Cosmetic Textiles: A Novel Technique of Developing Wearable Skin Care

BY

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ABSTRACT

With the growing trend in enhancing beauty through healthy means, customers request apparel and home textiles with extra functions, including environmental protection, anti-pollution, and health and beauty care, in an attempt to achieve a more natural and healthier life. Cosmetotextiles development transforms daily ordinary textile products into cosmetically active products, ending the need to actively apply the cosmetic substance. The textiles can act as delivery systems of bioactive compounds such as vitamins, peptides, antioxidants, fragrances, metallic compounds, and drugs, as well as some animal and plant-based compounds. Active ingredients are normally integrated with textiles by microencapsulation, plasma, sol-gel, dope insertion inside the synthetic fiber via spinning processes or they are applied by coating/grafting or impregnation onto the finished fabric in order to stabilize the cosmetic ingredients, provide sustained skin therapy, and prolong dermo cosmetic efficiency. Current cosmetotextiles in the market claim to be moisturizing, cellulite reducing, perfumed, body slimming, energizing, rejuvenating, refreshing, UV protective, anti-ageing, improving the firmness and elasticity of skin or reducing the appearance of fine lines and wrinkles. The market for cosmetic textiles is growing, particularly in response to the increased demand for hygiene products and the need for extra hygienic and cosmetic benefits in personal care products. Thus, the development of novel applications of cosmetotextiles will open up new market potential for textile and garment manufacturers. This article provides an overview of the development history, important cosmetic ingredients and their applications, and commercial cosmetotextile products available in the market.

Keywords: Cosmetic Textiles; Active Ingredients; Microencapsulation; Skin Care and Health; Cosmetic Products.

1. INTRODUCTION

Cosmetotextile is a technology of merging cosmetics and textiles by the incorporation of cosmetic active agents into the textiles with different techniques. A cosmetotextile is a textile article containing a substance or a preparation that is released over time on different superficial parts of the human body, especially skin, and claiming special properties such as cleaning, perfuming, changing appearance, protecting, keeping in good condition or correcting of body odours. As the textiles are in contact with the skin, all kinds of skin care ingredients can be incorporated in the textile materials and the released substances from the clothing may directly be absorbed by the skin. These textiles are able to help people who are not able to use any cosmetic products (Jamal and Rani, 2018).

With the growing trend in enhancing beauty through healthy means, customers request apparel and home textiles with extra functions, including environmental protection, anti-pollution, and health and beauty care, in an attempt to achieve a more natural and healthier life. The textile industry is optimistic that cosmetic textile-based products will open new target groups and sustainable markets

(Bhargava and Jahan, 2012). Cosmetotextiles are textiles that aim to enrich modern-day life, such as slimming by cellulite reduction, skin moisture management, energising the human body, protection from ultraviolet radiation, providing pleasant fragrance, or providing anti-ageing-appearance properties (Singh *et al*., 2023). In wound dressings, where a slow release of the drug is essential, drug complexes with natural compounds, such as chitosan, hyaluronic acid, and alginates serve this purpose (Nelson, 2002; Singh *et al*., 2011). According to the European Cosmetic Directive, cosmetotextiles are any textile product containing a substance or preparation that is released over time on different superficial parts of the human body, notably on human skin, and containing special functionalities such as cleansing, perfuming, changing appearance, protection, keeping in good condition, or correction of body odours (Amanda, 2022). The various functions of the cosmetic textiles are shown in **Figure 1.**

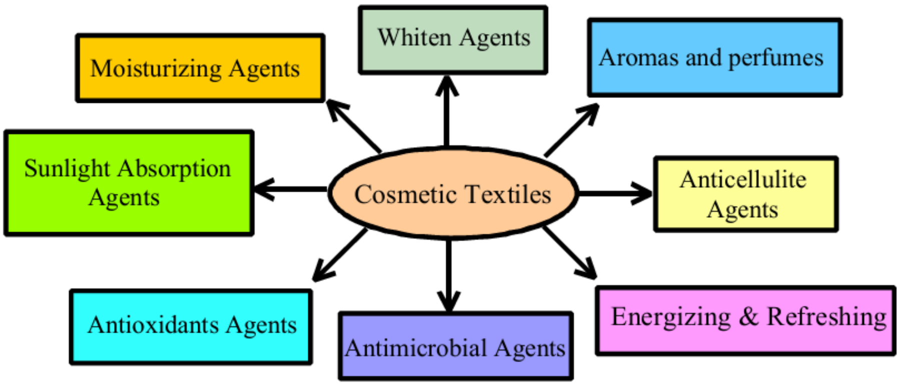


Figure 1. Schematic diagram of different types of cosmetic textiles

2. COSMETIC INGREDIENTS

Generally, major cosmetic ingredients originate from inorganic and synthetic chemicals, animal derivatives, and plant derivatives. Plant derivatives such as aloe vera, padina povonica, flowers, fruits, essential oils, animal derivatives such as chitosan, squalene, and sericin, and synthetic materials such as iron oxide, titanium dioxide, ethane-diol, zinc oxide, and zinc nanoparticles are used (Goyal and Jerold, 2013).

2.1. Chitosan

Chitosan found in shellfish, like shrimps or crabs, and is used for wound healing, blood clotting, antibacterial, as well as skin protection (**Figure 2**). The results of the various research studies indicate that chitosan might act as active compounds in textiles, e.g., as antimicrobial finishing of textiles, and cosmetotextiles (Nadia *et al*., 2019). Microcapsules containing chitosan can be embedded onto the fabric for products of different efficacy, including moisturising, cooling, energising, relaxing, anti-heavy legs, and mosquito repellent benefits (Cheng *et al*., 2008). The incorporation of chitosan into a textile substrate can be done during polymerization, dope formation, or at the finishing stage (Jamal and Rani, 2018).

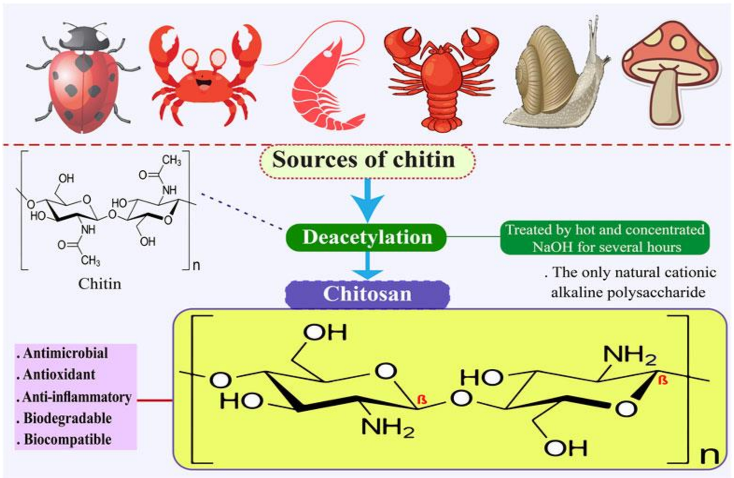


Figure 2. Sources of chitin and structure of chitosan

When a virus comes in contact with a textile surface treated with chitosan, the latter bind with the outer layer of the virus and inhibit its vital mechanisms. Chitosan oxidize and dissolve the lipid or the glycoprotein layer and enter inside the virus structure and adhere to the genome (i.e. with the virus DNA or RNA) and deactivate the same by breaking it into fragments. Thus, the disintegration of the virus results, manifesting itself in the leakage of the viral genome and a loss of infectivity, leaving the viral particle inactive on the treated textile surface (Adel *et al.,* 2022). The antivirus mechanism of chitosan is shown in **Figure 3.**

