20 Encapsulation of Fragrances and Flavours: a Way to Control Odour and Aroma in Consumer Products

Jeroen J.G. van Soest
Kerkhuisstraat 13, 7037 DE Beek (Montferland), The Netherlands

20.1 Introduction

Fragrances or aroma chemicals are an essential additive in consumer products such as household detergent and laundry products [1–4]. They provide the control of odour. The search for attractive fragrances and making aromas durable on textiles is a long-time dream for textile chemists. Delivery of fragrances from detergents onto fabric is a challenge for the fabric-care industry. But, adsorption of fragrances to clothes is poorly understood [5].

Researchers are looking at controlled-release scents in order to extend fragrance longevity [6]. Encapsulation is a good route to control fragrance release and to make more durable fragrant finishing on textiles. However, the affinity between encapsulated aromas and fabrics is still a problem. Many washing products contain surfactants, which form micelles in water. As many fragrances are hydrophobic they tend to migrate to the micelles, rather than deposit on the substrate. A fixing agent can be applied with capsules on a fabric, but the fabric must pass a curing process to fix the capsules. Recently also various detergents were introduced on the market containing additives that absorb odours [7]. Presently, sustainability and making non-toxic and environmentally friendly products are a must in the laundry industry. Legislation and self-imposed industrial standards will provide the consumer with safe new products [8–10]. More efficient products are sought which reduce the amount of aroma chemicals which end up in the environment, for instance via the sewer. (Micro)encapsulation can be an important tool to protect unstable or non-substantive biodegradable fragrances from aggressive detergent components [11]. Also encapsulation, using natural products, could have a positive effect on reducing the frequency of perfume dermatitis in humans [12].

In this chapter, several (biopolymer-based) materials and encapsulation routes will be discussed in relation to their suitability for use as odour control in consumer and detergent products. The discussion of selected applications will illustrate current developments of delivery systems in perfumed laundry or home-care products.

20.2 Encapsulation

Encapsulation has been used in the pharmaceutical industry for many years, for controlled release and delivery of drugs [13]. Because of the additional high costs of early encapsulation techniques, the applicability of encapsulation has been limited. However, more cost-effective techniques and materials have been developed and production volumes are increasing; therefore, the application range has broadened, in particular in foods and consumer products [14–19]. One of the main application areas is encapsulation of aroma chemicals, flavour and fragrances. In the last decade the demand for fragranced products has been growing, and it is thought it will expand and diversify in the future. The following are examples of typical fragranced consumer products: air fresheners bath additives, candles, decorative cosmetics, deodorants, antiperspirants, perfumes, soaps, and hair-care, household, oral hygiene, personal-care, shaving, skin-care and laundry (detergents, softeners) products.

Detergent and laundry products, in general, have a fragrance level in the range 0.2–1%. Perfumes are added to fulfil three tasks:

1. To mask unpleasant odours of cleansing agents
2. To give the message of cleanness during storage and use
3. To impart a nice smell to the fabric

Encapsulation is an elegant way of improving the performance, such as substantivity, tenacity or endurance, of perfumes in washing powders, tablets or conditioners. The performance of fragrances tends to fade by evaporation, interactions with other components, oxidation and chemical degradation. Encapsulation can be the answer to various problems:

- Reduce the reactivity of the fragrance with the outside environment, for example oxygen, pH and water
- Decrease the evaporation rate of the fragrance, control the release rate and provide sustained release
- Promote the ease of handling of the fragrance
- Prevent lumping
- Improve the compatibility with other constituents
- Convert a gas or liquid to a solid form
- Promote easy mixing
- Dilute the core material to achieve uniform dispersion in the product
- Stabilise and protect the fragrance during storage
- Reduce the losses (of top notes) during repeated opening of the packages
- Increase use levels without affecting solubility and dispersing behaviour
- Reduce loss levels in washing water and sewers
- Extend shelf life
- Increase deposition and adhesion on textiles

