Aromatherapeutic Textiles

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Additional information is available at the end of the chapter

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Abstract

Only innovative products will be sustainable to open up new markets and new horizons for textile industry. As a response to consumer demand, in recent years textile manufacturers are demonstrating increasing interest in added value products by getting the insect repellents, cosmetics, antimicrobials, phase-change materials, fire retardants, counterfeiting, polychromic and thermochromic effects. Aromatherapy application in textile industry led to a series of value-added products that give besides comfort a number of other properties (anti-acne, antimicrobial, fragrance, anti-inflammatory sedation, or soothing properties). In recent years, aromatherapeutic textiles were applied in many fields such as food, cosmetics, medicine, tobacco, textiles, leather, papermaking and pharmaceutical industries. The purpose of this chapter was to present the essential oils used in textile finishing, textile supports used for aroma finishing, embedding methods and the controlled release of essential oils.

Keywords: aromatherapy, essential oils, textile materials

1. Introduction

Although medicinal plants have been used for centuries as remedies for human diseases, in recent years, they have reached a great interest due to their low toxicity, pharmacological activities and economic viability. It shows a more pronounced shift from chemical and nonsustainable products to natural products that are not harmful, biodegradable and with health and wellness benefits [1]. After Mahboob et al., a good part of the population prefer traditional medicine because of the scarcity and cost-effectiveness of this sector.

Natural additives from plants can be compounds, groups of compounds, or essential oils [2]. Among natural additives, essential oils present a particular interest due to multiple benefits it shows such as antiviral, antifungal, antibacterial, antioxidant, antiparasitic, insecticidal, radical-scavenging properties, anti-inflammatory, antiseptic, germicide, healing and emollient effects.

Essential oils are made up of complex mixtures of several hydrocarbons (alcohols, terpenes, aldehydes, esters, phenols, oxides and ketones) and are obtained by conventional or advanced methods (**Figure 1**) [3, 4].

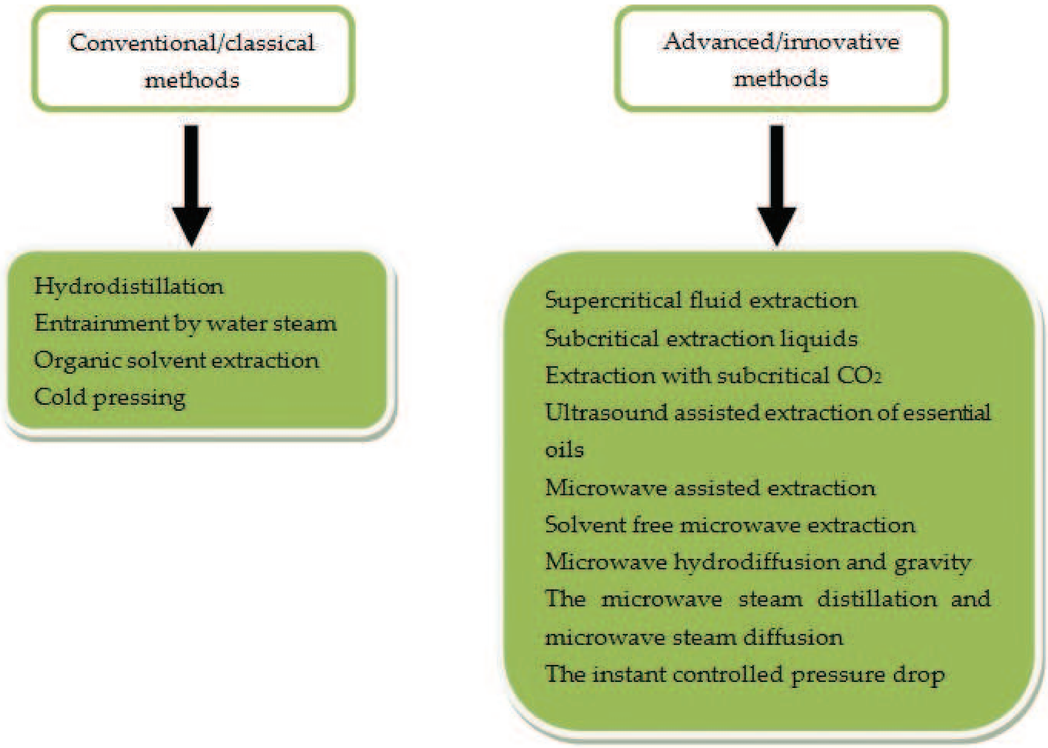

Figure 1. Extraction methods of essential oils.