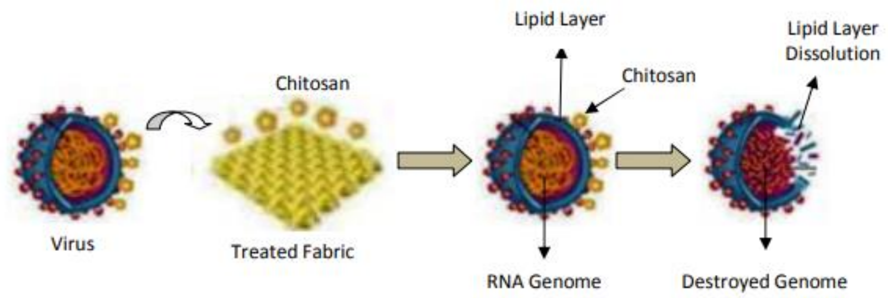


Figure 3. Antivirus mechanism of chitosan treated fabric

2.2. Squalene

Squalene is a natural antioxidant, chemically resembles the natural skin lipid called sebum and is found in palm and olive oil, but is extracted from shark liver. It supports the skin's ability to regenerate and maintain hydration by absorbing into the skin. Squalene, along with ascorbyl phosphate, vitamin E, and hyaluronic acid, helps to protect the skin against photoaging and the formation of brown age spots (Lim and Hudson, 2003). Human skin easily absorbs and spreads squalene with zero oily and greasy marks and reduces wrinkles due to its humectant potential (Kim and Karadeniz, 2012).

2.3. Sericin

Sericin is normally found in natural silk and is rich in serine, aspartic acid, and glycine, with a high concentration of hydroxyl groups (Gupta *et al.,* 2014). Sericin is a biomolecule of great importance, and it has antibacterial, antioxidant, and hydrating properties (Pornanong *et al.,* 2012). The amino acid components of sericin provide excellent retention of moisture on the skin, so it can be used as an addition to high-quality cosmetics (Sheng *et al.,* 2013). Sericin operates in stimulating the migration, proliferation, and production of collage and the presence of amino acid methionine of sericin is important in collagen synthesis, essential in the healing process. (Aramwit *et al.,* 2010).

2.4. Aloe Vera

Aloe vera is rich in minerals, polysaccharides, vitamins, and amino acids, making it a good antimicrobial, anti-inflammatory, antioxidant, and moisturising agent used in skin care products. Scientific research has proved that textiles treated with aloe vera are very pleasant to wear, having a significant effect on energy levels, which offers a feeling of wellbeing. Aloe vera is used to obtain antibacterial, antiviral, antimitotic, wound healing, and anti-inflammatory effects (**Figure 4**) (Eshun and He, 2004).

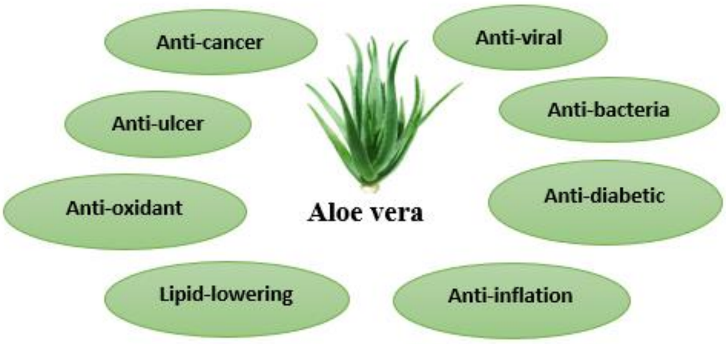


Figure 4. Functions of aloe vera

2.5. Ginseng

Ginseng oil has antibacterial, deodorising, moisturising, and, antioxidant properties, and the extract can be used to protect the skin from cancer and inflammation. Ginseng has also been studied as a way to improve mood and boost endurance, as well as treat: cancer, heart disease, fatigue, erectile dysfunction, hepatitis C, high blood pressure, and menopausal symptoms.

Sujin and Jaeyum (Ryu and Shim, 2023) prepared ginseng oil microcapsules using the situ polymerization technique and applied them to nylon/polyurethane fabrics (**Figure 5**). The treated fabric exhibited 99.9% antibacterial activity against Staphylococcus aureus and Klebsiella pneumoniae and a 99% deodorising effect with the adsorption of ammonia gas.Thus, ginseng microcapsules were successfully used to fabricate highly hygienic fabric, highlighting their potential for application in various types of hygienic products based on the fabric.

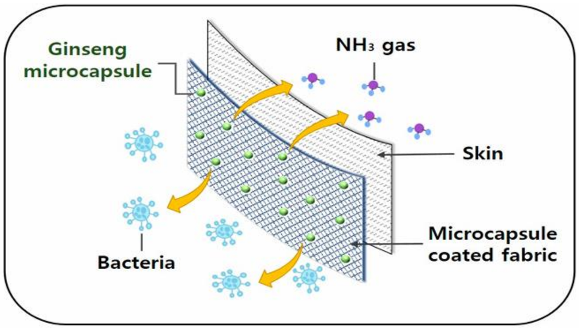


Figure 5. Schematic diagram of ginseng oil encapsulating and fabrication of cosmetic textiles with microcapsule coating

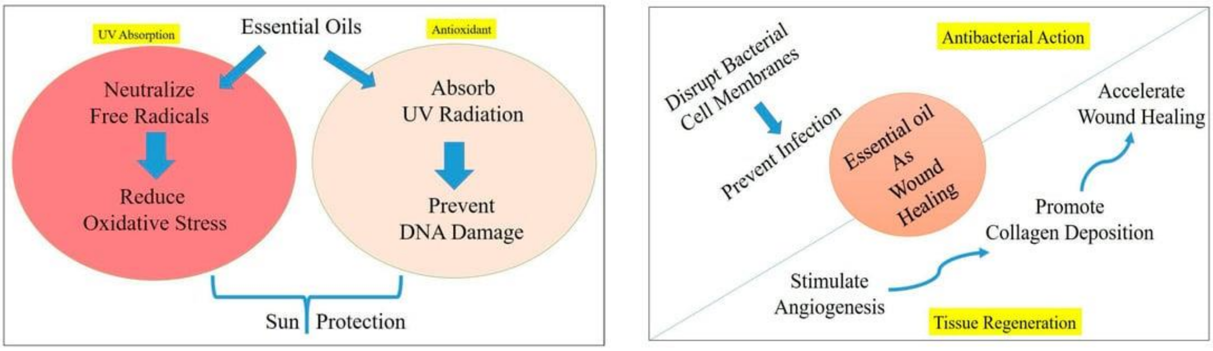
2.6. Essential Oils

Essential oils of various plants are increasingly used for integration into textile products (Ali *et al*., 2015; Sarkic and Stappen, 2018; West, 2014). Essential oils are extracted from the flowers, seeds, leaves, and barks of various aroma plants and have wide applications in the pharmaceutical and cosmetic industries (Giuseppe *et al*., 2018). For cosmetotextile application, essential oils of pleasant smells or cosmetic efficiencies such as antimicrobial, antioxidant, and moisturising and cell rejuvenation are employed and have found their use in aroma therapy, providing skin with glowing, moisturising, refreshing, and other wellness effects.

