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# "Encapsulations"

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## Introduction

It is reasonable to say that there is a very natural connection between food and encapsulation, considering the fact that many traditional foods from different cuisines around the world bear unmistakable similarities to modern encapsulation products. For example, the traditional Chinese food tangyuan can be regarded as macro-capsules of flavoured fillings. It is therefore no surprise that the concept of encapsulation has been associated with the food manufacturing industry from a very early time. Nowadays encapsulation has become an indispensable technology of the food industry. Conscious employment of various encapsulation techniques has helped to move the industry to the stages of functional or smart food. Food industry oriented encapsulation has become an important technology field and is as active as ever. Many developments made in this area in the period starting from the late 1990s to around 2015 are summarised in the book "Encapsulations", which is the second volume of Nanotechnology in the Agri-Food Industry, a series aiming at bringing together the most recent and innovative applications of nanotechnology in the agri-food industry and to present the future perspectives in the design of new or alternative foods. The book series is edited by Alexandru Mihai Grumezescu from the Department of Science and Engineering of Oxide Materials and Nanomaterials, Politehnica University of Bucharest, Romania. Grumezescu is an experienced and frequently published researcher and editor in the fields of nano- and biostructures.

The volume "Encapsulations" comprises 20 chapters, written by different groups of authors independently. Excluding Chapter 10 which discusses nanocomposite food packaging, the remaining 19 chapters review food encapsulation and related technologies from different angles. Altogether the various aspects of food encapsulation, methods and processes, materials, food ingredients to be encapsulated, functions and impacts of encapsulation are described and discussed. In consistency with the aim of the whole series, nanoencapsulation is the intended focus of the book.

## Food Ingredients and the Need for Encapsulation

Many ingredients and additives used in the food industry are functional and often costly. Microencapsulation of these ingredients can bring many benefits and add value to the food products. This is the basis and driving force for food microencapsulation. As background, the food ingredients which benefited from microencapsulation are described in most chapters of the book.

A large proportion of this book (Chapters 1–4, 6, 9, 14, 16, 18 and 19) deals with the encapsulation of flavours and aromas. A synopsis of flavour and aroma compounds, with classifications, is given in Chapter 2 by Sushama Talegaonkar (Jamia Hamdard University, India) *et al*. An introduction to essential oils (EOs) is provided in both Chapter 3 by Juan Felipe Osorio-Tobón (University of Campinas, Brazil) *et al*. and Chapter 14 by Jayamanti Pandit (Jamia Hamdard University, India) *et al*. The issues and challenges of using EOs as flavours and aromas in foods, such as chemical stability, water solubility, volatility and degradative reaction caused by interactions with air or other food components, are highlighted. A brief summary of biosynthesis, extraction and properties of aroma and flavour compounds can also be found in Chapter 4 by Miriana Kfoury (University of the Littoral Opal Coast, France) *et al*. The advantages of an encapsulated form of these compounds, such as improvement in chemical stability, enhancement of nutrition and taste and masking of undesired flavours and aromas, are summarised in Chapters 2 and 6 by Suphla Gupta (Indian Institute of Integrative Medicine, India) *et al*.

The encapsulation of EOs as antimicrobials and therapeutics, with a view to enhancing the performance and enabling sustained release, are looked at in Chapter 7 by Tarik Bor (North Carolina Agricultural and Technical State University, USA) *et al*. and in Chapter 15 by Sumit Gupta (Bhabha Atomic Research Centre, India) *et al*.

The encapsulation of polyphenol compounds is described in Chapter 11 by Leslie Violeta Vidal Jiménez (University of Concepcion, Chile), Chapter 13 by Sandra Pimentel-Moral (University of Granada, Spain) *et al*. and Chapter 19 by Mohamed H. Abd El-Salam (National Research Centre, Egypt) *et al*. In Chapter 11, a review is provided to cover the health benefits of polyphenols from natural sources, particularly from berries such as the Chilean blackberry. The information presented includes mechanistic understanding of antioxidant effects, metal chelation, enzyme inhibition and gene regulation properties of polyphenol compounds. Different polyphenols from phytochemical sources are reviewed in Chapter 13. The potential to help stabilise polyphenols in food processing and to increase bioavailability by microencapsulation is highlighted.

The nanoencapsulated microemulsions of nutraceuticals, cosmeceuticals such as vitamin E, and EOs are summarised in Chapter 12 by Sergio Enrique Flores-Villaseñor (Center for Research in Applied Chemistry, Mexico) *et al*. The increased protection against oxidation and the bioavailability of essential bioactive compounds (polyunsaturated lipids) are the targets of encapsulation discussed in Chapter 5 by Maria G. Semenova (N. M. Emanuel Institute of Biochemical Physics of Russian Academy of Sciences, Russian Federation) *et al*. Encapsulation of lipids and water soluble vitamins are reviewed in Chapter 19.

Apart from the above food ingredients, encapsulation of colourants, enzymes and living cells are also described in Chapter 1 by Anatol Jaworek (Polish Academy of Sciences, Poland).

