Mini Review

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# Functional textiles for skin care by active substance encapsulation

**Abstract**

Cosmetotextiles are novel textiles which contain carriers with active and cosmetic substances, these carriers, generally by polymeric nature, release their active compounds when in contact with the human body. The aim of this mini review work is to report the new developments in cosmetic textiles, focusing in the obtaining of microcapsules containing skin care substances, physically or chemically bound to the fiber surface. The selection of the encapsulation technique and shell material depends on the final application of the product, considering physical and chemical stability, concentration, required particle size, release mechanism and manufacturing costs. This review discusses the most commonly used microencapsulation processes as: interfacial polymerization, In Situ polymerization, coacervation and phase separation, spray drying and electro spraying. Microcapsules can be applied to the textiles by different methods: padding, coating, spraying or immersion methods. All these methods are also briefly explained here. To the end of this article, some commercial products are listed.

**Keywords:** textiles, microcapsules, impregnation, skin care, cosmetotextile, functional fibers

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Vanesa Muñoz, Jimena S Gonzalez, María Alejandra Martinez, Vera A Alvarez
Institute of Research in Materials Science and Technology (INTEMA), National University of Mar del Plata (UNMdP), Argentina

**Correspondence:** Dr. Vera A Alvarez, Thermoplastic Composite Materials, Institute of Research in Materials Science and Technology (INTEMA), CONICET-National University of Mar del Plata (UNMdP), Av. Colón 10890, Mar del Plata, 7600, Argentina, Tel 5422 3626 0600, Email alvarezvera@fi.mdp.edu.ar

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## Introduction

Creation of smart textiles which can respond to external stimulus or the improvement of particular properties is the most important reasons for the functionalization of textiles. To prepare functional textiles stimuli-respond polymers can be used. The applications of stimuli-active polymers in textiles can be broadly classified into finishing (coating and laminating) and built-in (blending and spinning) methods.[1] Moreover, polymer nano-composites offer the possibility of developing a new class of finishing materials for these classes of textiles.[2]

Textiles can possess skincare properties; they are called cosmetotextiles.[3] Cosmetotextiles are textiles which contain carriers with active substances, these carriers, generally by polymeric nature, release their active compounds when in contact with the human body.[4] The European Union Cosmetics Directive defines a cosmetic as "any substance or preparation intended to be placed in contact with the various external parts of the human body (epidermis, hair system, nails, lips and external genital organs) or with the teeth and the mucous membranes of the oral cavity with a view exclusively or mainly to cleaning them, perfuming them, changing their appearance and/or correcting body odors and/or protecting them or keeping them in good condition.

In order to obtain cosmetotextiles one strategy is to employ the microencapsulation technique. Microencapsulation can be used in the application of fragrances, skin softeners substances, phase-change materials (that help the thermoregulation of the body), antimicrobial agents and drug delivery systems among others as it shows in Figure 1.[5]

Recent researches have reported the preparation of microencapsulated systems having functional groups on their outer surface, so that functional groups would help increasing physical interactions between microcapsules and fiber surface.[6] Moreover, researchers have created textiles with antioxidant and antimicrobial properties using the extracts of brown algae. Antimicrobial property has been imparted to the cotton fabric using microcapsules of brown seaweed extracts using the pad-dry-cure method.[7]

The aim of this mini review work is to report the new developments in cosmetic textiles, focusing in the obtaining of microcapsules containing skin care substances, physically or chemically bound to the fiber surface. Microcapsules can be applied to the textiles by different methods: padding, coating, spraying or immersion methods. All these methods are also briefly explained here.