The actions of essential oils are given in **Figure 6 (A and B)**

The essential oils have been used in encapsulated form to overcome their poor thermal stability and to improve sustainability during washing. Microencapsulated oils are applied to cotton, polypropylene, polyacrylonitrile, and polyamide fibers. The prominent essential oils are lavender oil, thyme oil, sage oil, peppermint oil, eucalyptus oil, and camomile oil (Singh *et al*., 2017). Also, essential oils have healthier effects on skin, like anti-bacterial, anti-fungal, anti-inflammatory, strengthening vascular walls, delaying ageing, removal of metabolic waste, improvement of lymph circulation, and anti-cellulite actions (Sarkic and

Stappen, 2018; Michalak, 2018; Gaware *et al.*, 2013)



(A) **(B)**

Figure 6. Action of essential oils in (A) UV protection and (B) in wound healing

2.7. Hinokitiol

Hinokitiol is a natural tropolone based compound and an essential oil identified in the heartwood of cupressaceous plants (Chamaecyparis taiwanensis) (Wei *et al.*, 2019). This natural compound has shown numerous pharmacological properties, including anti-bacterial, antifungal, anti-inflammatory, anti-enzymatic, anticancer, antioxidant, neuroprotective, antidiabetic, and antiviral (El Hachlafi *et al.*, 2021). Rocha et al. (Rocha *et al.*, 2023) used the extracts from powdered cork to produce stable cosmetic formulations with improved antioxidant activities. The extracts can also be applied as dyeing agents to dye cotton fabrics.

2.8. Vitamin E

Vitamin E belongs to the group of lipid-soluble vitamins, is used as an antioxidant, and is helpful in guarding against various skin diseases and protecting the epidermis and dermis against oxidative stress (Manela-Azulay and Bagatin, 2009; Broadhead *et al.*, 2021). The most active form of vitamin E is α-tocopherol (Ghaheh *et al.*, 2017; Sarkic and Stappen, 2018). Due to its antioxidant properties, it can protect against lipid peroxidation and has the ability to slow skin ageing (Lee and Han, 2018).

When Vitamin E is applied to textiles using a controlled release microencapsulation system, it protects the skin and has anti-ageing and moisturising properties (Başyigit *et al.*, 2018). The grafting of vitamin E microcapsules into fabrics has been reported to significantly increase skin moisture and elasticity, reduce skin wrinkles and roughness (Son *et al.*, 2014). The role of vitamin E in deflecting UV rays is both noteworthy and natural. As an antioxidant, it can neutralize lipid-peroxyl radicals, agents responsible for breaking down cells and causing skin damage under UV radiation exposure (Clelia, 2024).

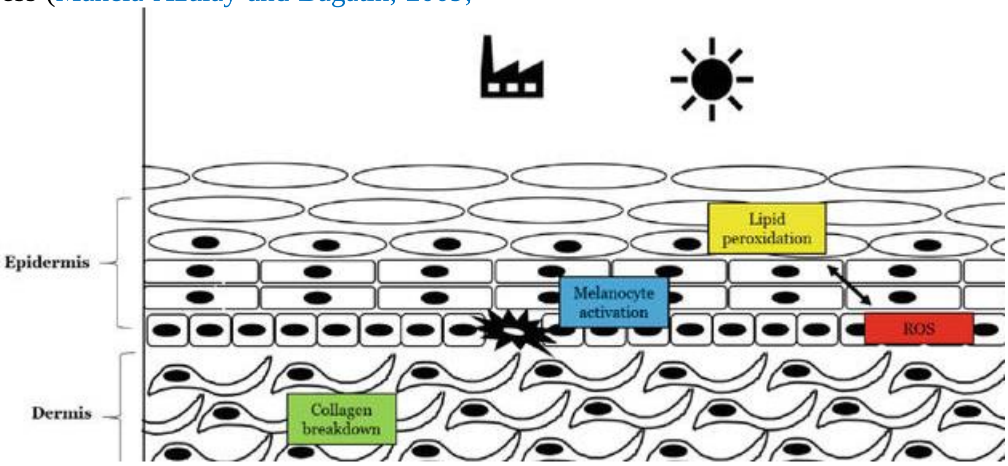


Figure 7. Oxidative mechanisms involving vitamin E in human skin exposed to ultraviolet radiation and pollution. ROS, reactive oxygen species

Vitamin E can eliminate FR induced by UVA radiation, protect endogenous antioxidants from degrading processes, prevent lipid peroxidation and reduce immunosuppression caused by UVR. vitamin E, more specifically alpha-tocopherol, can be considered a substance with antioxidant activity with the ability to protect long-chain unsaturated fatty acids. It is also capable of playing an important role in a wide variety of physiological and biochemical functions, mediated by the antioxidant function or by its stabilizing effect on cell membranes, breaking down the peroxyl chain propagation reactions and eliminating the efficient lipid peroxyl radicals (**Figure 7**).

Vitamin E is the most well-known fat-soluble non-enzymatic antioxidant, mainly for its ability to inhibit the activity of pro-oxidant agents generated by reactive oxygen species (ROS). Vitamin E can eliminate free radicals induced by endogenous and/or exogenous agents such as ultraviolet radiation, drugs and pollution agents, avoiding their deleterious effects. The antioxidant activity of vitamin E is directly linked to its ability to inhibit the lipid peroxidation in unsaturated fatty acids, incorporating itself into cell membranes, which effectively inhibits lipid peroxidation (Aparecida et al., 2021).

2.9. Vitamin C

Vitamin C accelerates collagen synthesis and slows down the decomposition of collagen. It is also effective in preventing the formation of wrinkles on the skin (Manela-Azulay and Bagatin, 2009; Ravetti *et al*., 2019). Gelatin/vitamin C microcapsules have been successfully prepared using the emulsion hardening technique and grafted onto textile materials by padding (Yuen, 2009). The gelatin micro-capsules containing Vitamin C can be successfully applied to cotton fabrics. The function of vitamin C (ascorbic acid) as an antioxidant and an enzyme cofactor is very important in maintaining skin health and preventing skin aging (Boo, 2022).

2.10. Hyaluronic Acid (HA)

HA is a natural linear polysaccharide that has been extensively used in cosmetic products to improve skin elasticity, turgor, and moisture by acting as a sponge in the skin to retain water (PN and MH, 2014). HA grafted pullulan polymers showed a high swelling ratio and a relatively quick hemostasis ability, making it a promising wound healing dressing (Li *et al*., 2018).