20.2.1 Matrix or Coating Materials

There are three main types of encapsulated products based on size roughly divided into:

1. Macro-coated powders with sizes larger than 0.1 mm
2. Matrix microparticles or microcapsules with sizes in the range 0.1–100 μm
3. Nanoparticles or nanocapsules with sizes smaller than 0.1 μm

Macro-coating is used mainly to stabilise fragrances or transform them from liquid to free-flowing solid powder. Microencapsulation or nanoencapsulation is the process of enclosing a substance inside a miniature capsule. These capsules are referred to as microcapsules or nanocapsules. The substance inside the capsule can be a gas, liquid or solid. The capsule wall can consist of various materials, such a wax, plastic or biopolymers like proteins or polysaccharides.

In the literature a difference is made between "matrix" encapsulation and "true" encapsulation. In matrix encapsulation the resulting particles are more correctly described as aggregates of actives in a matrix material. A significant portion of the active is lying on the surface of the particles. True encapsulation is used for processes leading to core–shell-type products. However, this distinction of true and matrix is prone to argumentation.

The products can have a variety of shapes, such as spherical, oblong or irregular, can be monolithic or aggregates, and can have single or multiple walls. In Fig. 20.1 some typical morphologies of capsules are shown. The capsules consist of the coated or entrapped materials referred to as active, core material, fill, internal phase or payload (such as aroma chemicals). The coating or matrix material is called wall, membrane, carrier, shell or capsule.

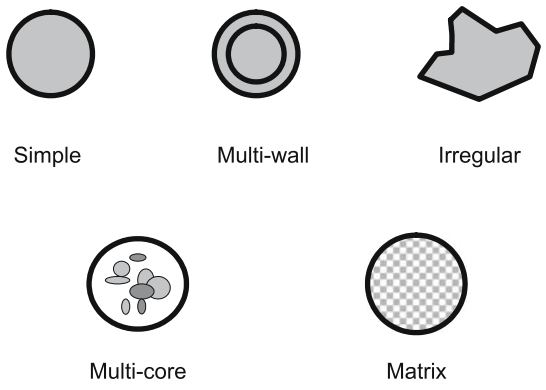

Fig. 20.1 Some typical forms of capsules

Amongst the most commonly used matrix materials are:

- Polysaccharides and sugars (gums, starches, celluloses, cyclodextrin, dextrose, etc.)
- Proteins (gelatin, casein, soy protein, etc.)
- Lipids (waxes, paraffin, oils, fats, etc.)
- Inorganics (silicates, clays, calcium sulphate, etc)
- Synthetics (acrylic polymers, poly(vinylpyrrolidone), etc.)

Biodegradable polymers, both synthetic and natural, have gained more attention as carriers because of their biocompatibility and biodegradability and therewith the low impact on the environment. Examples of biodegradable polymers are synthetic polymers, such as polyesters, poly(*ortho*-esters), polyanhydrides and polyphosphazenes, and natural polymers, like polysaccharides such as chitosan, hyaluronic acid and alginates.

20.2.2 Hydrophilic Matrices

Encapsulation of volatiles in glassy or crystalline matrices is used to extend the shelf life of aroma chemicals. Polysaccharides and glassy sugars, such as starch and maltodextrins, are very suitable for encapsulation of hydrophobic actives owing to the low solubility and low free volume in the glass available for diffusion [20, 21]. Furthermore, hydrophilic matrices have a low oxygen permeability, making them a protective environment for fragrances subject to oxidation.

20.2.3 Processing Routes

Various routes are available based on methods such as spray-drying, spray-cooling/chilling, spinning disk and centrifugal coextrusion, extrusion, fluidised bed, (complex) coacervation, alginate beads, liposomes, supercritical solution and inclusion encapsulation. For most techniques solvent evaporation (drying of water or evaporation of organic solvent in emulsions) plays an important role. Some typical examples are discussed inn the following subsections.