Essential oils are fat soluble and thus they have the ability to permeate the skin membranes and drained into the systemic circulation, which reaches all targets organs as described by Radulovic et al. [5] and Kandori [6]. Essential oils are considered "vital force" of the plants. The role of these oils in plants is similar to that of the blood in the body. Fat-soluble structure of essential oils is similar to that of cells and tissues in the human body. This makes them compatible with human proteins and allows them to be easily identified and accepted by the body. Due to the fat-soluble structure and very small-size molecules, essential oils serve as transport agents that easily penetrates the cell membrane. Only one application of essential oils is sufficient to stimulate and revitalize the entire body. Recent research has shown that essential oils are able to penetrate the barrier blood/brain due to their small size (≤500 amu) [7].

2. Chemical composition of essential oils

Essential oils represent less than 5% from vegetal dry matter and are complex mixtures of volatile compounds extracted from plants [8].

Chemical composition of the main essential oils used in textile industry, identified by gas chromatography (GC) and GC-mass spectrometry (GC-MS), is presented in **Table 1**:

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Essential oil	Chemical type	Main compounds	Composition (%)	References
Peppermint	Oxygenated compounds	Menthol	36	[11]
		Menthone	21.24	
		Menthyl acetate	6.92	
		Eucalyptol	6.58	
		Isomenthone	4.71	
		Neomenthol	4.06	
	Bicyclic sesquiterpene	β-Caryophyllene	2.07	
	Monoterpenes	Pulegone	1.72	
		D-Limonene	2.09	
		β-Pinene	1.02	
		Menthofuran	3.00	
Citronella	Oxygenated compounds	Citronellal	55.24	[12]
		Citronellol	13.41	
		Geraniol	26.29	
Thyme	Oxygenated compounds	Carvacrol	14.1–77.6	[13]
		Thymol	0.5–27.8	
		Borneol	0.2–16.3	
	Monoterpenes	γ-Terpinene	3.8–6.6	
		p-Cymene	3.5–7.9	
		α-pinene	1.2–7.8	
Ocimum sanctum L.	Oxygenated compounds	Carvacrol	2.04	[14]
		Eugenol	61.30%	
	Bicyclic sesquiterpene	β-Caryophyllene	11.89%	
	Monocyclic sesquiterpenes	Germacrene-D	9.14%	
	Tricyclic sesquiterpene	α-Cubebene	2.54%	
	Byclic sesquiterpenes	β-Selinene	1.34%	
Lavender	Monoterpenes	α-Pinene	3.4%	[15]
	Oxygenated monoterpenes	1,8-cineole	33.0%	
		Camphor	23.1%	
		α-Bisabolool	14.1%	
	Monoterpene	β-Pinene	4.1%	
Sage	Oxygenated monoterpenes	1,8-cineole	13.7%	
		Camphor	23.8%	
	Bicyclic monoterpene	cis-thujone	5.9%	
		Camphene	5.2%	
Rosemary	Bicyclic Monoterpenes	α-Pinene	28.2%	

Essential oil	Chemical type	Main compounds	Composition (%)	References
	Oxygenated monoterpenes	1,8-cineole	7.4%	
		Camphor	7.9%	
	Oxygenated compounds	Borneol	6.5%	
Chamomile	Monoterpenes	Sabinene	27.9%	
		β-Pinene	16.0%	[16]
		Limonene	2.0%	
	Oxygenated compounds	4-terpineol	1.4%	
	Monoterpenes	α-Pinene	43.9%	
Lemongrass	Oxygenated compounds	α-Citral (geranial)	43.356	[17]
		β-Citral (neral)	36.548	
		Geranyl N-butyrate	2.661	
	Sesquiterpenes	β-Caryophyllene	1.998	
	Monoterpene	cis-Verbenol	1.495	
		Camphene	1.005	
Citrus	Monoterpenes	Limonene	84.73–98	[18, 19]
		β-Pinene	1.37–3.36	
		Sabinene	0.28	
		α-Pinene	0.27–1.06	
		Myrcene	1.2–2.16	
	Oxygenated compounds	Octanol	0.34–0.54%	
		L-α-Terpineol	2.80	
		Terpinen-4-ol	1.18	
Geranium	Oxygenated compounds	Citronellol	26.7	[20]
		Geraniol	13.4	
		Nerol	8.7	
		Citronellyl formate	7.1	
		Geranyl formate	2.5	
	Sesquiterpenes	β-Caryophyllene	1.5	
		10-epi-g-Eudesmol	4.4	
	Oxygenated compounds	Geranyl propionate	1.00	
		Geranyl tiglate	1.0	
		Geranyl butyrate	1.4	
Turmeric	Sesquiterpenes	α-Phellandrene	33.9	[21]
	Oxygenated monoterpenes	Eucalyptol (1,8-cineole)	10.6	
	Monoterpenes	Terpinolene	21.1	

