Trends in Food Science & Technology 69 (2017) 1–12

Contents lists available at ScienceDirect

Trends in Food Science & Technology

journal homepage: http://www.journals.elsevier.com/trends-in-food-science-and-technology

Review

Innovative technologies for encapsulation of Mediterranean plants extracts

Marko Vinceković [a], Marko Viskić [a], Slaven Jurić [a], Jasminka Giacometti [b], Danijela Bursać Kovačević [c,**], Predrag Putnik [c,*], Francesco Donsì [d,e], Francisco J. Barba [f], Anet Režek Jambrak [c]

[a] University of Zagreb, Faculty of Agriculture, Department of Chemistry, Hall 3, 2. Floor, Svetošimunska cesta 25, 10000 Zagreb, Croatia
[b] Department of Biotechnology, University of Rijeka, Radmile Matejčić 2, HR 51000 Rijeka, Croatia
[c] Faculty of Food Technology and Biotechnology, University of Zagreb, Pierottijeva 6, 10000 Zagreb, Croatia
[d] Department of Industrial Engineering, University of Salerno, via Giovanni Paolo II 132, 84084 Fisciano, Italy
[e] ProdAl Scarl, via Ponte don Melillo, 84084 Fisciano, SA, Italy
[f] Nutrition and Food Science Area, Preventive Medicine and Public Health, Food Science, Toxicology and Forensic Medicine Department, Faculty of Pharmacy, Universitat de València, Avda. Vicent Andrés Estellés, s/n, Burjassot, 46100, València, Spain

ARTICLE INFO

Article history:
Received 13 July 2017
Received in revised form
5 August 2017
Accepted 6 August 2017
Available online 18 August 2017

Keywords:
Encapsulation
Plant extract
Bioactive compounds
Essential oils
Volatile compounds
Mediterranean herbs

ABSTRACT

Background: High-added value biological compounds (BACs) from herbal and plant sources, such as essential oils (EO), antioxidants and volatile compounds, often exhibit remarkable features, ranging from nutritive and medicinal properties, as well as antimicrobial and antioxidant activities, which can be exploited in the production of functional foods. However, most BACs exhibit low water solubility, strong off-flavors/odors, and are generally unstable and easily degraded under common processing and storage conditions. Encapsulation is a technology that enables the delivery in food systems, the protection, as well as the controlled and targeted release of BACs.
Scope and approach: The aim of this review is to summarize the most important information for encapsulation of natural extracts using unconventional technologies.
Key findings and conclusions: Encapsulation is an excellent choice to stabilize BACs, and in particular EOs, and mask their strong flavors and odors. In particular, spray drying is one of the most economic and common encapsulation technologies. However, the challenges of reducing the operating costs, of developing high-throughput processes, of minimizing the use of organic solvents, and of increasing the level of functionality of the encapsulation systems are driving the research towards the implementation of innovative strategies and non-conventional methods, which incorporate the concepts of Green Food Processing.

1. Introduction

Encapsulation is a technology, which is specifically suitable to deliver high-added value compounds, able to stabilize and control the release, of high-added value compounds extracted from fruits, vegetables or waste materials (i.e. antioxidant bioactive compounds, vitamins, acidulants, flavors, aromas, enzymes, microbial cells and others) into products. It is a common practice in the preservation or improvement of bioactivity of natural extracts (Nikmaram et al., 2017). Over the last years, encapsulation has attracted a significant interest from food, pharmaceutical, nutraceutical, and cosmetic industries, due to its wide application in the design of functional products such as foods and/or food ingredients. The different encapsulation processes can be classified as mechanical, physical and chemical (Gouin, 2004).