20.2.3.1 Spray-Drying

Spray-drying is an economical effective method widely used for flavour encapsulation [22–27]. The technology has been used in the food industry since the late 1950s to provide protection of aroma chemicals against oxidation or degradation and to convert liquids into free-flowing solids. The main limitations

of the technology are that the process needs shell materials, which are soluble in water at acceptable levels and loss of significant amounts of actives. Typical shell materials are gum arabic, maltodextrins and modified starches. The usage of other polysaccharides and proteins is often very tedious and more expensive. The higher the water content in the feed, the higher the energy costs in evaporating the water during the process. Payloads of up to 50% have been achieved, while maintaining free-flowing properties. Double-layered microcapsules have been made using aqueous two-phase systems or multiple emulsions.

20.2.3.2 Spray-Cooling—Chilling

Spray-cooling or chilling is one of the least expensive methods, where the active is mixed with the carrier and atomised using cool air [14–16]. The matrix material is usually a regular, hydrogenated or fractionated vegetable oil. Spray-cooling is a matrix encapsulation method. A significant amount of the active is located at the surface, making the technique less efficient for volatile perfumes. Combinations of spray-drying and spray-cooling have also been described; however, the combined routes are more expensive and lead to low payloads.

20.2.3.3 Extrusion

Microencapsulation using extrusion is mainly described for glassy carbohydrate matrices [14–16, 28–29]. The glassy carbohydrates, such as starch and maltodextrins, are melted at elevated temperature and low water contents and are intensively mixed with the active in the extrusion barrel. Extrusion has been used for volatile and unstable flavours. The shelf life of flavour oils could be extended from several months to 5 years, compared with 1 year for spray-dried materials. The main drawbacks of the technology are the high investments costs and the formation of rather large particles (500–1,000 μm).

20.2.3.4 Rotational Suspension Separation

This is a relatively new technology involving mixing of the core and wall material and a rotational or centrifugal step [14–16]. Typical and similar processes are spinning disk and centrifugal coextrusion. The techniques are industrial alternatives for other traditional encapsulation methods using conventional devices to atomise suspensions or emulsions such as spray-draying or spray-cooling. Spinning-disk technology is an interesting route because of the high throughput and similar processing costs as spray-drying and spray-cooling. The

continuous process can take place within seconds to minutes. Solids, liquids or suspensions of 30–200 μm can coated with a layer of 1–200 μm of matrix material. Typical matrix materials are meltable hydrophobic substances such as fats and poly(ethylene glycol). Centrifugal extrusion has been performed using various biopolymer coatings, such as alginates, gums and caseins, giving spherical microcapsules. The technique is more prone to clogging than spray-drying.

20.2.3.5 Air Suspension or Spray-Coating

Air suspension coating is done by suspending a solid core material in a fluid bed of heated or cooled air and spraying the solid with a molten or dissolved matrix material [14–16]. Fluidised-bed technology can be used to apply a uniform layer of almost any kind of material (polysaccharides, proteins, fats, etc.) [30]. The technology is limited to solids or frozen products with minimal particle sizes of approximately 100 μm, making it not so suited for most fragrances. An agglomeration or granulation step can be an integral part of this technology, leading to perfume materials with controlled-release features of fragrances in wash liquors.

20.2.3.6 Coacervation

Coacervation [14–16] consists of the following steps:

1. Disperse the oil (active) in n solution of a surface-active hydrocolloid.
2. Precipitate the hydrocolloid onto the oil by lowering the solubility of the hydrocolloid (add a non-solvent or change pH or temperature).
3. Induce the formation of a polymer–polymer complex by addition of a second complexing hydrocolloid.
4. Optionally, add a cross-linker to stabilise or improve barrier properties of the microcapsules.
5. Dry the material to form microparticles with sizes of 10–250 μm.