## Encapsulation Materials, Methods and Processes

Food ingredients are obviously special in terms of sensitivity, stability, nutrition, health and safety. For successful encapsulation of such active payloads, appropriate materials suiting the application must be used in the first instance. The selection of encapsulation materials is discussed by many authors in the book. Nontoxicity, biocompatibility and biodegradability are agreed to be basic requirements. Generally recognised as safe (GRAS) materials are often preferentially used for food encapsulation. Reviews of materials suited for food encapsulation including natural polymers (polysaccharides and proteins), biocompatible synthetic polymers and inorganic materials, lipids and waxes are provided in Chapters 2, 3, 6, 7 and 11. Despite being a non-polymer, the widely used cyclodextrin is often grouped together with other carbohydrate chemicals into natural polymers. A thorough overview of natural polymers based on the types and classifications is presented in Chapter 19. In Chapter 5, natural polymers are selected as a good choice of smart stimuli-sensitive nanoscale vehicles for polyunsaturated lipids, for reasons including non-toxicity, bio-origin, biocompatibility, biodegradability, natural abundance and diversity, nanoscale dimensions, amphiphilic nature and organisational ability, water solubility and environmental responsiveness. Studies carried out by the authors of the chapter and other scientists on the interactions of natural polymer-lipids, their structure and the properties of the resultant nano-vehicles are reviewed.

Reflecting on the specialties of food ingredients on encapsulation design, it turns out that physical and physico-chemical methods and processes are more likely to be used for food encapsulation. The commonly used encapsulation methods such as coacervation phase separation, spray drying, spray chilling/cooling, freeze drying, fluidised bed coating, extrusion, emulsion diffusion and co-crystallisation are well employed in food encapsulation and this is documented in Chapters 2, 6 and 7 as well as Chapter 9 by Kata Trifković (University of Belgrade, Serbia) *et al*. and Chapter 13.

Despite the intended focus of the book being on nanoencapsulation, most of the above encapsulation processes do not offer exclusively nanoencapsulation. In fact, micro- or even larger scale encapsulation is commonly used in food manufacturing and much of the research work cited in the book is indeed normal microencapsulation, i.e. the size of the capsules is on the micrometre scale or well above.

An undoubtedly nanoencapsulation (or indeed molecular encapsulation in many cases) technique is inclusion complexes involving the use of molecular carriers. Cyclodextrin is the most commonly used host material in food encapsulation. In this book, Chapters 4, 17 by Paweł K. Zarzycki (Koszalin University of Technology, Poland) *et al*. and 18 by Eva Fenyvesi (CycloLab Cyclodextrin Research & Development Laboratory Ltd, Hungary) *et al*. are dedicated to cyclodextrin encapsulation. A full account of the chemistry of cyclodextrin including its interaction with food ingredients is given and the application of cyclodextrin to encapsulate flavours and aromas, antioxidants and other bioactive compounds is well described. Good summaries of cyclodextrin encapsulation are also provided in Chapter 8 by Lucia Zakharova (Russian Academy of Sciences, and Kazan National Research Technological University, Russian Federation) *et al*., as well as in Chapters 9, 13 and 14. In Chapter 8, more supramolecular approaches for food nanoencapsulation, for example micelle and in particular β-casein protein micelles, are described too.

The next level of nanoencapsulation is the building of nanocontainers. Polymer nanocontainers *via* self-organisation, polymerisation and layer-by-layer assembly, mesoporous silica nanoparticles and halloysite nanotubes are described in Chapter 16 by Shailesh Ghodke (North Maharashtra University, India) *et al*. Polymer nanoparticles encapsulation is summarised in Chapter 14. A technique for largely nano- (but can range to micro-) scale encapsulation is lipid based encapsulation, including liposomes and lipid based solid nanoparticles. Lipid based food encapsulation is summarised in Chapters 3, 6–9 and 13–15. It has been pointed out that liposomes can act as carriers for both lipophilic and hydrophilic compounds.

Further routes to nanoencapsulation are encapsulation through microemulsion and 'nanoemulsion'. Chapter 12 of this book focuses on thermodynamic stable microemulsions. A good account of the chemistry of microemulsions is provided and the use of biocompatible microemulsions to encapsulate nutraceuticals and cosmeceuticals is briefly reviewed. The process technologies of nanoemulsion (the term 'miniemulsion' is used in some publications, which is thermodynamically unstable) and nano-sized emulsions are described in Chapter 20 by Siddhartha Singha (National Institute of Food Technology Entrepreneurship and Management, India) *et al*.

Other emerging encapsulation technologies are presented in this book. Supercritical fluids (SCFs), particularly supercritical $CO_2$ based encapsulation techniques including rapid expansion of supercritical solution (RESS), supercritical solvent impregnation (SSI), supercritical antisolvent (SAS), particles from gas-saturated solutions (PGSS) and supercritical fluid extraction of emulsions (SFEE) are well elucidated in Chapter 3. These techniques have been used to encapsulate flavours and aromas.