The ability of HA of attracting and binding water molecules to the skin assists the skin to stay hydrated and functioning at a stable rate, as well as continuing with the body's own natural production of HA. HA is the most hydrophilic molecule as it can attract 1000 times it's own molecular weight in water. The action of hyaluronic acid is shown in **Figure 8** (Michaela, 2025)

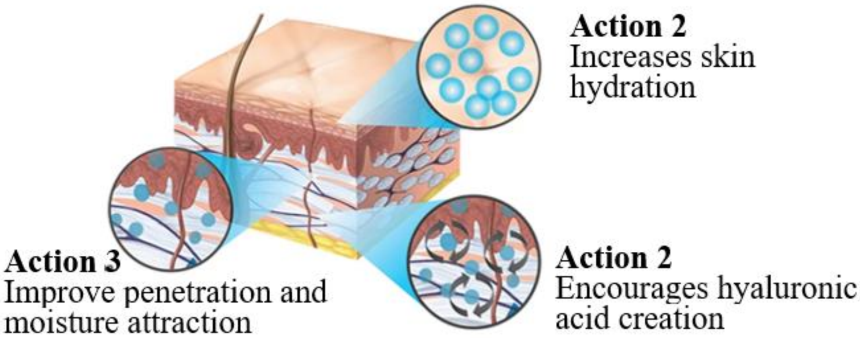


Figure 8. Actions of hyaluronic acid and long-lasting results

2.11. Gallic Acid (GA)

Gallic acid has recently been recommended as an active component for the production of cosmetic textiles (Marti *et al.*, 2014; Tiwari *et al.*, 2017). Inclusion of GA in the form of microspheres prepared from e-poly-ε-caprolactone as an antioxidant into polyamide knitted fabric improves the skin's photoprotection ability (Alonso *et al.*, 2016).

GA is a polyphenolic herbal molecule that has been reported for several health benefits. Important biological activities of GA include its anti-inflammatory, antimicrobial, antifungal, anticarcinogenic, anti-tyrosinase, antitubercular, antidiabetic and cardioprotective. Its ability to eliminate free radicals efficiently makes it a potent antioxidant (Harwansh *et al.*, 2024).

2.12. Peptides

Peptides have many functions as cosmetic ingredients, including skin moisturising, firming, elasticity-promotion, and anti-wrinkle. Besides, peptides can play a role in scaffold construction for biomedical patches, just like chitosan. The high water content and large pore size of most peptide hydrogels may result in the relatively rapid release of drugs (Ali *et al*., 2015).

The bioactive peptides can exert their biological as well as cosmetic functions in different ways. Signal peptides can prevent aging by stimulating skin fibroblasts, resulting in increased biological responses such as collagen, elastin, fibronectin, glycosaminoglycan, and proteoglycan production. Carrier peptides (copper) have been designed to deliver essential wound healing cofactors for enzymatic processing and wound repair, which leads to the stimulation of cellular regulation molecules, and the regeneration and healing of skin and other tissues (Pai *et al*., 2017).

2.13. Retinol and Caffeine

Retinol and caffeine extracts are generally added to compressional garments for slimming, as well as a reduction in muscle damage and maintaining muscle function to fight cellulite (Gupta *et al*., 2011). Cosmetic ingredients with a strong free radical scavengering effect can be employed for plant extracts from coffee, cocoa, or cinnamon (Moraczewski *et al*., 2019).

Lytess slimming leggings have a combination of caffeine and shea butter, which is clinically proven to substantially reduce the hips, thighs and moisturise the skin in 18 days (Ali *et al*., 2015; Sarkic and Stappen, 2018).

2.14. Silver

Ag-NPs have gained popularity in industrial sectors including textiles, food, consumer products, and medicine (Yetisen *et al*. 2016). German et al. (German *et al*., 2021) suggested that Ag-NPs may be successfully incorporated in natural fibres like wool and cotton) in order to perform biocide properties, as confirmed by using Bacillus subtilis. To keep the wearer feeling unsullied and fresh all day long, increasing comfort in all environments, the fabric includes a silver based solution that inhibits the growth of odour-causing bacteria.

2.15. Titanium Dioxide

The integration of TiO_2 increases the possibility of moisture absorbance on textile surfaces through the photocatalytic process. Titanium oxide, zinc nanoparticles, iron oxide, zinc oxide, and various other chemicals are used to improve the UV protection factor (UPF) of textiles (Reinert *et al*., 1997; Gupta *et al*., 2002; Levin and Momin, 2010; Patra and Gouda, 2013).

2.16. Copper Oxide

Impregnated cotton and synthetic fabrics with copper oxide show powerful biocidal effects and can be used for the production of socks to prevent fungal infection (Gabbay *et al*., 2006; Sarkic and Stappen, 2018). Copper oxide is used to promote healing and anti-microbial functionality in textiles. The socks composed of 10% cotton fibres, when incorporated with copper, remove all the symptoms of an athlete's foot within a few days (Borkow and Gabbay, 2004). Copper plays a key role in several processes of skin formation and regeneration (Baek *et al*., 2012). It was studied that sleeping on a pillowcase made up of a PES/cotton mixture containing 0.4% copper oxide for 2-4 weeks led to a significant reduction in wrinkles and the improvement of facial skin (Borkow *et al*., 2009). The use of pillow cases containing copper oxide did not cause any side effects such as skin irritation, itching, or inflammation (Baek *et al*., 2012).

2.17. Zinc Oxide

The use of zinc oxide can give it multifunctional properties, like photocatalytic self-cleaning, antimicrobial activity, UV protection, flame retardancy, thermal insulation and moisture management, hydrophobicity, and electrical conductivity. The fabrication of ZnO-functionalized textiles, with an emphasis on understanding the specificity and mechanisms of ZnO action that impart individual properties to the textile fibres (Verbic *et al*., 2019).

2.18. Benzoic Acid

After covid-19, the demand for antimicrobial based products has been growing due to public awareness of the potential threats from pathogenic bacteria (Maryan *et al*., 2013). Lee et al. investigated β-cyclodextrin as a carrier for encapsulating antibacterial chemicals, benzoic acid and vanillin, and embedded them onto cellulose fibres by using N-methylol-acrylamide. They found the anti-bacterial activity resistant to 10 laundering cycles (Lee *et al*., 2000; Borkow, 2016).

2.19. Allantoin

In another study, allantoin loaded liposomes were prepared and applied to polyamide and cotton fabrics. It was shown that allantoin loaded liposomes were successful for moisturising the skin, thus making them suitable for cosmetotextile applications (Sayit *et al*., 2022).