Simple or complex coacervation is still not commonly used to encapsulated flavours or fragrances. The technique is complicated and expensive to use. In particular for food ingredients, there are only a few food-grade coating polymers available, such as gum arabic and gelatin. For gelatin systems, additional cross-linking of the shell is done using glutaraldehyde, making it less "label"-friendly. Eventually harmful cross-linkers could be replaced by enzymatic treatments, although industrially viable enzymes are presently not available. It is said that the processing costs can be reduced by optimisation of the drying step. By

replacing the usual isolation-drying step (filtration followed by fluidised bed or freeze drying) with a spray-drying step, costs can be reduced significantly. The advantage of coacervation is the efficiency in encapsulation of the actives making high payloads possible of more than 90%. The technique is used for encapsulation of essential oils and fish oil.

20.2.3.7
Emulsion and Interfacial Polymerisation

Microcapsules can be made using oil-in-water or water-in-oil emulsions (or multiple emulsions) [14–16, 31]. The actives are trapped inside a monomer or polymer matrix, which can be polymerised and cross-linked. After breaking the emulsions, the microcapsules can be dried by solvent evaporation or other drying methods. Interfacial polymerisation occurs with monomers or polymers with surface-active properties or which are rendered insoluble by the polymerisation or cross-linking reactions [32]. Polymerisation takes place at the water–oil interface. The use of these methods is limited since the preferred matrix or coating materials are non-renewable or non-food grade, such as polyesters, polyamides, polyurethanes, polyacrylates or polyureas, often leaving traces of toxic monomers. More recently also polysaccharide-based systems have been described using food-grade cross-linkers.

20.2.3.8
Miscellaneous Routes

Various routes are described in the literature which are based on very specific interactions of actives with a specific polymer or coating molecule or specific processing techniques [14–16]. Some of them are mentioned next.

20.2.3.8.1
Liposomes

Liposome entrapment [14–16] is mainly used in pharmaceutical and cosmetic applications. Liposomes (the most common being phospholipids) can form membrane-like vesicles, with diameters in the range 25 nm–10 μm, which show selective permeability for small molecules. Both hydrophobic and hydrophilic ingredients can be entrapped. Application of liposome entrapment is still limited in food (flavour) or fragranced household products because of the high price of phospholipids and difficulties in scaling up the process at acceptable cost in use and creating a good delivery form. Research is progressing in finding cheap alternatives for phospholipids based on hydrophobic emulsifiers and using microfluidisation as a cost-effective continuous processing method.

20.2.3.8.2
Inclusion Complexation

Inclusion complexation or molecular encapsulation is based on the molecular inclusion of an active inside the cavity of another molecule. The most well-known systems are based on cyclodextrins [33]. Cyclodextrins are used to protect heat-, light- or oxygen-sensitive ingredients. They are used to increase the solubility of hydrophobic substances and to reduce the volatility of aroma chemicals. The central cavity of the cyclodextrin is hydrophobic, making it attractive for hydrophobic substances to occupy it. To obtain complexation, guest molecules are coprecipitated or cocrystallised from aqueous solution. To obtain high loadings from hydrophobic actives with low solubility, the method is expensive because of the high drying costs and the high price of cyclodextrin.

Although in principle amylose can also be used to form inclusion complexes, its use is not widespread because of the low solubility and high price of pure amylose and the low specificity of high-amylose containing starches [34].

20.2.3.8.3
Alginate Beads

Gelling gum based beads can be produced very easily on a laboratory scale [16]. The technique is well described in scientific literature for the preparation of alginate-based microcapsules [35]. Scaling up of the small batch process to an economically viable process is difficult, although recently several methods have been described to facilitate scaling up. Furthermore the beads are very porous, making them not very suitable for aroma chemicals, where extended shelf life or sustained release is wanted. Most attention has been given to alginates (being easy to use and renewable). However other gelling agents are being used already in various fragranced consumer products, such as gellan and carrageenan.