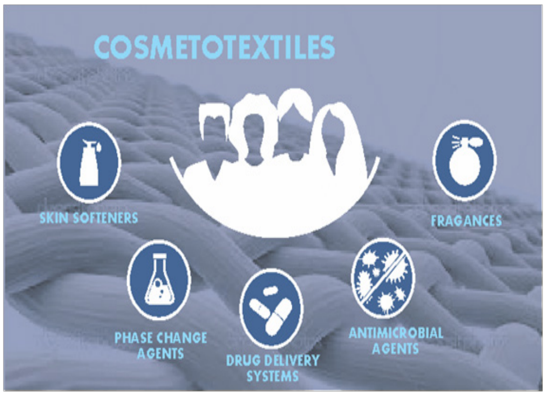


**Figure 1** Types of cosmetotexiles cointaing differente active principles.

## Discussion

### Encapsulation

Microencapsulation is an efficient technique by which it is possible to confine active compounds within a matrix or polymeric membrane at a micro or nanometric scale, in order to isolate and protect them from an external environment, preserving their reactivity and allowing their subsequent release under the conditions desired.[8,9]

A micro or nanocapsule is defined as a small portion of an active substance that is surrounded by an encapsulating agent with dimensions in the micro or nanometer, thus isolating this substance from the external medium (Figure 2).

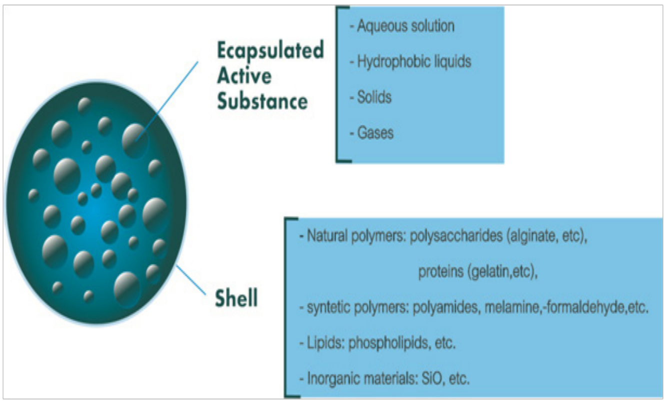


**Figure 2** Structure of a micro or nano capsule.

The active substance may be in a liquid or solid form. It also refers to the core contents, internal phases, encapsulations or fillers. The shell may be a polymer coating that surrounds the active ingredients which may also be called the wall, shell, external phase, membrane or matrix. It may be natural, semi-synthetic or synthetic polymer.[10]

Figure 3 shows the scanning electron microscope (SEM) image of microcapsules in textile fibers. The core content may be released by friction, pressure, change of temperature or PH, diffusion through the polymer wall, dissolution of the polymer wall coating and biodegradation.[10] Currently there are many encapsulation technologies depending on the active compound and the final application of the microcapsules.[11]

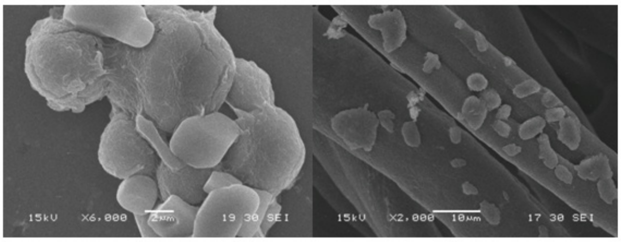

**Figure 3** SEM images of microcapsules in textile fibers.

In the textile industry microencapsulation technology is a technique used to control the release properties of active ingredients which prolong this functionality. In contact with the body and skin, cosmetic textiles are designed to transfer substance for protective purposes such as the transfer of vitamins. To achieve these functional effects, the microencapsulation technology is an alternative way of providing satisfactory performance

There are three types of technologies capable of encapsulating active substances in micro- and nano-sized capsules which are summarized in the Figure 4. There are numerous research works in which it describes in details these techniques as well as the field of application of the microcapsules, for example in the medicinal industry, food, agriculture or cosmetics.[12,13]

The selection of the encapsulation technique and shell material depends on the final application of the product, considering physical and chemical stability, concentration, required particle size, release mechanism and manufacturing costs.[14] This review discusses the most commonly used microencapsulation processes used in our laboratory.