From ancient times, herbs were used as foods, medicine, and for cosmetic purposes. Their rich aromas made them suitable for poultices and imbibed infusions for various medicinal purposes. Such medicinal properties include anti-allergic, antioxidant, antibacterial, anti-inflammatory, and antiviral. Most of these properties can be attributed to its high BAC content (e.g. polyphenols,

* Corresponding author.
** Corresponding author.
E-mail addresses: dbursac@pbf.hr (D. Bursać Kovačević), pputnik@alumni.uconn.edu (P. Putnik).

http://dx.doi.org/10.1016/j.tifs.2017.08.001

isothiocyanates, etc.). Nutrients found in herbs include vitamins, proteins, minerals, and antioxidants. Various sources report a great number of potentially beneficial herbal compounds and their multifunctional properties for the production of health-promoting nutraceuticals, food additives/supplements, etc. (Barba, Esteve, & Frígola, 2014; Granato, Nunes, & Barba, 2017; Hashemi et al., 2017).

2. Mediterranean herbs

Medicinal and aromatic Mediterranean herbs were used since antiquity for healing (Kumar, Kumar, & Khan, 2011) and for flavoring (Petrovska, 2012). More than 30% of the entire plant species are utilized for medicinal purposes with approximately about 21,000 plant taxa (Groombridge, 1992). Twenty-five percent of worldwide prescribed drugs originated from plants (Sahoo, Manchikanti, & Dey, 2010). Thus, the importance of medicinal plants for the economy is constantly growing.

Among the Mediterranean herbs, oregano, basil, rosemary, sage and thyme are regularly used and consumed as fresh or dried. In addition, these herbs are the essential components of Greek, Middle-eastern, Northern African, and Italian cuisine (Barba et al., 2014). Aside as folk medicine, they were used for other purposes, including food preservation that gradually spread around the world (Putnik, Bursać Kovačević, Penic, & Dragovic-Uzelac, 2015; Putnik, Bursać Kovačević, Penić, Fegeš, & Dragović-Uzelac, 2016). Some of the main medicinal benefits are derived from the high content of micronutrients and BACs (e.g. polyphenols), many of which possess powerful antioxidant activity with ability to act as antimicrobials and/or to prevent onset of chronic and degenerative diseases (Barba et al., 2014; Krishnan, Kshirsagar, & Singhal, 2005).

Recently, it was clinically verified that the plant extracts that contain BACs may be beneficial in treatment of chronic conditions such as: cardiovascular disease, diabetes, obesity, hypertension, and stimulation of immune response (Deshpande, Neelakanta, & Hegde, 2006; Masella et al., 2004; Noratto, Porter, Byrne, & Cisneros-Zevallos, 2009; Rosenblat & Aviram, 2009; Spencer, Rice-Evans, & Williams, 2003). Additionally, various studies confirmed that different BACs were associated with anti-microbial, antioxidant, anti-mutagenic, anti-chemotactic, anti-cancer, anti-inflammatory, anti-genotoxic, hypocholesterolemic functions, and that are beneficial for treatment of gastrointestinal conditions (Durling et al., 2007; Gülçin, Güngör Şat, Beydemir, Elmastaş, & İrfan Küfrevioğlu, 2004; Harbourne, Jacquier, & O'Riordan, 2009; Lv et al., 2012; Petronilho, Maraschin, Coimbra, & Rocha, 2012; Roby, Sarhan, Selim, & Khalel, 2013; Singh, Shushni, & Belkheir,). For instance, Yoo, Lee, Lee, Moon, and Lee (2008) investigated relative antioxidant and cytoprotective activities of 17 selected herbs. Their results confirmed the higher protective effect on gap–junction intercellular communication (GJIC) as compared to gallic acid and catechin. Enhanced activity of the antioxidative enzymes (superoxide dismutase and catalase) was evident in a dose-dependent manner (Yoo et al., 2008).

However, there is a lack of clear understanding of undergoing physiological pathways in humans (Petronilho et al., 2012). Nevertheless, antioxidants from natural sources are more readily acceptable than synthetic ones, therefore much focus has been given to identifying the active compounds in plants with respect to research-based evidence of its biological effects (Pokorný, 2007). There is scarce literature on the health effects of whole herbs or extracts of entire herbs (Paur, Carlsen, Halvorsen, & R., 2011).