20.2.3.8.4
Cocrystallisation

Cocrystallisation is mainly done from supersaturated sugar solutions [15]. Aggregated particles (of 3–30 μm) of sugar crystals are formed which entrap guest molecules. The sugars form an oxygen barrier, thereby extending the shelf life of aroma chemicals. The procedure is simple and inexpensive, because relatively cheap encapsulation matrices can be used, such as sucrose.

20.2.3.8.5
Supercritical Solutions

Supercritical solutions can be regarded as dense solvating gasses or low-viscous low-density liquids. The most well-known and probably most interesting candidate is based on carbon dioxide. Supercritical carbon dioxide can be regarded as an organic solvent. Various concepts have been developed using supercritical flu-

ids, such as a method similar to conventional spray-drying and rapid expansion of supercritical solutions [16]. The early methods were restricted to shell materials which could dissolve in the supercritical fluid; however, a slight adaptation of the process broadened the applicability to matrix material, which can swell in supercritical fluids, such as proteins and polysaccharides. The use of supercritical carbon dioxide renders the use of organic solvents obsolete and makes the technology environmentally interesting and interesting for food applications.

20.2.4 Recent Developments and Trends

There are various reasons for applying encapsulation. Numerous patents are filed every year dealing with new microencapsulation techniques. Some of these new technologies and processes have currently no industrial relevance, because of high cost in use, difficult scale-up and narrow range of applicability. For fragranced consumer products, controlling costs is even more important than in applications found in pharmacy or even foods. The market is very competitive and therefore additional costs should be considered. But, some old or new technologies look promising for the near future. Old technologies have become more efficient and scaling-up processes have improved. Also environmental issues related to raw material use, energy and waste control are more important. Designing fragrances with better biodegradability has led to fragrances with too low stability towards oxygen and water, making them unsuitable for most applications. Encapsulation could be a good tool in protecting these fragrances.

20.2.4.1 New Technologies

Development of new encapsulation methods is time- and effort-consuming, requiring a multidisciplinary approach. In contrast with foods, materials used for fragrance encapsulation are not subject to the extensive legislation that applies to food approval. This makes the use of new materials as matrix materials easier. Some new developments with potential for the near future are discussed next.

20.2.4.1.1 Nanotechnology

Nanotechnology is hot in the world of science [36]. Research focuses on properties, which arise from scaling down structural features of materials to the nanometre range. Two strategies are used to make nanostructured materials:

1. Top down—break down larger structures
2. Bottom up–build from individual atoms or molecules capable of self-assemblage

The most important materials developed are nanocomposites and nanotubes. Fabrication of the first nanocomposites was inspired by nature (biomineralisation). Nanocomposites based on nanoclays and plastics are seen as ideal materials for improved barrier properties against oxygen, water, carbon dioxide and volatiles [37]. This makes them in particular suitable for retaining flavours in foods. The technology is rather straightforward using commercially available nanoclays and extrusion processing.

Even newer generations of nanomaterials are based on carbon nanotubes using the bottom-up approach. The materials are still very expensive, but the technology is evolving rapidly. Another type of nanotube has been prepared based on self-assembly of specific molecules such as chitosan-based nanoparticles of polypeptides, DNA or synthetic polymers. Phospholipids or dendrimer-coated particles are suitable for the entrapment of actives in very small vesicles. The current materials are still lacking in selectivity and yield (costs).

For delivery systems to be effective, the encapsulated active compounds need to be delivered to the appropriate locations, without losing activity. In particular in textile washing, fragrances need to be delivered to the cloth during washing, without losing activity during storage or without losing fragrances in the wash water. In particular, nanoparticles or nanospheres are said to have improved encapsulation and release characteristics [38]. Also the small sizes make them more suitable for adjusting the adhesion properties to various textile fibres. Although the preparation of nanoparticles is more developed for synthetics and inorganics, also biopolymer-based technologies are being developed. Examples are given in the literature of polysaccharide-based materials [39, 40].