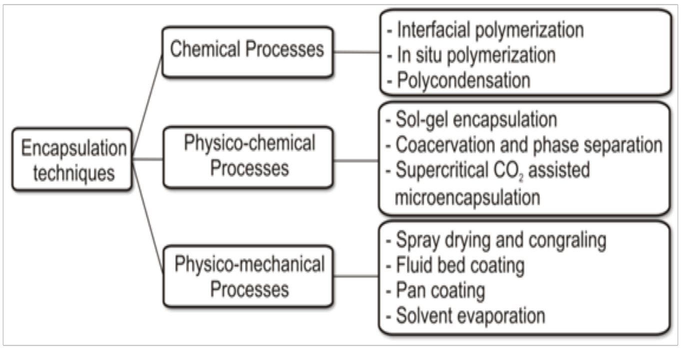


**Figure 4** Classification of the most important encapsulation techniques.

## Chemical processes

**Interfacial polymerization:** The technique of interfacial polymerization the capsule shell is formed by polymerization reaction of two monomers at the interface of two immiscible liquids in an oil-water emulsion. The organic phase contains one of the monomers and to initiate the polymerization a second monomer, usually an amine, is incorporated into the continuous aqueous phase (Figure 5). A rapid polymerization reaction is then produced at the interface which finally generates the capsule shell. Both the liquid and solid can be encapsulated by interfacial polymerization reactions.

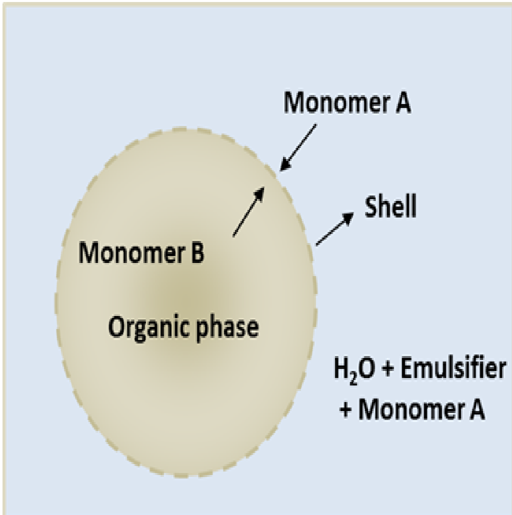


**Figure 5** Interfacial Polymerization scheme.

**In situ polymerization:** For in-situ polymerization, capsule shell formation occurs because of the polymerization of monomers that is added into the continuous aqueous phase (Figure 6). Polymerization occurs exclusively in the continuous phase and on the continuous phase side of the interface formed by the dispersed core material and continuous phases. Polymerization of reagents produces a relatively low molecular weight prepolymer. As this prepolymer grows in size, it deposits onto the surface of the dispersed core material being encapsulated, where polymerization with cross linking continues to occur, thereby generating a solid capsule Shell.[10]

**Physico-chemical process: coacervation and phase separation:** Coacervation is the separation phase of a liquid into a polymer-rich phase called complex coacervation. The coacervation process is commonly used in the food and pharmaceutical industries to encapsulate bioactive ingredients.

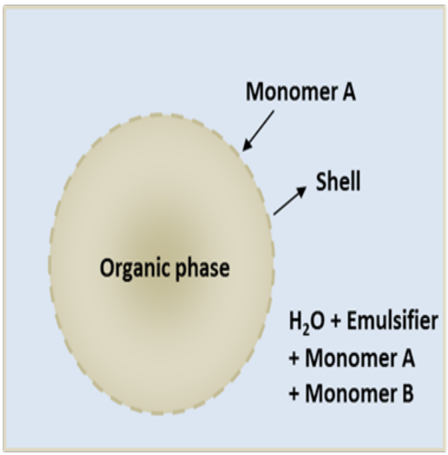


**Figure 6** *In-situ* Polymerization scheme.

The complex coacervate is cause by the interaction of two oppositely charged colloids coacervation.[15] When the complex coacervate forms, it will be in equilibrium with a dilute solution called the supernatant that acts as the continuous phase, and the complex coacervate acts as the dispersed phase.