Table 1. Commercially available cosmetic textiles products

Developed by	Trade name	Active agent	Functions	Reference
Cognis, Germany	Skintex	Chitosan	moisturising, cooling, and mosquito repellent	(Bhargava and Jahan, 2012)
Lenzing	Tencel®C	Chitosan	skin-soothing, skin elasticity, and stimulate skin cell regeneration	(Persico and Carfagna, 2013).
Ohara Paragium Chem. JP	Parafine SC-3000	raspberry and squalane	fat-burning, moisture-retaining and skincare	(Singh *et al*., 2011)
Dogi International Fabrics, Spain	Hydrabra	Aloe vera	moisturising, calming, antioxidant, and anti-ageing benefits	(Javed and Atta, 2014). (Nascimento *et al*., 2017).
CPC International, UK	Bio-Cap	Aloe vera and Vitamins	skin moisturising, body cooling, thermal regulating, and well-being	(Han *et al*., 2020; Ristic *et al*., 2022). (Cheng *et al*., 2008).
Nurel, Spain	NOVAREL	Aloe vera	skin beauty	(Novarel, 2024).
Skin'Up Lab, France	Skin'Up	phytomarine actives and safflower seed oil	skin anti-ageing, body thermoregulation, toxins elimination, slimming, and cellulite prevention	(Ali *et al*., 2015; Sarkic and Stappen, 2018; Skin'Up, 2024).
Devan Chemical, Belgium	SceNTL	essential oils	enhancing relaxation, wellbeing, and feel-good sensations	(Devan, 2021).
Dystar Auxiliaries GmbH, Germany	EVO™ Care Vital	vitamin E, aloe vera, and jojoba oil	anti-ageing function and is devoted to improving the firmness and resilience of skin	(Singh *et al*., 2011).
Ohara Paragium Chem. JP	Parafine-5000	extracts from rice germ oil and vitamin E	anti-oxidation, bio-membrane stabilization, and blood circulation	(Singh *et al*., 2011).
Nurel, Spain	NOVAREL – Anti-Ox	Vitamin E into nylon	anti-ageing skin	(Novarel, 2024).
Nylstar, Spain	Meryl®-Hyaluronan	Hyaluronic acid	skin elasticity, softness, and firmness for innerwear	(Ali *et al*., 2015; Sarkic and Stappen, 2018).
Calze GT, Italy	Meryl Hyaluronan fibre	Gold and hyaluronic acid	slimming, firming, anti-ageing, and moisturising effects	(Yaluronica, 2024)
Ohara Paragium Chem. JP	Parafine SC-1000, Parafine SC-3000, and Parafine-5000	silk based amino acids	skin well-being by enhancing the amount of moisture on the skin	(Singh *et al*., 2011).
Camangi Corporation, Taiwan	UMORFIL*Beauty Fibre and UMORFIL*N6U™	peptide amino acids	comfort to the skin, soft touch, and better elongation	(Devan, 2021; UMORFIL, 2024).
Lipotec, Spain	Argireline	hexapeptide	anti-wrinkle	(Dana and Rotsztejn, 2017
Billerbeck, German	Matricol®	collagen peptide	skin anti-ageing, hydration, rejuvenation, and facial masks	(Ali *et al*., 2015; Sarkic and Stappen, 2018).
Croda, UK	Solaveil™ ST-100	Titanium dioxide	UV protection	
Lenzing	SeaCell	zinc oxide in cellulose fibre	UV protection, antibacterial	(Lenzing, 2012).
Pulcra Chemicals	Cyclofresh Plus	cyclodextrins and silver ions	protection from unpleasant body-odour and release of fragrances	(Cognis and Pulcra Chemicals, 2007)
Tejin Company, Japan	Amino jeans	amino acid arginine	rejuvenation of the skin	(Ali *et al*., 2015; Sarkic and Stappen, 2018).
Ajinomoto and	Amiono Veil	peptide	improve skin hydration,	(Ali *et al*., 2015; Sarkic

Mizuno Corporation, Japan			maintain skin pH levels and rejuvenation (Tennis and golf clothes)	and Stappen, 2018)
Billerbeck, Germany	Matricol®	collagen peptide	skin anti-ageing, hydration, skin and facial masks	(Ali *et al*., 2015; Sarkic and Stappen, 2018).

3. APPLICATION TECHNIQUES OF COSMETIC INGREDIENTS ON TEXTILES

Textiles materials are designed to transfer an active substance for cosmetic purposes with the natural movement of the body. The cosmetic effects of different agents can be obtained by different techniques. Some practiced incorporation techniques are: dyeing method; microencapsulation technique, insertion during synthetic fibre manufacturing; grafting; coating; and layer by layer deposition (Singh *et al*., 2011; Kanjana and Nalankilli, 2018; Kumar, 2021).

3.1. Dyeing method

Here, the organic cotton yarn or fabric is dyed in a carefully controlled mixture of herbal dyes, depending on the disease or ailment being treated.

3.2. Microencapsulation

Microencapsulation technology is an effective technique used to control the release properties of active ingredients in cosmetic textiles (Cheng *et al*., 2008). In cosmetic textiles, the major interest in microencapsulation is currently in the application of vitamins, essential oils, skin moisturising agents, skin cooling agents, and anti-ageing agents. Encapsulation is a method in which functional materials can be surrounded by wall material via an appropriate polymerization method, depending on the characteristics of the core material (Salaun *et al*., 2011; Black *et al*., 2014; Yang *et al*., 2023). The microcapsules are produced by depositing a thin polymer coating on small solid particles or liquid droplets, or by dispersing solids in liquids (Cheng, 2010; Ghaheh *et al*., 2017).

3.3. Dope additives

The cosmetic active agents are added to the fibre forming material at the time of dope preparation before fibre extrusion. For example, the manufacturing of inherently conductive, UV absorbing, and de-lustering fibres can be possible by using carbon nanotubes, Zn nanoparticles, and TiO_2, respectively, as dope additives. Inherently functionalised fibres can be used to manufacture textile materials for various purposes (Wang *et al*., 2005).

3.4. Grafting

Various cosmetic ingredients are grafted onto fibre, yarn, and fabric surfaces to achieve cosmetic effects. After the successful grafting, the active cosmetic agents are sprayed or treated with the CD grafted fabric. The fabric treated was found to be satisfactory after various aroma and antimicrobial finishing tests without any significant modification of the original fabric surface (Pierandrea *et al*., 2002). CDs have proven to be suitable wellness substances. A research group has permanently grafted β-CD molecules onto a Tencel fabric surface (Pierandrea *et al*., 2003).

3.5. Coating

The direct application of functional substances to fibres by coating is the simplest and most widely used method, but, owing to the low durability of the resulting fabric, volatile substances cannot be used; furthermore, the functional substances can make the textile products stiff or degrade their feel and appearance (Salaun *et al*., 2011).