Manipulation of materials at the nanometre level opens to door to improved functionality of aroma chemicals. However, nanotechnology needs to be made more economically viable to have lower cost-in-use.

20.2.4.1.2
Colloidosomes

A very recent development is encapsulation of actives in colloidosomes [16, 41]. The method is analogous to liposome entrapment. Selectively permeable capsules are formed by surface-tension-driven deposition of solid colloidal particles onto the surface of an inner phase or active ingredient in a water-in-oil or an oil-in-water emulsion composed of colloidal particles. Initially synthetic polymer microparticles were used but more recently a natural alternative has been described based on small starch particles. After spray-drying, redispersible emulsions can be formed.

20.2.4.1.3
High-Pressure Gelation

High-pressure gelation could be an interesting new approach [16]. It has been shown that native starches can be gelatinised using high-pressure treatments

[42]. It is possible to control the degree of granule disintegration much better than with low-pressure gelatinisation. Also proteins can be gelled at high pressure and the microencapsulating capability of this process has been shown [16].

20.2.4.1.4
Sol–Gel Processing

The sol–gel process originates from the ceramic industry [16, 43]. It can be regarded as the inorganic analogue of interfacial polymerisation encapsulation. During the sol–gel encapsulation, an inorganic gel network is formed by gelation of a sol (a colloidal suspension). The most commonly used precursors are metal alkoxides, which can react and undergo the sol–gel transition in aqueous environment.

20.2.4.2
Recent New Materials

Besides new technologies also new materials are being found. Several (patent) overviews of the art of the encapsulation of various materials, such as flavours and fragrances, can be found in the literature [44, 45]. This section highlights some typical more recent new patented carrier materials used for improvement of fragrance performance in detergents using encapsulation methods.

New synthetic-based matrices are being developed. Enhanced deposition of fragrances to fabrics is obtained using a fragrance-containing acrylate-based gel capable of being mixed with a detergent composition [46]. Enhanced longevity is also claimed. In another invention, microcapsules are described based on free-radical polymerisation [47]. A more scientific development is based on the grafting of temperature-sensitive hydrogels to fabrics. Environment-sensitive deodorant fibres and delivery fabrics can be made on the basis of these hydrogels [48].

In particular, matrices based on polysaccharides or other biopolymers are of interest using well-known technologies such as spray-drying and extrusion. Mixtures of various carriers can be used to tailor properties such as release, deposition and substantivity [49]. A particular example of a new material used for fragrance encapsulation is the use of polysaccharide esters such as starch acetate [50]. The methods described are very easy and can be scaled up. The patent addresses the issues of fragrance stability during storage and the loss of most of the fragrances in the wash water [51]. Also matrices containing inorganic materials have been developed that are suitable for transforming fragrances into free-flowing powder with improved deposition properties for laundry application [52].

20.3 Performance of Fragrances in Consumer Products

To be able to bring the "message of freshness, cleanness, newness" of fragrances to the consumer, it is of great importance to understand the way fragrances work in various applications and environments [3, 4, 53–58]. Research has focused on the interactions with the complex chemical compositions of the various products and the targeted substrates. The way the consumer perceives the odours depends not only on the fragrance composition but also on the other components and on the type of substrate, such as fabric, floor, hair and skin. A classification of perfumed consumer products can be made depending on how the product is transferred to the substrate:

- Direct application of the perfumed product to the substrate (e.g. deodorant, cream)
- Transfer of the product via a wash or rinse step (e.g. detergent, softener, shampoo)

The consumer experiences various stages in perceiving the odour sensation:

- Odour of the product
- Wet odour impact
- Dry odour (*tenacity*) or initial dry odour impact (*perceived substantivity*)
- Odour during use (*long-lasting*)

It is clear that encapsulation has a strong effect on all of these properties. In using encapsulation for the design of new fragranced consumer products, the effects have to be taken into account in the reformulation procedures.