As the water-insoluble core materials are dispersed in the system, each droplet or particle of dispersed core material is spontaneously coated with a thin film of coacervate. The liquid film is then solidified to make the capsules harvestable. This method has been applied to encapsulate many water-immiscible liquids and is used in a variety of products (Figure 7).

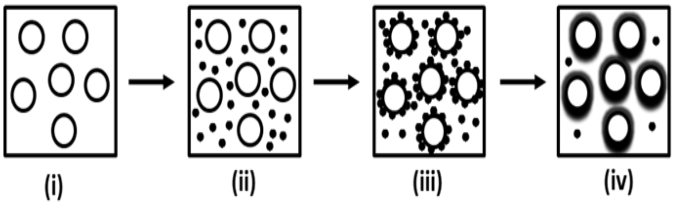


**Figure 7** Schematic presentation of the formation of microcapsules of oil droplets in water by complex coacervation. (i) Core material dispersion in solution of shell polymer. (ii) Separation of coacervate from solution. (iii) Coating of core material by micro droplets of coacervate. (iv) Coalescence of coacervate to form continues shell around core particles.

## Physico-mechanical process

**Spray drying:** Spray drying serves as a microencapsulation technique when an active material is dissolved or suspended in a polymer solution and becomes trapped in the dried particle.

In the widely used spray drying process, the dried solid is formed by spraying an aqueous solution of the core material and the film-forming wall materials as fine droplets into hot air (Figure 8).

The water then evaporates and the dried solid is usually separated by air-separation. This method has been used to encapsulate labile materials because of the brief contact time in the drier. However, one disadvantage of using the spray drying method is that some low-boiling point substances can be lost during the drying process. Figure 9 illustrates a laboratory scale spray dryer.

**Electro spraying:** Electro spraying is a method of liquid atomization that utilizes electrical forces to overcome the surface tension force (Figure 10).[16]