4. CONCLUSION

Today, consumers are increasingly interested in fitness, health, and appearance for beauty and anti-ageing products. It is anticipated that the development of cosmetic textiles will continue to grow and explore completely new possibilities for providing beauty and personal care to the wearer in near future. It is really a challenging and exciting time for both the textile and medical industries. Numerous cosmetic active ingredients can be successfully applied by techniques like, grafting, encapsulation, plasma, sol-gel, doping, exhaustion and spraying. Adidas, Nike and L'Oreal also have strong interest in cosmetotextiles, indicating the customer's requirement of cosmetotextiles. A variety of garments categories of cosmetic functionality like, garments with slimming, skin care, energising, cooling, fragrances, pain relief, insect repellent, an tiodour properties and ultraviolet protections are available. Customers worldwide have turned towards well-being through natural resources in an eco-friendly health promoting environment. It currently represents a niche market, but the development of new applications will provide new market opportunities for textile and apparel firms

The market for cosmetotextiles has greatly expanded in recent years to encompass a wide range of garments that are designed to appeal to health conscious consumers. Manufacturers claim that their products can reduce cellulite, moisturise the skin, cool the body, or even deliver vitamins. Once we wear the cosmetic textiles, the body will be cared for all the time until the active ingredients are used out. With the rising demands and expectations of consumers, more sustainable and cost-effective cosmetotextiles of various health benefits are being developed worldwide.

REFERENCES

Adel, E., Khmais, Z., Dhouha, B. and Mohamed, H. (2022) 'Use of chitosan as antimicrobial, antiviral and anti-pollution agent in textile finishing', *Fibres and Textiles,* 29, pp. 51-70.

Ali, B., Al-Wabel, N.A., Shams, S., Ahmad, A., Khan, S. A. and Anwar, F. (2015) 'Essential oils used in aromatherapy: A systemic review', *Asian Pacific Journal Tropical Biomedicine,* 5(8), pp. 601-611.

Alonso, C., Martí, M., Barba, C., Lis, M., Rubio, L. and Coderch, L. (2016) 'Skin penetration and antioxidant effect of cosmeto-textiles with gallic acid', *Journal of Photochemistry & Photobiology, B: Biology,* 156, pp. 50-55.

Amanda, Lim (2022) 'Microbiome-friendly clothes; Cosmax set to commercialize 'wearable cosmetics' with anti-ageing ingredient', Available at: https://www.cosmeticsdesign-asia.com/Article/2022/05/11/cosmax-set-to-commercialise-wearable-cosmetics-with-anti-ageing-ingredient (Accessed: 13 Feb 2025).

Aparecida Sales de Oliveira Pinto, C., Elyan Azevedo Martins, T., Miliani Martinez, R., Batello Freire, T., Valéria Robles Velasco, M., and Rolim Baby, A. (2021) 'Vitamin E in human skin: functionality and topical products', *IntechOpen*. doi: 10.5772/intechopen.98336.

Aramwit, P., Sangcakul, A. (2007) 'The effects of sericin cream on wound healing in rats', *Bioscience, Biotechnology and Biochemistry,* 71, pp. 2473–2477. doi: 10.1271/bbb.70243.

Baek, J.H., Yoo, M.A., Koh, J.S. and Borkow, G. (2012) 'Reduction of facial wrinkles depth by sleeping on copper oxide containing pillowcases: a double blind, placebo controlled, parallel, randomized clinical study', *Journal of Cosmetics Dermatology*, 11(3), pp.193-200.

Başyigit, Z., Kut, D., Yenilmez, E., Eyupoglu, S., Hocaoglu, E. and Yazan, Y. (2018) 'Vitamin E loaded fabrics as cosme-totextile products: formulation and characterization', *Tekstil ve Konfeksiyon,* 8, pp. 162–169.

Bhargava, D. and Jahan, S. (2012) 'Cosmetic textiles: An innovative Alliance of Textile and Cosmetics', *China Textile Science Journal,* 3, pp. 41-45.

Black, K.A., Priftis, D., Perry, S.L., Yip, J., Byun, W.Y. and Tirrell, M. (2014) 'Protein encapsulation via polypeptide complex coacervation', *ACS Macro Letters*, 3, pp.1088-1091.

Boo, Y.C. (2022) 'Ascorbic acid (Vitamin C) as a cosmeceutical to increase dermal collagen for Skin antiaging purposes: Emerging combination therapies', *Antioxidants*, 11, pp. 1663-1681.

Borkow, G. (2016) 'Cosmetotextiles - sometimes the simple things work', *Journal of Cosmetology and Trichology,* 2, p.1000e103.

Borkow, G. and Gabbay, J. (2004) 'Putting copper into action: copper impregnated products with potent biocidal activities', *FASEB Journal,* 18(4), pp. 2004-2029.

Borkow, G., Gabbay, J., Lyakhovitsky, A. and Huszar, M. (2009) 'Improvement of facial skin characteristics using copper oxide containing pillowcases: a double-blind, placebocontrolled, parallel, randomized study' *International Journal of Cosmetic Science,* 31(6), pp. 437-443.

Broadhead, R., Craeye, L. and Callewaert, C. (2021) 'The future of functional clothing for an improved skin and textile microbiome relationship', *Microorganisms,* 9, p. 1192.

Cheng, S.Y. (2010) 'Systematic characterization of cosmetic textile', *Textile Research Journal,* 80(6), pp. 524-536.

Cheng, S.Y., Yuen, C.W.M., Kan, C.W. and Cheuk K.K.L. (2008) 'Development of cosmetic textiles using microencapsulation technology', *Research Journal of Textile and Apparel,*12(4), pp. 41-51.

Clelia G. (2024) 'What is the role of vitamins in skin care?'. Available at: https://organicskincare.com/what-is-the-role-of-vitamins-in-skin-care/. (Assessed: 1 March 2025)

Cretu Viorica (2014) 'Beauty, health and well-being with cosmetotextiles', Available at: https://textile.webhost.uoradea.ro/Annals/Vol%20X

V-no%20I/Art.%20nr.%207,%20pag%2035-40.pdf (Accessed: 2 January 2025).

Cognis and Pulcra Chemicals exhibit active cooling, freshness, and protective textile technologies (2007), Available at: https://risnews.com/cognis-and-pulcra-chemicals-exhibit-active-cooling-freshness-and-protective-textile-technologies-or (Accessed: 10 February 2025).

Dana, A. and Rotsztejn, H. (2017) 'The peptide argireline-the importance of local application on the skin, in the light of current knowledge', *Letters in Drug Design and Discovery*, 14, pp. 1215-1220.

Devan launches bio-based fragrances for textiles (2021), Available at: https://www.textiletechnology.net/technology/news/Devan-Bio-based-fragrances-for-textiles-23715 (Accessed: 14 December 2024).

El Hachlafi, N., Lakhdar, F., Khouchla, A., Bakrim, S., El Omari, N., Balahbib, A., Shariati, M.A., Zengin, G., Fikri-Benbrahim, K. and Orlando, G. (2021) 'Health benefits and pharmacological properties of hinokitiol', *Processes*, 9, pp.1680.

Eshun, K. and He, Q. (2004) 'Aloe vera: a valuable ingredient for food pharma and cosmetics-a review', *Critical Review in Food Science Nutrition*, 44, pp. 91-96.

Gabbay, J., Borkow, G., Mishal, J., Magen, E., Zatcoff, R. and Shemer-Avni, Y. (2006) 'Copper oxide impregnated textiles with potent biocidal activities', *Journal of Industrial Textiles*, 35, pp. 323-335.

