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Review article

Potential use of polymers and their complexes as media for storage and delivery of fragrances

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ABSTRACT

The use of fragrances is often essential to create an elegant, welcoming, or exhilarating environment. Through encapsulation, the release and delivery of fragrances are customized in many consumer products. For such purposes, cost-effective techniques have been developed and employed with the use of various polymers and porous organic materials to efficiently impart fragrances to foods and various other consumer products. After entrapment or uptake/storage of fragrant molecules within a polymeric complex, the properties can be investigated by automated thermal desorption (ATD) analysis. For efficient delivery, fragrances are adsorbed (or entrapped) in some media (e.g., fabric or paper). The release of such entrapped fragrances usually is achieved by spraying. Fragrances can be also loaded in a media by purging aroma gases or by adding fragrance essence directly into a liquid medium. Porous materials, such as zeolites, have been traditionally used for air purification as well as in cosmetics and similar applications. Similarly, other polymeric porous complexes have also been used in fragrance delivery as a templating agent for aromatherapy textiles. Such polymeric materials offer an advantage in terms of development of new hybrid blends via homogenous mixing of two or more matrices. Such blends may possess different desirable physical properties as encapsulants. This review article is aimed at presenting an overview of polymers and their complexes as the main media of fragrance encapsulation. This study also discusses the expansion and future application of porous materials as host matrices for fragrances.

1. Introduction

Fragrances are used as one of the most indispensable ingredients in food and fabric industries. Controlled delivery of fragrant molecules has remained a research focus in the flavor and fragrance industry. To elongate the limited longevity of olfactive perception, the development of pro-perfumes or pro-fragrances has attracted attention over the years. Many volatile chemical compounds have been used as perfumes or deodorants in various consumer goods. Their volatility is essential to provide a pleasant olfactory response, while this property also can be a disadvantage.

For fragrances used in various products (e.g., cosmetics, fabrics, household goods, food, and personal care products), one of the main interests is to improve the delivery of imparted fragrant molecules with controlled release and long life [1,2]. There is also great interest in infusing scent into everyday materials such as fabrics or in turning liquid flavors into free-flowing powders so as to increase their shelf life in food products [3]. Most fragrance delivery systems have the drawbacks of premature evaporation and degradation during storage. Additionally, the lifespan of flavors is short, and their perception to the sensory system is also affected by external factors like heating, oxidation, or chemical interactions. The selection method for a particular fragrance delivery depends upon the nature of the consumer goods and the stimulus that triggers the release mechanism. Hence, for the selection of a particular method, a number of criteria need to be considered [4]. First, it is important to consider the targeted application of fragrances, e.g., food items and fabrics. Second, the required level of humidity in the product is also important, as this factor is directly related to the storage conditions. The third criterion is the reaction mechanism that will be used to trigger the release of molecules [5,6].

Constraints on the use of fragrances are commonly accompanied by environmental concerns on the large-scale production of non-

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biodegradable fragrances and toxicity associated with their release. The introduction of encapsulation technique opened up the way to avoid the problems of using such products which was not possible before because of their significantly low chemical stability (during processing, storage, or usage). In fact, a straightforward route exists to develop microencapsulated fragrance material(s) which can be adopted from the pre-existing methods in other fields of applications (e.g., foods and agriculture, pharmacy, or cosmetics). Nonetheless, industrial constraint (e.g., cost in use) is an important factor to consider in a cost-competitive market area as observed from various commercial products. As such, there are at least a few parameters that should be controlled during encapsulation process such as process retention, protection, deposition, triggered release, and sustained release of volatiles. To resolve problems associated with such variables, detailed evaluation is required to assess not only the interactions between the volatile ingredients and the carrier (or encapsulant material) but also the behavior of the selected material under several application conditions.

The selection of a particular delivery system depends not only on the nature of the product in which this delivery system is to be used but also on the kind of release mechanism that is actually required. In this respect, encapsulation should be the tool to make more efficient use of fragrances as slow or controlled delivery systems. Further, for the release mechanism of fragrance, a list of factors should be considered such as its initial loading in the polymer, solubility in the solvent, equilibrium partitioning between polymer and solvent (and any possible diffusional barriers). There are two major concerns regarding the development of fragrance delivery system such as the time required to produce a stable capsule and price of its constituents [4]. It appears that much work is still to be made in three major areas. Firstly, the retention of volatile components in carrier materials should be improved, especially in case of products that are subjected to drastic storage or handling conditions. Secondly, the potential of triggered and sustained release systems in terms of hedonic benefits should be investigated more in depth. Finally, the cost level of current delivery systems is still an issue in many fragrance applications. It is thus believed that progress in all of these areas will require a better understanding of the materials science aspects underlying encapsulation as well as a better integration of the delivery systems into the perfume/flavor creation process. In parallel with the continuing work on the common encapsulation technologies, it is desirable to pursue new developments to further advance from current scientific levels, especially in nanobiotechnology fields such as molecular recognition, new polymers, and novel composite materials.