3. Extraction techniques prior encapsulation

Each particular family, genera and species of the Mediterranean herbs is characterized by a peculiar content of BACs. With regards to the chemical structure, BACs can be classified into several categories (e.g. polyphenols, alkaloids, terpenoids, organosulfur compounds, etc.) (Tiwari, Brunton, & Brennan, 2013), with great structural diversity and different physical/chemical properties (e.g. many are thermally unstable). Accordingly, extraction of BACs from Mediterranean herbs can be a daunting and challenging task. Many recent studies focused on finding the most appropriate approach to obtain high-quality BAC in the extraction of various plant materials (Barba, Zhu, Koubaa, de Souza Sant'Ana, & Orlien, 2016; Lovrić, Putnik, Bursać Kovačević, Jukić, & Dragović-Uzelac, 2017; Poojary et al., 2017; Putnik, Bursac Kovacevc et al., 2017; Putnik et al., 2016; Putnik, Bursać Kovačević, Radojčin, & Dragović-Uzelac, 2017; Putnik, Bursać Kovačević, Režek Jambrak et al., 2017).

The most frequently used techniques includes heated conventional extractions (CE) with solvents and agitation, mainly because of their simplicity, low cost, and versatility. Selection of the most appropriate technique relies on the selection of the right solvent for the particular plant, as one of the most important factors that defines the extraction efficiency (Gupta, 2012). On one side, the CE is indeed a relatively simple method, but on the other it can be rather slow with poor extraction efficiency, consume large quantities of organic solvents, and cause thermal degradation of target compounds (Wang & Weller, 2006). Therefore, the application of advanced methods is suggested to decrease the length of the extractions (Dragović-Uzelac et al., 2015), the solvents consumption, as well as the increase of yield and quality of the extracts. For instance, extractions with the assistance of microwaves (MAE), ultrasound (UAE), and high-pressure (HPAE) in comparison to the CE offer highly selective and efficient recovery of the high-quality BAC extracts from different plants (Bursać Kovačević et al., 2015; Zhang et al., 2011). Moreover, extractions with ultra-high pressure (UPE) (Xi, 2015), negative pressure cavitation (NPC) (Roohinejad et al., 2016), high voltage electrical discharges (HVED), pulsed electric fields (PEF) (Barba, Galanakis, Esteve, Frigola, & Vorobiev, 2015), and mechano-chemical methods (Wu, Ju, Deng, & Xi, 2017), resulted to be very efficient in recovering BACs from plants. These techniques are able to provide valuable plant extracts in an environmentally friendly way, that is well aligned with the nowadays preferred “green concepts” (Herrero, Plaza, Cifuentes, & Ibáñez, 2010). These procedures are rapid, convenient, economical, sustainable, and efficient, and with great potential for industrial upscaling (Chemat et al., 2017).

4. Encapsulation of bioactive compounds

Encapsulation is one of the most intriguing fields in the area of active agents' delivery systems. This interdisciplinary technology requires fundamental competences on colloid and interface chemistry, material science, and in-depth understanding of active agents' stabilization (Rodham, 2000; Thies, 2006).

Encapsulation can be described as a method of entrapment of a core material (i.e. active ingredient, fill, internal phase, or payload phase) within another solid or liquid immiscible substance, thereby producing capsules with diameters ranging approximately from 10 nm to 10 μm (Donsì, Sessa, & Ferrari, 2016). Core materials include solid particles, liquid droplets, or gas bubbles. The immiscible substance is also known as the carrier(s) or wall material, shell, coating, membrane, external phase, or matrix. Generally, one can differentiate between two main forms and structures (morphology) of encapsulated systems, namely core-shell type (capsules) and matrix (spheres) type, which are schematically shown in Fig. 1. In the core-shell type, the core material forms a continuous phase enclosed in a shell, while the matrix type has core material uniformly distributed inside a homogeneous solid-phase matrix. In addition to these basic morphologies, capsules