Measurements of fragrance performance involve the following aspects:

- Control of experimental settings
- Dynamics if processing (e.g. drying rate and temperature)
- Interpretation in terms of olfactory dose–response characteristics

Without a doubt the process is influenced by factors such as water solubility and hydrophobicity of the fragrance constituents and the presence of surfactants and cosurfactants, and many more. To help the development of effective fabric-care products, it is important to develop a better understanding of the factors that influence retention of aroma chemicals on textiles and their release. New methodologies, also used to study the distribution of chemical finishing agents and soils on fibres, can be helpful to study the distribution of unsaturated aroma chemicals on textiles, in order to gain a deeper understanding of the mechanisms of their deposition, adsorption and retention on fabrics. One of the main tools in measuring odour characteristics is quantitative gas chromatography–headspace analysis [53–57]. The aroma chemical distribution on cotton, Lyocell and polyester fibres was studied using backscattered electron microscopy and X-ray microanalysis [58]. Various parameters have been identified to determine perceptible odour, such as vapour pressure, water solubility,

temperature, log*P*(oil/water) or hydrophobicity, volatility, and concentration of fragrance and other ingredients. It is obvious that most parameters will be strongly affected by the encapsulation matrix material and the method used, as illustrated in Fig. 20.2.

The selection of a specific encapsulation route or delivery system depends on the nature of the product where the delivery system will be used, on which property one wants to improve (process retention, protection, deposition or release mechanism). Fragranced consumer products can make use of a broader selection of matrices than foods and pharmaceuticals; however, there are other strict constraints. Fragrances are commodity ingredients in consumer products and additional costs owing to the encapsulation process should be low. In order to meet consumer acceptance, the products should meet the olfactory requirements. Another selection criterion is the presence of water in the product and the humidity during storage. At low water levels or in dry products, hydrophilic matrices can be used. Water is a plasticiser for hydrophilic matrices such as starches. The lower glass-transition temperature, swelling and dissolving effect of water will have a negative effect on storage stability and retention. In liquid aqueous (wet) products, hydrophobic matrices are to be used. Hydrophobic matrices are worse oxygen barriers and are less effective as a barrier for other hydrophobic ingredients. The next selection is based on the release characteristics required, such as the mechanism and kinetics (sustained versus triggered). Examples of release triggers giving burst-like release are water, heat, mechanical stress, enzymes, ion strength and pH. Additional criteria are toxicity, compatibility and biodegradability.

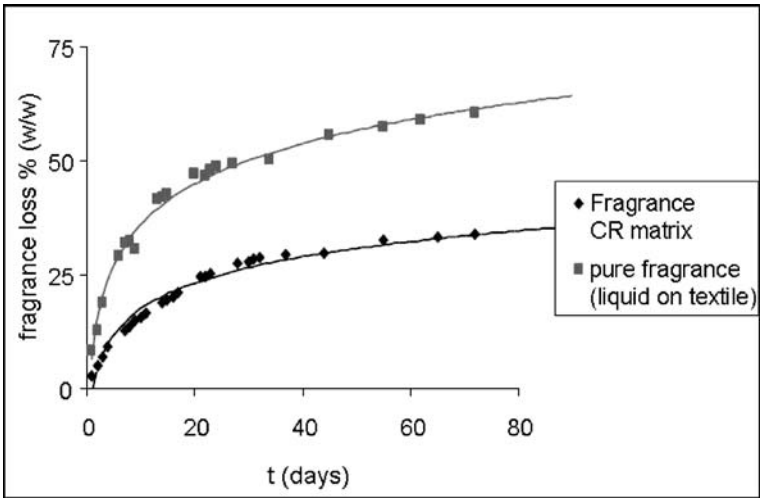

Fig. 20.2 Release profile of an encapsulated fragrance compared with that of the pure fragrance. *CR* controlled release

20.4 Market Developments and Products

There are two reasons why it is difficult to give examples of already marketed products based on encapsulation used in detergents or even household and consumer products. One is the fact that the technology is still not always applicable in a cost-effective way. The other reason is that it is not always known that an encapsulated material is used, because companies like to keep the know-how in-house. Still some technologies are being used in daily life already [1, 2, 59].