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Essential oil	Chemical type	Main compounds	Composition (%)	References
		α-Pinene	1.7	
		Myrcene	3.3	
		p-Cymene	5.6	
		γ-Terpinene	2.9	
	Oxygenated compounds	Carvacrol	2.2	
		Curlone	1.3	
Eucalyptus	Monoterpenes	α-Pinene	3.8	[22]
	Sesquiterpenes	α-Phellandrene	1.9	
		Aromadendrene	19.7	
		Allo-aromadendrene	2.5	
		Ledene	3.1	
	Oxygenated monoterpenes	Eucalyptol (1,8-cineole)	19.8	
		Isovaleraldehyde	2.4	
	Oxygenated Sesquiterpenes	Epiglobulol	6.4	
		Globulol	23.6	
		Eudesmol	2.1	

Table 1. Chemical composition of essential oils.

2.1. Terpene hydrocarbons

Terpenes are found in a wide variety of essential oils and many of them are of industrial importance [4]:

- *Monoterpene hydrocarbons*: Monoterpene consists of two isoprene units and can be classified into three categories: acyclic, monocyclic and bicyclic. The chief sources of the monoterpenes and their derivatives are the essential oils obtained by distillation or extraction under pressure of various plant parts [9].
- *Sesquiterpenes*: Sesquiterpenes are made of isoprene units and have empirical formula of $C_{15}H_{24}$. Some plant-derived sesquiterpenoids have been identified as anti-inflammatory and anti-carcinogenic species [10].

2.2. Oxygenated compounds

- *Phenols* (thymol, eugenol, carvacrol and chavicol);
- *Alcohols* (linalol, menthol, borneol, santalol, nerol, citronellol and geraniol);
- *Aldehydes* (citral, myrtenal, cuminaldehyde, citronellal, cinnamaldehyde and benzaldehyde);

- *Ketones* (carvone, menthone, pulegone, fenchone, camphor, thujone and verbenone);
- *Esters* (linalyl acetate, geraniol acetate, eugenol acetate and bornyl acetate);
- *Lactones* (nepetalactone, bergaptene, costuslactone, dihydronepetalactone and alantrolactone);
- *Coumarins* (warfarin, acenocumarol and phenprocoumon);
- *Ethers* (linalyl acetate, geraniol acetate, eugenol acetate and bornyl acetate);
- *Oxides* (bisabolone oxide, linalool oxide, sclareol oxide and ascaridole).

3. Application of essential oils in textile field

Due to essential oils that can act both at local level and through odor, they have great important applications in many fields such as food, cosmetics, medicine, tobacco, textile, leather, papermaking, pharmaceutical and perfume industries [23].

Essential oils add much value to the textile materials. The most commonly used essential oil in aroma finishing is lavender essential oil due to its properties: anti-acne, antibacterial, calming, anti-inflammatory, treatment of eczema and dermatitis. The most used essential oils in the textile industry are presented in **Table 2**.