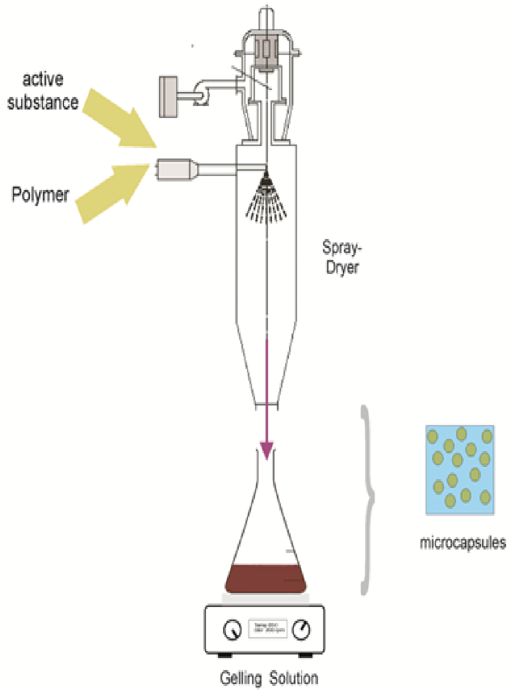


**Figure 8** Spray drying scheme.

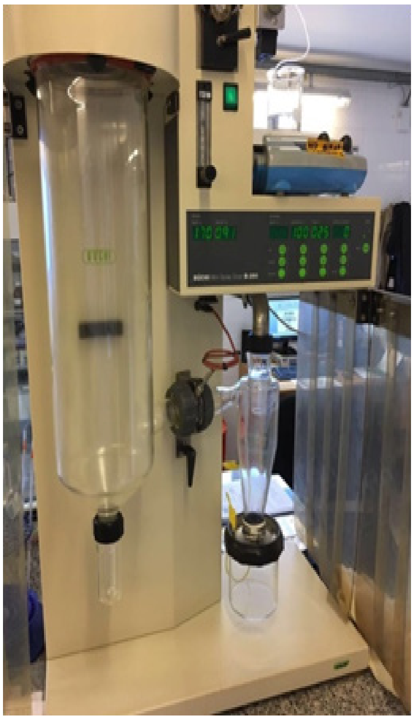

**Figure 9** Picture of a laboratory scale spray dryer.

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The droplets may be extremely small, of the order of nanometers, and the charge and size of the droplets can be controlled by adjusting the flow rate and the voltage applied to the nozzle.[17] This method is applied in many industrial processes as a tool for the production of micro- and nano emulsions and micro- and nano capsules. Due to its properties, is considered as an effective route to nanotechnology. Research in this field was aimed at developing new drug delivery systems or medicine production and application of this technique in cosmetic and food industries.

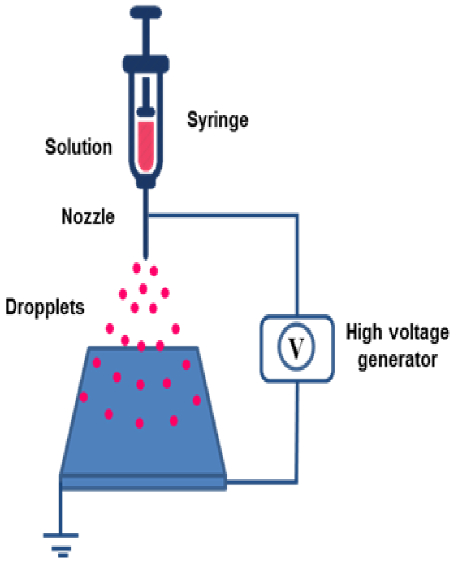


**Figure 10** Electro spraying scheme.

## Impregnation

There are several techniques to impregnate textiles. Two of the most important ones are exhaustion impregnation and the use of a Foulard. The impregnation system represents a very important part of the textile ennoblement processes. They are based on first depositing a dye, sizing product or functional agents on a textile article, to proceed subsequently to its fixation.

**Foulard's process:** The Foulard's process is the operation of impregnating a textile in a chemical solution containing a certain bath (dye, sizing or functional agent), and then drained by pressure cylinders. If it is a dye solution, the dye is trapped between the substrate, giving color to the fabric and if it is a product to give a specific finish, is impregnated, leaking excess liquid on the bucket.

If the padding solution contains a functional agent, it will be deposited on the textile, and depending on the type of functional agent (product) and fiber to bathe may require a fixing process, so that, it is necessary to perform a series of post-paddling operations. The fixing systems are varied depending on the type of product and fiber to be impregnated.[18] The amount of functional agent deposited in the textile depends on the absorption of material; the amount of deposited functional agent bath (impregnated / drained) and the amount of functional agent (product) in the impregnation bath.

The Foulard machine has a series of cylinders or rollers that force a substrate to pass through a bucket that is filled with some solution. The essential elements of the foulard are four:

a. The winding and collection cylinders of the textile
b. The driving guides to the bath
c. The bucket or "canoa pastera": device where the impregnation takes place and
d. The squeezing cylinders of the substrate once impregnated into the bucket or canoe.

The buckets must have adequate dimensions to accommodate the indispensable minimum of solution and that it is constantly renewed, automatically, always maintaining its concentration and all other constants of pressure, temperature, etc., always invariable. The good impregnation depends, first of all, on the affinity between the solution and the substrate; but also of the solution itself, since it transports the functional agent to the fiber or tissue. The tensactive forces between the solution and the substrate condition the speed and effectiveness of the impregnation; so it is common for humidifying products to be added to the dye solution.

There are two types of impregnation machines:

i. Of continuous process and
ii. Of discontinuous process.

This type of dyeing by impregnation is carried out in two stages: The first ones is to place the dye on the textile fiber or on the fabric, conveniently distributed and evenly whereas the second one consists on fixing the dye on the genus to be tinted and subsequent treatments, which may or may not be given, dedicated to obtaining greater strength or eliminating impurities.