One of the widely known novelties of using microencapsulation technologies in a consumer product is the InstaScent™ (scratch and sniff) or Snap&Burst™ scented overprint varnishes. Tiny glass-based capsules contain a liquid scent and are glued onto paper. This product manufactured by Lipo Technologies is a cost-effective way of presenting fragrances to customers. When the paper is scratched, some of the capsules are ruptured and the scent is released. Another technology making use of fragrance microcapsules, which make use of triggered release by breaking the capsules, was developed by Bayer-Lanxess (Euderm® and Bayscent®). The microcapsules are prepared using interfacial polymerisation and are applied to leather or textiles by spraying.

A well-known example of the use of cyclodextrins is found in Fébrèze from Proctor & Gamble as odour control. Fébrèze, a spray used for eliminating bad odours on fabrics, has been adapted for use in fabric softener (Lenor Stayfresh). An alternative is provided by Henkel's Neutralin technology, which combines the odour-reducing zinc ricinoleate (Tegosorb™ from Degussa) with a fragrance. The material is claimed to perform better in water, making it suitable for detergent applications.

An example of a fragranced consumer product is Crayola® Magic Scent (from Binney & Smith) food-scented crayons containing gelatin-encapsulated aromas like orange, cherry, chocolate, strawberry, peach, blueberry, liquorice, lime, bubble gum, banana, lemon, coconut and grape. In personal care, Kleenex® Cold-Care facial tissues from Kimberly-Clark make use of the same type of capsules to protect volatile menthol fragrance. The Breathe Right® family of products (from CNS) and Vicks® (from Proctor & Gamble) were developed to make it easier for more people to breathe freely using encapsulated mentholated vapours.

New technologies are being developed or adapted for household cleaning and detergents. Examples are Microflex (a microemulsion delivery system for fragrances from International Speciality Products) and Hallcrest's microcapsules based on coacervation and liquid crystals. Henkel developed a new technology making it possible to selectively deposit a chemically linked fragrance compound on a fabric. Slow release is then triggered by air humidity.

Various companies are expressing there efforts in the areas of innovative delivery technologies for the soap and detergent market, such as Alco (part of National Starch and ICI), ISP, Rhodia, Cognis and Ciba. Alco has access to the flavour encapsulating starch technologies from National Starch and acquired Salvona delivery technologies and is adapting them with the focus on detergents and fabric softeners.

For powdered detergents Givaudan launched Granuscent® encapsulation technology. Protective granules are made by spray-drying a fragrance emulsion, forming a glassy hydrophilic matrix. Similar efforts are being made by Symrise (formerly Dragoco and Haarmann & Reimer). They are exploring the use of the starch-based InCap and poly(vinyl alcohol) PolyCap technology for dry products. Their urea resin or gum-based SymCap system is directed towards liquid systems. Ciba is pursuing fragrance delivery form the point of extending scent longevity on the shelf (using the excited state quencher, ESQ™, technology developed for increased colour stability).

20.5 Conclusions

Various encapsulation techniques are available for improving the efficiency of aroma chemicals in fragranced consumer products. Encapsulation techniques are still being optimised in terms of fragrance performance, scaling up and costs. Environmental aspects are becoming more important, putting constraints on the use of non-biodegradable fragrances, which are used in large excess and end up in the environment. Encapsulation could be the tool to make more efficient use of fragrances as slow or controlled delivery systems. Encapsulation opens the way in using biodegradable fragrances which could not be used before because of the too low chemical stability (during processing, storage or usage). A straightforward route to develop microencapsulated fragrance materials is to adapt existing methods developed for pharmacy, foods, agriculture or cosmetics. However, industrial constraints (cost in use) should be taken into account in a cost-competitive market area such as consumer products.

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