Introducing the concept of aromatherapy, textile materials came with increasing consumer demands in terms of quality, comfort and functionality of textiles. There was a shift in their

Essential oil	Final product destination/effect	References
Peppermint	Sedative, stimulatory, antiviral, and antibacterial properties	[24]
Citronella	Mosquito repellent	[25]
Thyme *Ocimum sanctum* L.	Antimicrobial natural textiles	[26, 27]
Lavender	Garment's packaging and storage system Health and well-being Medical applications in treatments at skin level Antibacterial textiles	[28–30]
Chamomile	Garment's packaging and storage system Health and well-being	[31]
Moluccella spinosa L.	Antibacterial activity for historical textiles	[32]
Lemongrass	Antibacterial and antifungal properties	[33]
Citrus species	Medical textiles Fragrant textiles Cosmetic textiles	[34–37]
Geranium	Health-care textiles	[38]
Turmeric	Food-packaging materials	[39]
Eucalyptus	Antibacterial wound dressing	[40]
Rosemary Sage Lavender	Health-care textiles Antimicrobial skin-care textiles Nonwoven textile shoe insoles	[41–43]

Table 2. Major essential oils used in textile finishing.

values. Instead of wanting the finest natural materials, people look at beauty through engineering, innovative design, smart appearance and added value of products [44].

Aroma finish is a process by which the textile materials are treated with bioactive systems (e.g., chitosan/essential oil, alginate/essential oil systems) and finally get the multifunctional properties such as therapeutic effects and a feeling of well-being and freshness in the wearer.

Aromatherapy textiles are used in medicine and alternative healing, home textiles, body-care textiles, household cleaning and cosmetic products.

Aromatherapeutic textiles first appeared on the market were scented women's tights. Hosiery and intimate apparel have been the more widely explored product categories to apply aroma finishing. In recent years, a number of companies around the world turned their attention to aromatherapy textiles. Woolmark™ is applying aroma technology to hosiery, lingerie, socks, outdoor clothing, underwear, carpeting and other interior textiles. The Invista Company, owner of fiber brands such as LYCRA®, TACTEL® and SUPPLEX®, launched the LYCRA® Body Care Collection that includes moisturizing and fragrance features in the yarns to enhance the wearer's sense of well-being in the intimate apparel category. The Nike clothing brand has also explored encapsulation methods to a limited extent [45, 46].

Cooperation of specialists from medical and textile fields leads to rapid development in various fields, such as medical, barrier, hygiene and controlled-release textiles. Textiles used for obtaining aroma products are presented in **Table 3**.

Textiles	Destination	References
Linen/cotton blended fabric 100% eco-friendly cotton knitted fabrics Cotton/regenerated bamboo (50/50) knitted fabrics Flax knitted fabrics	Antimicrobial protection	[47–57]
knitted fabrics (plain stitch) of polyamide	Cosmeto-textiles	[48]
Pure cotton Polyester/coton (40:60) blend fabrics Silk Synthetic fibres (polyamide or polyester)	Flavors and fragrances in textile applications	[49–52, 55, 56]
100% Viscose Hydroentangled nonwoven	Medical textiles	[53]
Nylon net fabrics Cotton fabrics	Mosquito repellent efficiency	[54]

Table 3. Textiles used in aromatherapy.

4. Embedding techniques of essential oils

Losses by evaporation and difficulties in their controlled release make essential oils commercial application limited. In this case, nanocarrier systems (lipid-based particles, nanoemulsions and biocompatible polymer-based particles) can provide an ideal solution for realizing a controlled and targeted delivery of the essential oil. In the last few years, the application of a biocompatible and biodegradable polymer-based formulations as a controlled-release form has generated immense interest [58]. Because polymers (e.g., chitosan, alginates, starch, poly (DL-lactide-co-glycolide), poly-ε-caprolactone, polyethylene glycol, gum Arabic, maltodextrin, modified starches, mesquite gum) are friendly for the environment and safe for human health, they are commonly used in medicine, pharmacy, textiles, food and other fields [59]. As known, essential oils are adsorbed by the skin from the textile fabric through a mechanism of controlled release [60].

Bioactive systems are applied to the textile materials by a variety of techniques such as follows.

4.1. Microencapsulation techniques

Microcapsules are spherical or irregular shape (1–100 μm) containing one or more active ingredients (core) coated by synthetic or natural polymer (shell) material which gives controlled release of core materials. The core may contain a solid or liquid substances, solutions or suspensions and mixture of solids or liquids.