Once the substrate has been impregnated, the functional agent is fixed thereon. If the diffusion coefficient of the functional agent is high and the affinity between the functional agent and the substrate also, this allows this binding process to be done at a temperature below 100°C. If not, it is necessary to look for other alternatives and for that there are several fixing systems in the industry. According to the medium and the heating method, the following types of paddles, differentiated by dry or cold heating, could be found:

**Continues foulard (paddling to dry):** Padded with diffusion and fixed in dry. There may or may not be an intermediate drying, between 100 and 150 depending on the substrate; in that case the subsequent setting will be in temperatures ranging from 150°C to 160°C. The fabric continuously passes through a bath where it is impregnated with the bath, develops the same, is dried and finally collected in rolls the finished fabric. It is not advisable to use for those products that with the action of high temperatures degrade the active substances.

**Semi-continuous foulard (pad batch):** A quantity of cloth passes through a foulard and receives a impregnation with the bath of the functional agent. In other words it is a diffuser with diffusion and fixed in cold. Used when functional agents with high affinity for the substrate are used, with a high diffusion coefficient and with low tolerance to the high temperatures that degrades the active substances. It then continues the process continuously, is dried and collected in rolls. However; the dyeing process is usually long taking several hours. A typical scheme of this process is shown in Figure 11.

**Pad-steam:** It is a continuous process of rollers in which a cloth open wide, is impregnated of solution and later is fixed by means of steam. It is ideal for 100% cotton fabrics and/or blends. In some cases it is customary to do this process followed by a pad steam.

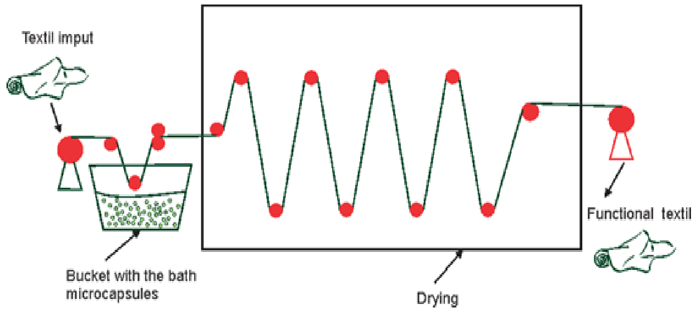


**Figure 11** Scheme of Foulard (Pad Batch).

**Exhaustive impregnation process:** In this process[18] whether of colorants, sizing or of functional agents, are dissolved in a solution (bath), and fixed in the textile material as a consequence of a transfer of the dye or the functional agent of the bath to the fiber, which is produced by the intervention of the affinity forces between dye or functional agent and textile to be treated. These dyeing systems and machines are characterized in that they cause a decrease in the amount of dye bath dye (depletion) and an increase in the concentration of dye in the material to be treated. In exhaustion dyeing machines, the bath ratios range from 1/3 to 1/60. Within the exhaustion procedures, they can be classified the machines as follows:

A. Autoclaves for cross coil or fabric. In this case, the textile remains static, which is called "packaging", the bath being circulated through it. They work in closed system, under pressure. They are mainly used in polyester dyes, which require temperatures in the range of 130˚C.

B. Jigger and tourniquet, are machines that operate with moving textile and static bath. The process is carried out by giving different "passages of the fabric", by the bath contained in the bucket, under certain process conditions, previously defined.