Gaware, V., Nagare, R., Dhamak, K., Khadse, A., Kotade, K., Kashid, V. and Laware, R. (2013) 'Aromatherapy: art or science', *International Journal of Biomedical Research*, 4, pp. 74-83.

German Montes-Hernandez, Mahaut Di Girolam Géraldine Sarre, Sarah Bureau, Alejandro Fernandez-Martinez, Cécile Lelong and Elise Eymard Vernain. (2021) 'In situ formation of silver nanoparticles (Ag-NPs) onto textile fibers', *ACS Omega*, 6(2), pp.1316–1327.

Ghaheh, F. S., Khoddami, A., Alihosseini, F., Jingb, S., Ribeirob, A., Cavaco-Paulob, A. and Silvab, C. (2017) 'Antioxidant cosmetotextiles: cotton coating with nanoparticles containing vitamin E', *Process Biochemistry*, 59, pp. 46–51.

Giuseppe, G., Stefano, S., Marco, L., Edoardo, N., Grazia, M., Viviana, C., Stefania, S. and Corrada, G. (2018) 'Essential oils encapsulated in polymer-based nanocapsules as potential candidates for application in food preservation', *Food Chemistry*, 269, pp. 286–292.

Goyal, N. and Jerold, F. (2013) 'Biocosmetics: technological advances and future outlook', *Environment Science and Pollution Research*, 30, pp. 25148 -25169.

Gupta, D., Agrawal, A. and Rangi, A. (2014) 'Extraction and characterization of silk sericin', *Indian Journal of Fibre & Textile Research*, 39(4), pp. 364-372.

Gupta, D., Chattopadhayay, R. and Bera, M. (2011) 'Comfort properties of pressure garments in extended state', *Indian Journal of Fibre & Textile Research*, 36, pp. 415-421.

Gupta, K. K., Tripathi, V. S. and Ram, H. (2002) 'Sun protective coatings', *Colourage*, 6, pp. 35-40.

Han, J., Liu, L., Fan, Z., Zhang, Z., Yang, S. and Tang, Y. (2020) 'Grafting cosmetic active ingredients for the functionalization of cosmetotextiles', *IOP Conference Series: Materials Science and Engineering*, 782, p. 022026.

Harwansh, R. K., Deshmukh, R., Shukla, V. P., Khunt, D., Prajapati, B. G., Rashid, S., Ali, N., Elossaily, G. M., Suryawanshi, V. K., and Kumar, A. (2024) 'Recent Advancements in Gallic Acid-Based Drug Delivery: Applications, Clinical Trials, and Future Directions', *Pharmaceutics*, 16(9), 1202. doi.org/10.3390/pharmaceutics16091202

Jamal Z. and Rani S. (2018) 'Cosmetotextiles: a wearable skin care', *International Journal of Home Science*, 4, pp. 31-35.

Javed, S.R. and Atta, U.R. (2014) 'Aloe vera gel in food, health products, and cosmetics industry', Atta, U.R. (Ed.), *Studies in Natural Products Chemistry*, Elsevier, New York.

Kanjana, S. and Nalankilli, G. (2018) 'Integration of cosmetics with textiles: an emerging area of functional textiles–a review', *Journal of Textile Engineering and Fashion Technology*, 4(4), pp.316-318. doi:10.15406/jteft.2018.04.00158.

Kim, S.K. and Karadeniz, K. (2012) 'Biological importance and applications of squalene', *Advances in Food and Nutrition Research*, 65, pp. 223-233.

Kumar Singh, M. (2021) 'Textiles functionalization - a review of materials, processes, and assessment', *IntechOpen.* Available at: https://doi:10.5772/intechopen.96936 (Assessed: 23 January 2025).

Lee, G. Y. and Han, S. N. (2018) 'The role of vitamin E in immunity', *Nutrients*, 10, p. 1614.

Lee, M. H., Yoon, K. J. and Ko, S. W. (2000) ‘Grafting onto cotton fiber with acrylamidomethylated β-cyclodextrin and its application’, *Journal of Applied Polymer Science*, 78, pp. 1986-1991.

Lenzing to produce Smartcel and SeaCell for smartfiber (2012), *Textile Magazine*. Available at: https://www.indiantextilemagazine.in/lenzing-to-produce-smartcel-seacell-for-smartfiber/ (Accessed: 13 February 2025).

Levin, J. and Momin, S. B. (2010) ‘How much do we really known about our favorite cosmeseutical ingredients’, *The Journal of Clinical and Aesthetic Dermatology*, 3, pp. 22-41.

Li, H., Xue, Y., Jia, B., Bai, Y., Zuo, Y., Wang, S., Zhao, Y., Yang, W. and Tang, H. (2018) ‘The preparation of hyaluronic acid grafted pullulan polymers and their use in the formation of novel biocompatible wound healing film’, *Carbohydrate Polymers*, 188, pp.92-100.

Lim, S.H. and Hudson, S.M. (2003) ‘Review of chitosan and its derivatives as antimicrobial agents and their uses as textile chemicals’, *Journal of Macromolecular Science –Polymer Reviews*, 43, pp. 223-269.

Manela-Azulay, M. and Bagatin, E. (2009) ‘Cosmeceuticals vitamins’, *Clinics in Dermatology*, 27, pp, 469-474.

Martí, M., Martínez, V., Carreras, N., Alonso, C., Lis, M. J., Parra, J.L. and Coderch, L. (2014) ‘Textiles with gallic acid microspheres: in vitro release characteristics’, *Journal of Microencapsulation*, 31, pp. 535-541.

Maryan, A. S., Montazer, M. and Harifi, T. (2013) ‘One step synthesis of silver nanoparticles and discoloration of blue cotton denim garment in alkali media’, *Journal of Polymer Research*, 20, pp.1-10.

Michaela (2024) ‘Hyaluronic acid + why you need it?’, Available at: https://laserclear.com.au/hyaluronic-acid-why-you-need-it/. (Assessed: 2 March 2025).

Michalak, M. (2018) ‘Aromatherapy and methods of applying essential oils’, *Archives Physiotherapy and Global Researches*, 22, pp. 25-31.

Moraczewski, K., Stepczynska, M., Malinowski, R., Karasiewicz, T., Jagodzinski, B. and Rytlewski, P. (2019) ‘The effect of accelerated aging on polylactide containing plant extracts’, *Polymers*, 11, p. 575.

Nadia Morin-Crini, Eric Lichtfouse, Giangiacomo Torri and Grégorio Crini (2019) ‘Applications of chitosan in food, pharmaceuticals, medicine, cosmetics, agriculture, textiles, pulp and paper, biotechnology, and environmental chemistry’, *Environmental Chemistry Letters*, 17, pp.1667-1692.

Nascimento do Carmo S., Zille, A. and Souto, A.P. (2017) ‘Plasma-assisted deposition of microcapsule containing Aloe vera extract for cosmetotextiles’, *IOP Conference Series: Material Science Engineering*, 254, pp.122007.