The shell material is generally formed of a polymer that must meet some conditions:

- Physicochemical compatibility with the core material
- Flexibility
- Impermeability
- Stability

Compatibility from core and wall material is an important criterion for efficacy microcapsules. Core size plays an important role in the diffusion, permeability, or controlled release of the active compound. The wall material protects temporarily or permanently the core from external factors and may be:

- Permeable
- Semipermeable (wall material is impermeable to the active compound and permeable to liquids with low molecular weight)
- Waterproof (membrane protects the active compound from external factors. Active compound is released by breakage or degradation of the wall) [61]

The main used methods of microencapsulation are shown in **Table 4** [62].

Microcapsules (core-shell system) in terms of morphology can be classified into mononuclear and polynuclear matrix (**Figure 2**).

Microencapsulation techniques			
Chemical methods	Simple coacervation Complex coacervation Coacervation phase separation Solvent extraction Solvent evaporation In situ polymerization Interfacial polymerization Nanoencapsulation Matrix polymerization Liposome polymerization	Physical methods	Spray drying Spray chilling Pan coating Rotary disk atomization Air-suspension coating Stationary nozzle coextrusion Multiorifice-centrifugal process Centrifugal extrusion

Table 4. Encapsulation process.

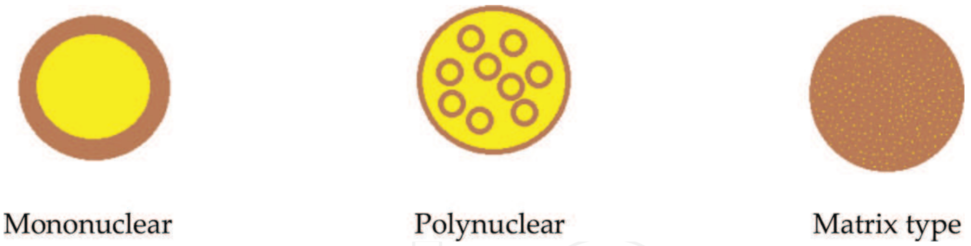

Figure 2. Morphology of microcapsules.

The microcapsules have many advantages, among which the most important are:

- protection of biologically active compound against environment;
- extends the life of biologically active compound by avoiding degradation reactions (oxidation and dehydration);
- controlled release of biologically active compound;
- microorganisms and enzyme immobilization.

The main useful shell materials used for obtaining microcapsules are presented in **Figure 3**.