C. Overflow and jet, are machines that operate with textile and bathroom in motion (Figure 12).

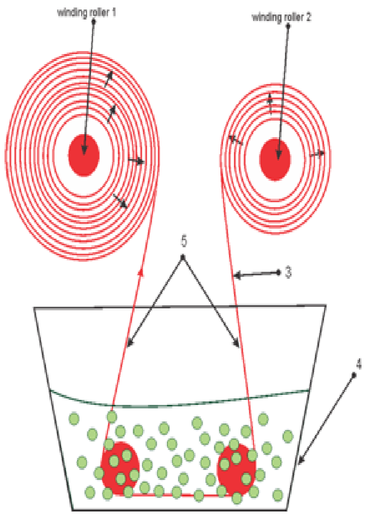


**Figure 12** Jigger scheme: suction means (5) between the winding roller (1) and the dye bath (4), said suction means (5) extending over the entire width of the strip of (3), characterized by the fact (5) between the winding rollers (2) and the dye bath (4), and having drive means such that the speed of the web of fabric increases during said passage.

**Finishing by spray:** Regarding this technique there are two main options:

a. Compressed air spraying,[18] technology based on applying chemical substrates or liquid dyes to spray media or spray guns using compressed air as a means of transporting them. Such technology presents the disadvantage an irregular distribution of the finishing agents in the treated fabrics.

b. By hydraulic spraying[18] known as airless spraying, where the liquid is atomized under very high airless pressure as a carrier medium and only the minimum amount of the required liquid is atomized to apply dyes or chemicals uniformly onto the substrate textile (Figure 13).

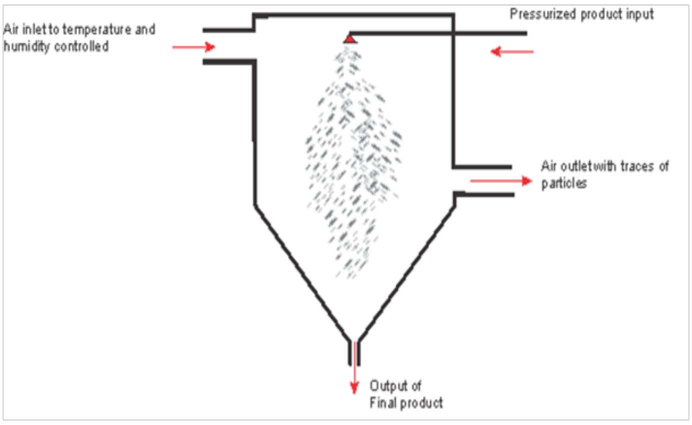


**Figure 13** Scheme of spray process.

This technique can be employed in all semi-continuous or fully continuous processes, regardless of the nature of the materials which, for example, may consist of spun yarns, flocks, nonwoven fabrics, warp yarns, fabrics or fabrics, as well as fleeces. In addition, this technology presents several advantages: reduces water consumption, far below those used in the art by impregnation; significantly reduces energy costs since less moisture should evaporate in the drying zone; decrease the consumption of chemicals and requires shorter times than those used in other techniques. A special advantage of the process lies in the fact that, unlike the padding method, there is no need for squeeze rollers and, thus, processing with high liquor concentrations is possible without the risk of liquor breakdown, such as occurs in the processes heretofore employed.

## Cosmetotexiles products

In terms of their influence on the human body, cosmetotextiles can be classified in the following groups (Figure 14). Characterization of Cosmetotextiles. European Standardization concerning the testing of multifunctional textiles propones evaluations to test several effects. The most important are summarized in the next figure (Figure 15).

The field of cosmetotextiles is full of potential for those that always work with a positive and optimistic mind-frame. This field feels a strong requirement for the clubbing together of different types of industries like the textile, cosmetic, herbal pharmaceutical, among other. Several manufactures have been produced cosmetotextiles based of different cosmetic ingredients. Some relevant examples are summarized on Table 1.