In this article, current applications of various polymers and their complexes in fragrance delivery systems are briefly reviewed. Functionality and applicability of these polymers are highlighted in order to provide a comprehensive view on the development of these materials in perfume industry. Through the extensive survey on the literature, the perspectives of polymer-based active packaging options for various encapsulants are highlighted. Fragrance loading rate of various aromas under varying temperature and pH conditions have also been discussed in details. The practical tools for the identification of encapsulation media such as Scanning Electron Microscope and Transmission Electron Microscope have also been discussed to assess the mechanisms controlling the entrapment of fragrances in the encapsulant. As such, we provide a comprehensive review on the capture and controlled release of fragrances in various products and summarized information on effective options to control the fragrance release process, such as microencapsulation process using various polymers and their complexes. We discuss about various methods to control encapsulation via chemical and engineering processes. Different types of triggering mechanisms for the release of the loaded fragrant molecules in diverse encapsulating agents have been elaborated. Different types of polymeric materials developed for the micro- or nanoencapsulation of various fragrances are also described. The importance of polymeric materials has been reviewed with respect to their properties for encapsulation along with the associated scientific challenges in this research area.

2. Mechanisms of encapsulation and release of fragrances

The encapsulation process is useful in improving the properties and usability of several industrial and commercial products, such as fragrances, self-healing materials, nutrients, and drugs. Fragrances and flavors have a limited lifetime as their constituents evaporate and degrade before or during use [7,8]. Flavors and fragrances have widely been applied in many fields (e.g., food, medicine, papermaking, textiles, leather, cosmetics, and tobacco). The encapsulation process basically functions to coat or capture a compound. Thus, synthesis of fragrance delivery systems is performed using methods like extrusion, grinding, spray coating, coacervation, and inclusion of complexes with cyclodextrins [9–11].

Fragrant molecules are encapsulated to prevent them from contamination, exposure to unfavorable environments, and rapid evaporation. Importantly, the encapsulates must have features such as a high-strength shell wall, compatibility with aqueous or organic shell cores, ease of use in time release (or thermal release applications), and simple fabrication [12,13]. In addition to external shielding, encapsulation provides extension of the shelf life of fragrances and flavors with extended storage time. With this method, the coating material acts as a protective barrier to increase the stability of fragrant molecules.

The encapsulate is a spherical protective wall material with an empty core, as illustrated in Fig. 1. They are of different types depending upon diameter: i.e., of the nanocapsule (smaller than 1 μm), microcapsules (between 1 μm and 1000 μm), and macrocapsules (larger than 1000 μm) [14,15]. These capsules can be made from various materials, with polymeric materials being the most common. Further, the controlled release of these fragrances is a challenging task. Long-lasting fragrance perception, a demand of the current market, requires tight control of the evaporation rate. Consequently, encapsulation imparts some degree of protection for the fragrances during storage.

The major composition of fragrances is either reactive or volatile. Volatile perfume ingredients are used for production, storage, and the ultimate intended use [13,16]. Therefore, researchers are interested in controlled release and stability of fragrances. Using polymeric capsules, fragrances can be stabilized for several days. For instance, the fragrance of fabrics impregnated with polymeric capsules could be maintained even after a few washing cycles. Research is continuing toward the development of encapsulates that can sustain more washing cycles without losing the impregnated molecules. The selection criteria for suitable polymer encapsulates depends on the targeted application of the polymer capsule and the extent of the controlled release required on the temporal and/or spatial scale [17,18].

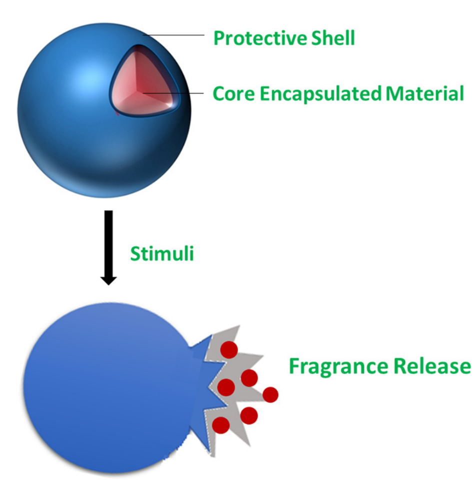

Fig. 1. Core-shell structure of encapsulant with the release mechanism.