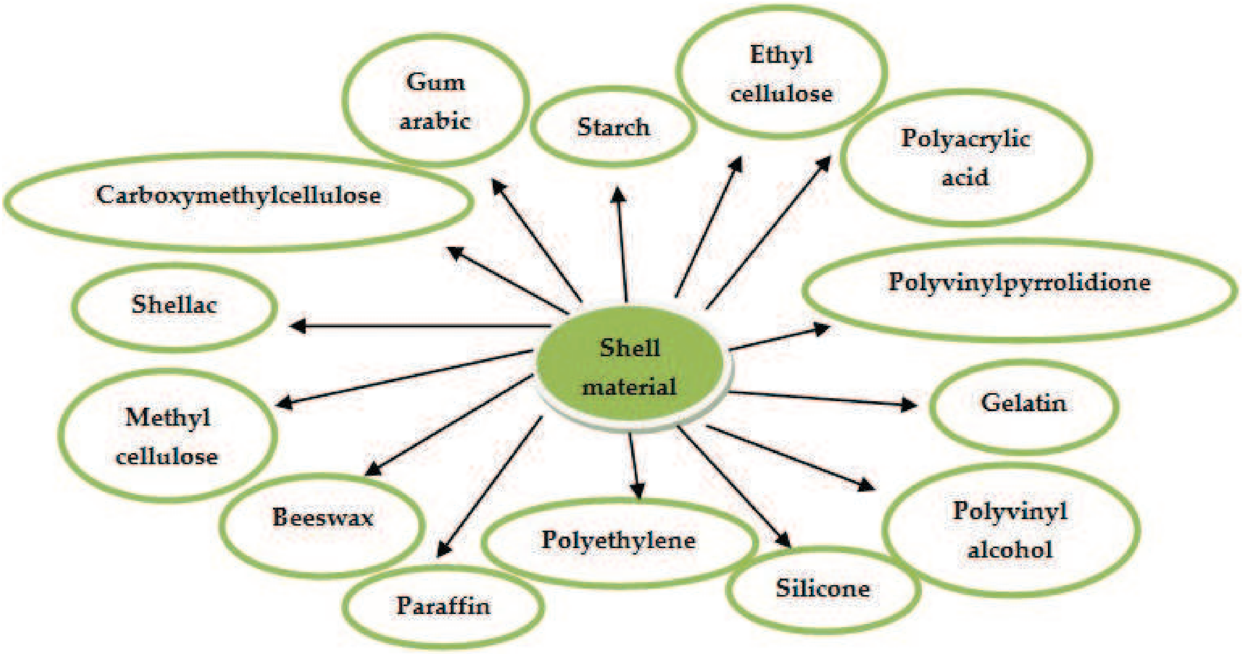

Figure 3. The main useful shell materials.

4.2. Application of biologically active compounds in the form of hydrogels

Hydrogel is a water-swollen and cross-linked polymeric network produced by the reaction of one or more monomers. The hydrogels can be classified on different bases as detailed below [63]:

Hydrogel source:

- Natural

- Synthetic hydrogels

Polymeric composition:

- Homopolymeric hydrogels

- Copolymeric hydrogels

- Multipolymer interpenetrating polymeric hydrogel

Hydrogels configuration:

- Amorphous hydrogels

- Semicrystalline

- Crystalline

Type of cross-linking:

- Chemically cross-linked networks

- Physical cross-linked networks

Physical appearance of hydrogels:

- Matrix

- Film

- Microsphere

Network electrical charge:

- Nonionic

- Ionic

- Amphoteric

- Zwitterionic

4.3. Application of biologically active compounds in the form of polymer matrices

There are various materials that can be used to attach the biologically active compounds, such as synthetic polyelectrolytes, natural polyelectrolytes, inorganic nanoparticles, fats, dyes, or polyvalent ions.

Generally, for polymer matrices, two classes of materials were used:

Natural materials [64] include

- Carbohydrates: agarose, carrageenan, alginate, chitosan, gellan gum and hyaluronic acid

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- Proteins: collagen, gelatin, fibrin, elastin, silk fibroin

Synthetic polymers [65]: aliphatic polyesters, polyacrylates, polyamides, polyepoxides, polyphosphazenes and poly(ethylene glycol).

4.4. Functional coatings

Functional coatings are applied to textile surfaces for decorative, protective, or functional purposes. The term "functional coatings" describes systems that presents besides basic functions (protective and decorative) and additional functions [66].

Functional coatings can be classified according to their characteristics [67] as follows:

- Functional coatings with optical properties (fluorescent, phosphorescent, or photochromic coatings)
- Functional coatings with physicochemical properties (hydrophilic or hydrophobic coatings)
- Functional coatings with thermal properties (heat-resistant coatings)
- Functional coatings with mechanical properties (anti-abrasive coatings)
- Functional coatings with electric/magnetic properties (antistatic, conductive, dielectric, or piezoelectric coatings)
- Functional coatings with hygienic properties (antimicrobial coatings)

4.5. Application of biologically active compounds by activating the textile support

Plasma treatment of textile materials is an alternative to chemical treatments in order to obtain new characteristics of the final product.

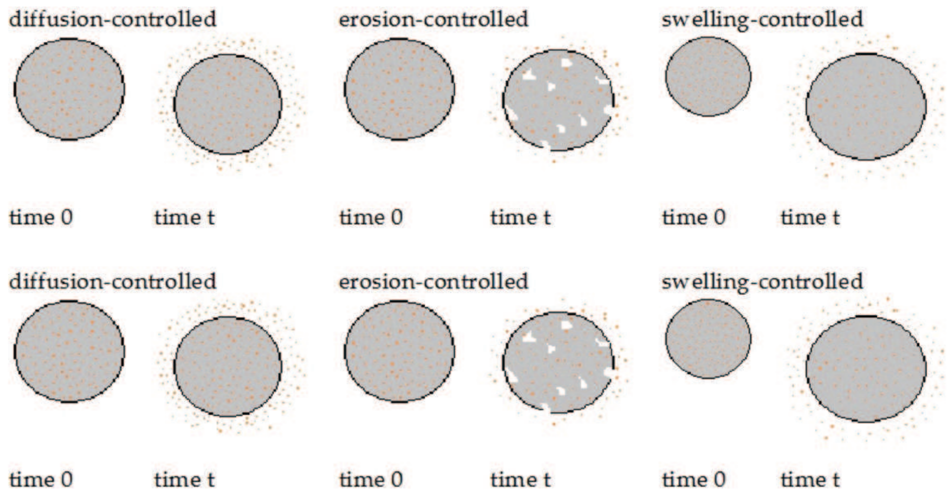
Usually, it is used in low-pressure plasma treatments and atmospheric pressure plasma treatments of textiles (ex. for hydro- and oleo-repellence). For the enhancement of the wettability of different fabrics, the plasma treatment with a dielectric barrier discharge [68] is most often used.