Nelson, G. (2002) ‘Application of microencapsulation in textiles’, *International Journal of Pharmacy*, 242, pp. 55-62.

Novarel, Cosmetic functional nylon fibers (2024). Available at: https://www.performancedays.com/files/performancedays/content/exhibitors/documents/1128/NOVAREL.pdf (Accessed: 1 March 2025)

Pai, V.V., Bhandari, P. and Shukla, P. (2017) ‘Topical peptides as cosmeceuticals’, *Indian Journal of Dermatology*, 83, pp. 9-18.

Patra, S. K. and Gouda, S. (2013) ‘Application of nanotechnology in textile engineering: an overview’, *Journal of Engineering and Technology Research*, 5, pp.104-111.

Persico Paola and Carfagna Cosimo (2013) ‘Cosmeto-textiles: state of the art and future perspectives’, *Advances in Science and Technology*, 80, pp. 39-46.

Pierandrea, L.N., Laura, F. and Piero, B. (2002) ‘Modification of a cellulosic fabric with β-cyclodextrin for textile finishing applications’, *Journal of Inclusion Phenomenon and Macrocyclic Chemistry*, 44, pp. 423-427.

Pierandrea, L.N., Laura, F., Francesca, R. and Piero, B. (2003) ‘Surface treatments on tencel fabric: grafting with β-cyclodextrin’, *Journal of Applied Polymer Science*, 88(3), pp. 706-715.

PN, S. and MH, R. (2014) ‘Beneficial effects of hyaluronic acid’, *Advances in Food and Nutrition Research*, 72, pp. 137-176.

Pornanong, A., Siritientong, T. and Srichana, T. (2012) ‘Potential applications of silk sericin, a natural protein from textile industry by-products’, *Waste Management & Research*, 30(3), pp. 217-224. doi.org/10.1177/0734242x11404733.

Ravetti, S., Clemente, C., Brignone, S., Hergert, L., Allemandi, D. and Palma, S. (2019) 'Ascorbic acid in skin health', *Cosmetics,* 6, p. 58.

Ristic, N., Nikolic, D.M., Zdravkovic, A. Micic A. and Ristic, I. (2022) 'Biofunctional textile materials: cosmetic textiles', *Advance Technology,* 11(1), pp. 63-75.

Rocha, D., Freitas, D. S., Magalhães, J., Fernandes, M., Silva, S., Noro, J., Ribeiro, A., Cavaco-Paulo, A., Martins, M. and Silva, C. (2023) 'NADES-based cork extractives as green ingredients for cosmetics and textiles', *Processes*, 11, p. 309.

Ryu, S. and Shim, J. (2023) 'Development of highly hygienic textile by coating with encapsulated ginseng oil', *Polymers,* 15, p. 4352.

Salaün, F., Bedek, G., Devaux, E., Dupont, D. and Gengembre, L. (2011) 'Microencapsulation of a cooling agent by interfacial polymerization: influence of the parameters of encapsulation on poly (urethane–urea) microparticles characteristics', *Journal of Membrane Science*, 370, pp. 23-33.

Sarkic, A. and Stappen, I. (2018) 'Essential oils and their single compounds in cosmetics—A critical review', *Cosmetics,* 5(11), pp. 1-21.

Sayıt, G., Tanrıverdi, S. T., Ozer, O. and Ozdogan, E. (2022) 'Preparation of allantoin loaded liposome formulations and application for cosmetic textile production', *The Journal of Textile Institute*, 113(5), pp.725-736. doi.org/10.1080/00405000.2021.1903197.

Sheng, J.Y., Xu, J., Zhuang, Y., Sun, D.Q., Xing, T.L. and Shen, G.Q. (2013) 'Study on the application of sericin in cosmetics', *Advance Materials and Research,* 796, pp. 416-423.

Singh, M.K., Singh, A. and Morris, H.V. (2023) 'Cosmeto-textiles', *Textile Progress,* 55, pp. 109-163.

Singh, M.K., Varun, V.K. and Behera, B.K. (2011) 'Cosmetotextiles: state of art', *Fibres & Textiles in Eastern Europe,* 19, pp. 27-33.

Singh, N., Yadav, M., Khanna, S. and Sahu, O. (2017) 'Sustainable fragrance cum antimicrobial finishing on cotton: indigenous essential oil', *Sustainable Chemical Pharmacy,* 5, pp. 22-29.

Skin'Up Slimming postpartum wear (2014). Available at: https://Smngbeauty.com.sg/collections/skinup (Accessed: 23 January 2025).

Son, K., Yoo, D. I. and Shin, Y. (2014) 'Fixation of vitamin E microcapsules on dyed cotton fabrics', *Chemical Engineering Journal*, 239, pp. 284-289.

Tiwari, D., Upmanyu, N., Malik, J. and Shukla, S. (2017) 'Cosmetotextiles used as a medicine', *International Journal of Pharmacy and Chemical Research*, 3, pp. 814-828.

UMORFIL* Bionic Fiber (2024). Available at: https://www.camangi.com/product.html (Accessed: 14 February 2025).

Verbic, A., Gorjanc, M. and Simoncic, B. (2019) 'Zinc oxide for functional textile coatings: Recent advances', *Coatings, 9,* p.550. doi.org/10.3390/coatings9090550.

Wang, C. X. and Chen, S. L. (2005) 'Aromachology and its application in the textiles field', *Fibres and Textiles in Eastern Europe,* 13, p. 54.

Wang, C. X. and Chen, Sh. L. (2005) 'Fragrance-release property of β-CD inclusion compounds and their applications in aromatherapy', *Journal of Industrial Textiles*, 34, pp.157-166.

Wei, K. C., Chen, R. F., Chen, Y. F. and Lin, C.H. (2019) 'Hinokitiol suppresses growth of B16 melanoma by activating ERK/MKP3/ proteosome pathway to own regulate survivin expression', *Toxicology and Applied Pharmacology,* 366, pp. 35-45.

West, A. J. (2014) 'A critical review of aroma therapeutic applications for textiles', *Journal of Textile and Apparel Technology Management*, 9(1), pp. 1-13.

Yaluronica (2024) 'Anti-age and beauty effect'. Available at: https://www.gtcalze.com/products/yaluronica-anti-aging-shapewear/ (Accessed: 3 March 2024)

Yang, Y., Du, H., Zou, G., Song, Z., Zhou, Y., Li, H., Tan, C., Chen, H., Fischetti, V.A. and Li, J. (2023) 'Encapsulation and delivery of phage as a novel method for gut flora manipulation in situ: A review', *Journal of Control Release,* 353, pp. 634-649.

Yetisen, A. K., Qu, H., Manbachi, A., Butt, H., Dokmeci, M. R., Hinestroza, J. P., Skorobogatiy, M., Khademhosseini, A. and Yun, S. H. (2016) 'Nanotechnology in textiles', *ACS Nano,* 10, pp. 3042-3068. doi:10.1021/acsnano.5b08176.

Yuen (2009) 'Cosmetic textiles with biological benefits: gelatin microcapsules containing Vitamin C', *International Journal of Molecular Medicine,* 24, pp. 411-419.