along the constant surface membrane.	[122]
first order	$\frac{M_t}{M_\infty} = 100(1-e^{-kt})$	The amount of active principle released depends on diffusion and / or dissolution.	[119]
Weibull	$\frac{M_t}{M_\infty} = 100\left(1-e^{-\frac{(t-t_0)}{\beta}^{\alpha}}\right)$	Describes exponential curves of dissolution / release and sigmoidal forms	[126]
Higuchi	$\frac{M_t}{M_\infty} = Kt^{0,5}$	Release from homogeneous spherical matrix systems, flat granular matrix systems and spherical granular matrix systems.	[124]
Hixson-Crowell	$1-\left(\frac{M_t}{M_\infty}\right)^{1/3} = Kt$	Kinetic dissolution model, is used to describe the release from erodible isometric matrices.	[127]
Korsmeyer-Peppas	$\left(\frac{M_t}{M_\infty}\right) = Kt^n$	Releasing a system with relaxation, where K is a constant that incorporates structural and geometric features, n is the release exponent, indicative of the release mechanism.	[125]
Baker-Londsdale	$\frac{3}{2}\left[1-\left(1-\frac{M_t}{M\infty}\right)^{2/3}\right] - \frac{M_t}{M\infty} = Kt$	Describes controlled release from spherical matrix.	[128]
Hopfenberg	$\frac{M_t}{M_\infty} = 1-\left[1-Kt(t-l)\right]^n$	elease from erosion systems with various geometries from infinite plates, spheres and cylinders, which undergo heterogeneous erosion.	[129]
Higuchi-ordem zero	$\frac{M_t}{M_\infty} = Kt + K_H t^{0,5}$	Indicative of release controlled by diffusion of membrane and that acts as a barrier for itself.	[119]

Higuchi

The first example of a mathematic model that had as objective to describe the release of a drug from a matrix system was proposed by Higuchi in 1961. Initially conceived for plane systems, it was extended to different geometries and porous systems.

According to Dash and collaborators [130] this model is based upon the hypothesis that: (i) the initial concentration of the active

principle in the matrix is much higher than its solubility; (ii) the diffusion of the active principle happens in only one dimension (border effect should be insignificant); (iii) the particles of the active principle are much smaller than the thickness of the system; (iv) the swelling and dissolution of the matrix are negligible; (v) the diffusivity of the active principle is constant; and (vi) the immersion conditions are always reached in the middle. Generally, it is possible to summarize the Higuchi model as the expression:

$$f = \frac{M_t}{M_\infty} = K_{H^t\!/_2}$$

Where $\frac{M_t}{M_\infty}$ the relation between the amount of active principle released at time t, K_H the dissolution constant of Higuchi.

Therefore, every active principle release system said as Higuchi system is based upon Fick's law, being, for this reason, named as fickian mechanism dependent on the square root of time [119].

Korsmeyer-Peppas Model

Korsmeyer and collaborators [125] created a simple semi-empiric model, that relates exponentially to the liberation of the active principle and the elapsed time. This equation might be written as it follows:

$$f = \frac{M_t}{M_\infty} = K_{Kp^{t^n}}$$

Being $\frac{M_t}{M_\infty}$ the ratio between the amount of active principle released with the time t and the release in the equilibrium, K_{KP} is the Korsemeyer-Peppas kinetic constant that incorporates structural and geometric characteristics, *n* is the exponent of release, indicative of the mechanism, that, according to Table 4 is related to the release geometry [122]

Surathi and Karbhari [131] show what are the relations between the diffusion mechanism, Table 4, and the polymeric matrix:

- Fickian mechanism: the diffusion velocity of the active principle is inferior to the mobility of the polymeric chain segment;
- Anomalous mechanism: the diffusion velocity and the mobility of the polymeric chain segment are comparable and it is dependent on the kinetics of swelling of the matrix.
- Non-fickian mechanism: the diffusion velocity is superior to the mobility of the polymeric chain segment, fostering the erosion process.

Table 4: Release system related to Korsmeyer-Peppas exponent n based on vessel geometry [107,122,130].

PLANE SURFACE	CYLINDER	SPHERE	DIFFUSION MECHANISM
0,5	0,45	0,43	Fickiana
$0,5<n<1,0$	$0,45<n<0,89$	$0,43<n<0,85$	Anômala
1,0	0,89	0,85	Não-Fickiana

Thus, the model proposed by Korsmeyer-Peppas is generally applied to analyze the discharge of polymeric forms of dosage, when the release mechanism is unknown, or, still, when it involves more than one type of release.

Carreras et al. [107] used the model proposed by Korsmeyer to evaluate ibuprofen in PCL-microspheres applied in fabrics of cotton, nylon, polyacrylic, polyester, obtaining fickian diffusion for the articles PA and COT ($n \leq 0,5$) and anomalous ($0,5<n<1$) to PET e PAC. Bezerra et al. [37], have microencapsulated citronella oil, applied in cotton and polyester fabrics, and evaluated the controlled release mechanism. In the first fabric, an anomalous diffusion was observed, whereas in the article of polyester the diffusion was fickian.

Sun et al. [106] have evaluated a thermosensitive microgel-loaded cotton fabric for controlled drug release and obtained a value of $n \leq 0,5$, thus, a fickian mechanism. When the microgel-loaded was evaluated, without the application in the fabric, it was obtained $0,5<n<1$, or an anomalous diffusion mechanism.

Radu et al., [118] performed grafting in cotton with complexes of CD and HCr and studied the liberation *in vitro*, obtaining n=0.79, anomalous. Schaccheti et al [132] functionalized cotton fabrics with complexes formed with β-cyclodextrin and thyme oil and evaluated the release mechanism, obtaining anomalous mechanism of oil diffusion $0,5<n<1,0$.

Considering this, the executed analysis has shown that the release is influenced by the textile matrix and the type of polymer that constitutes it. It is possible to modify the diffusion of the active agent; furthermore, to indicate that textile supports show high potential to the use in systems of release [105,114]. Therefore, the use of biofunctional textiles allows treating many skin diseases by the contact skin-textile, displaying advantages in relation to the administration of the active principle when compared to via-oral. This principle does not pass through the digestive system when it occurs a loss of part of the drug via digestion or excretion [133].

Conclusion

As can be seen from the experimental results obtained, there exist many possibilities to make "active" textiles substrates "against different environments", just using well designed vehiculizing systems to incorporate to the fabrics. These complex structures can be, among others, microcapsules, cyclodextrins or liposomes.

The response of the smart fabric "created" depends, strongly, on the existing interactions between the active principle, the molecular covered structure and on the interactions between these components with the textile substrate. The combination of these effects results in

the development of biofunctional textiles capable of combining specific characteristics of bioactive molecules that cannot be inserted directly into the fabric, as is the case of the essential oils that lose their effect due to their volatility.

Therefore, the use of biofunctional textiles allows treating many skin diseases by the contact skin-textile, displaying advantages in relation to the administration of the active principle.

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