The main plasma treatment effects are increasing the hydrophilic character, enhancing adhesion (composite materials, coated and laminated textiles), improving dyeing and printing properties, hydrophobicity and oleophobicity, deposition of fiber coatings (metallic coatings and polymer coatings), surface cleaning, inactivation of microorganisms, influencing physical properties of fibers (optical, mechanical and electrical properties), shrink-proofing of wool, improving the efficiency of wet-finishing processes and formation of radicals [69].

4.6. Controlled release of essential oil

Micro-encapsulation ensures the storage life of essential oils and can effectively control the release rate of the biologically active compounds.

Controlled release of biologically active compounds from shell material can be classified as [70] follows:



The methods for investigating the kinetics of biologically active compound release from controlled-release formulation can be classified into three categories [71]:

- Statistical methods
- Model-dependent methods: zero-order, first-order, Higuchi, Korsmeyer-Peppas model, Baker-Lonsdale model, Weibull model and so on
- Model-independent methods: difference factor (f_1), similarity factor (f_2)

The most used methods to investigate the release profile of essential oils are model-dependent methods. For empirical/semi-empirical mathematical modeling of biologically active compounds from polymeric layer, the Korsmeyer-Peppas model is generally favorable and is based on the Fickian diffusive release from a thin polymeric film [72]:

$$M_t/M_\infty = k \cdot t^n \tag{1}$$

where

K—Peppas release rate constant;

t—time (s);

Mt/M_∞—fraction of active compound released at time t;

n—the release exponent.

Transport mechanisms of active principle function are shown in **Table 5**.

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The release mechanism for the biologically active compound from the textile supports is primarily based on the diffusion process of the oil molecules. The main mechanism of essential oils release from shell materials is presented in **Table 6**.

Release exponent (n)	Active compound transport mechanism	dM_t/dt as a function of time
$n = 0.5$	Fickian diffusion	$t^{-0.5}$
$0.5 < n < 1$	Non-Fickian transport	t^{n-2}
$n = 1$	Case II transport	Zero-order release
$n > 1$	Super case II transport	t^{n-1}

Table 5. Transport mechanism of biologically active compound.

Essential oil	Shell material	Release mechanism	References
Rosemary	Chitosan film	Non-Fickian mechanismZero-order mechanism	[73]
Geranium	Chitosan matrix	Fickian mechanism	[74]
Citronella	GelatinGum Arabic	Fickian mechanismNon-Fickian mechanism	[75]
CloveThyme	Orabase	Mixed mechanism	[76]
Tea tree	Sodium alginate/quaternary ammonium salt of chitosan	Ritger-Peppas mode	[77]
Calendula officinalis L.	Chitosan grafted with sodium acrylate-co-acrylamide	Non-Fickian (coupling of Fickian diffusion and relaxation of entangled chains of the encapsulating polymer)	[78]
Coriandrum sativum L.	Chitosan/alginate/inulin microcapsules	Non-Fickian transport mechanism (diffusion or diffusion-swelling-controlled process)	[79]
Peppermint Eucalyptus	Polyvinyl pyrolidine (PVP)Ethyl cellulose (EC)	Zero-order release kinetic	[80]
Cardamom	Alginate-whey protein	Fickian diffusion	[81]

Table 6. Controlled release kinetics.

5. Conclusions

Aromatherapeutic textiles are a good choice for people who want to maintain harmony between their physical and psychological comfort. Applying of essential oils on textile materials shows great potential for the value-added textiles. Aromatherapy textiles application in various fields (cosmeto-textiles, home textiles, sport wears, medical textiles, etc.) made them indispensable in day-to-day life.

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