As an interesting technique, electrohydrodynamic microencapsulation is clearly presented in Chapter 1. Following the principles of electrohydrodynamic atomisation (EHDA), recently developed encapsulation techniques including electrospray drying, extrusion/coextrusion, cooling, mixing, reaction and submerged electrospray are introduced (**Figure 1**). The encapsulation of a variety of food ingredients are reviewed and tabulated in detail, including process parameters and the sizes of the resultant capsules.

## Further Remarks

This is a large volume. Potentially the contents of the book in its many chapters could have been consolidated to improve the structure of the book. Readers may also like to see more about developments in probiotic encapsulation on top of what is already presented in the book (Chapters 1 and 13). Further, as a volume of the integrated series, it is felt that it would be more complete if agrochemical encapsulation was covered in the book together with food encapsulation.

 

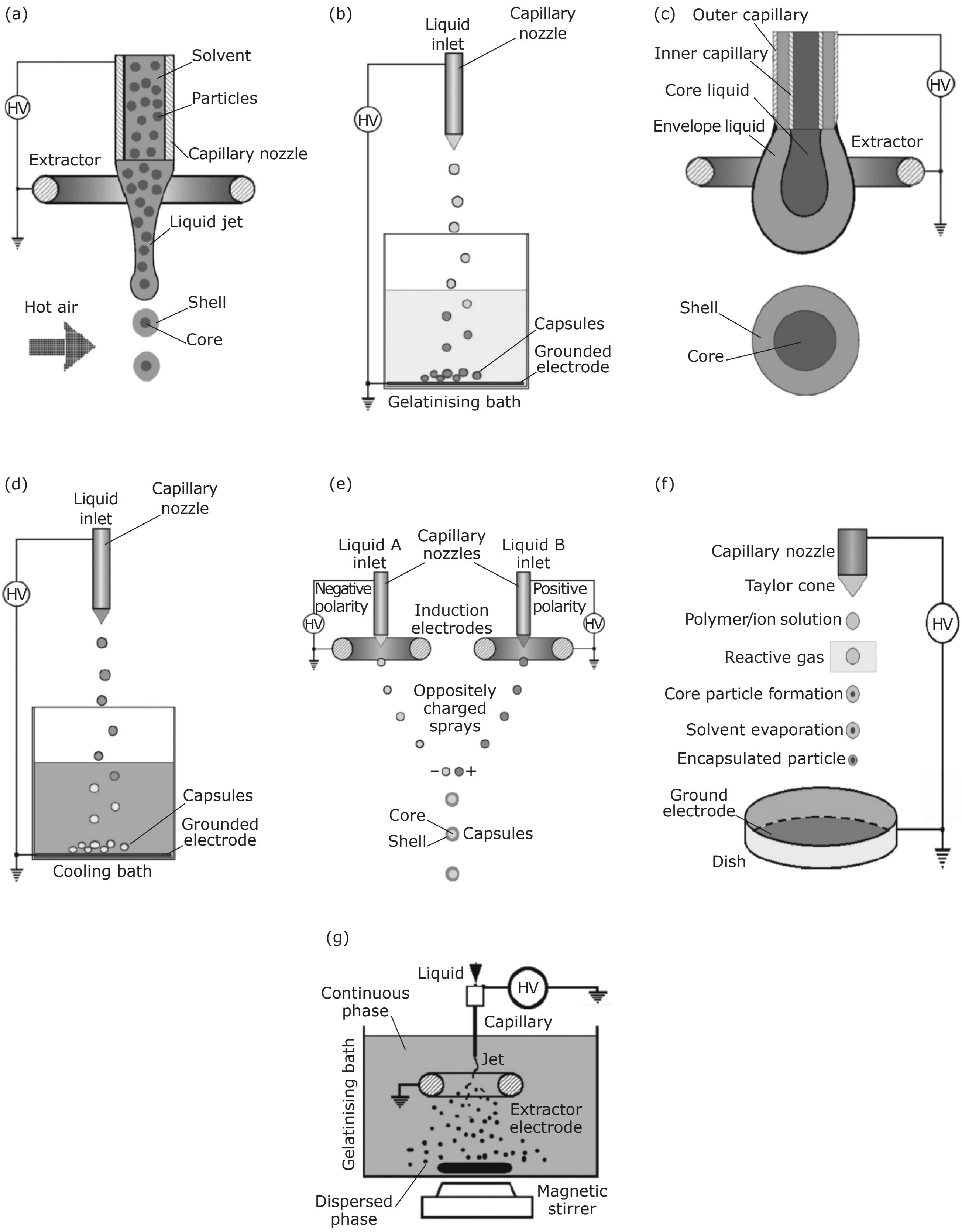


Fig. 1. Electrohydrodynamic microencapsulation techniques: (a) electrospray drying; (b) electrospray extrusion and gelling; (c) electrospray coextrusion; (d) electrospray cooling; (e) electrospray mixing; (f) electrospray microencapsulation in reactive gas; (g) submerged electrospraying. Reproduced with permission from Elsevier, copyright (2016) Academic Press

 

Overall, with the informative collections of food encapsulation research and development, the book is obviously a very practical and convenient handbook for both scientists and technologists who work in the food industry and who are interested in the development and application of encapsulation technology.

## The Reviewer

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