**Table 1** Examples of commercial Como textiles

| Manufacturer | Cosmetic ingredients (basic) | Characteristic of the products | References |
|---|---|---|---|
| Ajimoto-Mizuno Corp. USA (Amnino veil) | Arginine amino acid | Tennis and golf clothes. The amino acid dissolves into the wearer´s perspiration, enhancing the material´s ability to absorb moisture, keeping the skin pH level balanced and regenerating the skin. | 19 |
| Cognis Oleochemicals Corp. (Skintex) | Oils of plants, leaves and fruits | Provide care to tired feet and legs with invigorating aromas during several launderings. | 20 |
| Dogi International Fabrics | Aloe Vera | Smart fabrics with nanoparticles of aloe vera providing calming, moisturizing, antioxidant and anti-ageing. | 21 |
| Fuji Spinning, Japan (V-up) | Pro-vitamin C soluble in sebum | Cosmeto-clothing: Pro-vitamin C converts into vitamin C in the presence of sebum and is applied on blouses and shirts for men and women. | 22 |
| Hefel textile GmbH (Lyosilk) | Silk fibre | The active and breathable fibres became smoother, shinier and refined. | 23 |
| Hefel textile GmbH (Seacell active) | Lyocell fibre sea algae and silver ions | Fibre from cellulose and algae enriched with pure silver giving antibacterial and fungicidal properties. Functionallity lasts after 20 washes. | 23 |
| Invista | Aloe Vera and Chitosan with Phase Change Material | Leg wear and intimate clothing for women and men. Yoga lines. Delivering cosmetic and well-being benefit like freshness, moisturizing and massage for leg wear and intimate apparel. Stretch and recovery function through the use of Lycra. | 24 |
| Richa | Phase Change Material | Close-fitting for women motorbike. The material can be removed in warmer weather and reattached at lower temperatures. | 25 |
| Solidea (MicroMassage Magic) | 80% polyamide, 18% elastin, 2% cotton | Patented 3D wave like knitting process of fabric that provides skin massages by the natural body movement promoting circulation and drainage of fluids that cause orange peel. | 26 |
| Yonex | Xylitol | Tennis and badminton clothes. In this product the xylitol absorbs heat when it comes in contact with water and offers a cool feel when the wearer starts sweating. | 26 |

**Citation:** Muñoz V, Gonzalez JS, Martinez MA, et al. Functional textiles for skin care by active substance encapsulation. *J Textile Eng Fashion Technol.* 2017;2(6):538–545. DOI: 10.15406/jteft.2017.02.00082


**Figure 14** Classification of cosmetotextiles as a function of their influence on the human body.

| | |
|---|---|
| Chemical Properties | • Tested according extisting legal directives.<br>• 13 relevant directives for textiles and cosmetics.<br>• Actual development of standards of cosmetotextiles. |
| Toxicity Innocuosness | • Step I: Test of individual (cosmetic industry).<br>• Step II: Test the whole product (similar to an antimicrobial test). |
| Presence of Vitamin E | • Vitamin E content on textile surfaces.<br>• Colour reaction by the reductive properties of Vitamin E. |
| Efficacy | • Using the same testing tools as for cosmetics.<br>• Using the same testing conditions as for cosmetics. |
| Perfume and performance analysys | • Analysis of volatile compounds<br>• ASTM D3362, D3452, D4128 |
| Durability | • Wash fastness: several available testing metodologies |
| Labeling | • Labeling standard for cosmetotextiles being developed |

**Figure 15** Typical characterizations of Cosmetotextiles.

## Conclusion

Finishing will play a crucial role in developing value added products to compete in the real market in which the expectation of customers is accomplishment new heights every day. The optimization of the incorporation of cosmetic ingredients and on the enhancement of the durability of active substances effects are the two real challenges in this field.

In this context, cosmetotextiles is a growing industry in which natural resources in eco-friendly products are being explored and developed. Several natural products, potential to offer wellness effects, are available in the market and some more have to be developed. In addition, this kind of products have to be designed in such a fashion considering the composition and construction of textiles but also the clothing design and cosmetic finish in order to reach the optimum cosmetic effects.

It is important to remark that although today micro technology are used for producing cosmetotexiles, nanotechnology is potential tool to develop new and successful cosmetotexiles, toxicological and legal aspects should be studied before implementation in a safe way.

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## Conflict of interest

There is not any financial interest or other conflict of interest exists.

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