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Review

Probiotication of foods: A focus on microencapsulation tool

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ABSTRACT

Background: With almost thirty years of application in field of probiotics, microencapsulation is becoming an important technology for sustaining cell viability during food production, storage and consumption as well as for the development of new probiotic food carriers. Potentiality of microcapsules in protecting probiotics along human digestive tract seems to be well established. Instead, the inclusion of probiotics into foods, also in microencapsulated form, poses still many challenges for the retention of their viability, being food intrinsic and extrinsic factors crucial for this item.

Scope and approach: We collect the relevant literature concerning the use of microencapsulation for the inclusion of probiotics in traditional food vehicles such as milk derivatives and in novel food carriers that were grouped in bakery, meat, fruit and vegetable. Furthermore we intent to highlight within different food categories the main factors that act in challenging probiotics viability and functionality. What we aim is to establish how microencapsulation is effectively promising in the research and development of innovative probiotic foods.

Key findings and conclusions: Despite the relevant improvements toward the broadening of probiotic food products and categories, additional efforts have to be attempted. For this purpose, development of easy to use, stable and cheap probiotic microcapsules could be an important key for industrial spreading of microcapsules. Also the monitoring of cell stability along the entire food production including a real storage period as well as the assessment of encapsulated probiotic metabolism are some topics that require additional investigations.

1. Introduction

As defined by the Expert Committee FAO/WHO in 2001, probiotics are “live microorganisms which, when administered in adequate amounts, confer a health benefits on the host”. The concept of “pro-life” bacteria emerged with the observations of Elie Metchnikoff who hypothesized that the long and healthy lives of Bulgarian peasants were rooted in their consumption of fermented milk products containing beneficial *Lactobacillus* (Douglas and Sanders, 2008) and the positive influence that these microbes had on colonic health in the restoring a physiological intestinal microflora.

Belonging mainly to Lactic Acid Bacteria (LAB), probiotics were widely used in the production of dairy fermented foods such as yoghurt, korut and kefir, but several evidences of their healthy effects on humans and animals led to a modern forward looking research of probiotic functional properties toward their broader application both in food and pharmaceutical field. That of probiotic health benefits is an area of intensive research in different domains that, according to the target sites and mechanism of action could be distinguished in intestinal and extra-intestinal. As a matter of fact, probiotics have shown to play an important role for example in maintenance of the normal intestinal microflora, protection against gastrointestinal pathogens, lactose metabolism, infantile diarrhea, accordingly to the first domain. On the other hand, among extra-intestinal effects have to be highlighted the reduction of serum cholesterol level and blood pressure, reduction in the incidence of urogenital and respiratory diseases and prevention of some cancers (Khani, Hosseini, Taheri, Nourani, & Imani Fooladi, 2012).

The reported evidences for the impact of probiotics on diverse end points of human health is driving the commercial development of products containing them. Most of the probiotic food products are categorized as functional foods, and comprise between 60 and 70% of the whole functional food market (Tripathy & Giri, 2014). Indeed, according to a worldwide industrial analysis, the global market of probiotics has been estimated to get over 28.8 billion US

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dollars by 2015 (Global Industial Analysis, 2013). Because the dairy sector has pioneered the introduction of probiotics, dairy products, including fermented and non-fermented milk and cheese, remain the most popular form of consumption of probiotics (Sánchez, Ruiz, Guidemond, Ruas-Madiedo, & Margolles, 2012). Other types of probiotic foods such as fruit juices and chocolate-based products are available but they still represent only a small share of the market. In the last years, health care professionals, web sites and advertisings have promoted the administration of products containing probiotics increasing the consumer's consciousness in probiotic functionalities. From their part, consumers could be willing in promoting and maintaining their health and wellness through the consumption of this products category rather than medical treatment in the cases where the latter can be avoided or prevented. Hence, improving the functional products vehicles of probiotics may have a fundamental role in promoting human health. Nowadays, a great attention has to be given in extending the category of foods carrying probiotics in order to broaden the groups of people that usually have not access them for certain reasons, where the most foregone could be their dislike for milk and milk derivatives. Furthermore, non dairy probiotic foods such as fruit juices are often lactose-free, soy-free and vegan-compliant, and these attributes are becoming increasingly important to health-centric consumers concerned with their intake of cholesterol-containing foods, suffering from lactose intolerance, or following a specific diet (Gawkowsky & Chikindas, 2013). Doubtless, it is paramount that probiotics must survive and retain their functional features during the entire food processing operations, including storage. At this regard, a number of efforts have been made to improve the robustness, and then, the viability of probiotics in the variety of foods. Among these attempts, microencapsulation, defined as a technology achieving the coating and protection of sensitive compounds or living cells, is attesting its real potentiality in sustain probiotic viability from their processing (biomass production, lyophilisation, storage, application in food) up to their assumption and passage through gastrointestinal tract.

What we aim with this review is to summarize scientific works dealing with the application of microencapsulated probiotics in different food matrices in order to state how microencapsulation is explored in the overcoming the wide spectrum of detrimental factors encountered. In other words, how microencapsulation procedure is effectively promising in the research and development of new probiotic foods.

2. Probiotic foods, health claims and labels

The consumption of probiotic products is in constant growing among the population. In Europe, probiotic products for human diet include foods (nutraceuticals or functional foods), food ingredients and supplements. It is common for probiotic products to be marketed on the premise that they have an important effect on the intestinal microbiota. Their most commonly reported claim “its consumption promotes the balance of the intestinal microflora” did not configure as a health claims rather than a structure/function claim because it is referred to a physiological effect of the normal, not diseased, structure or function of the human body (Sanders, 2009). Although a great number of health claims applications, often supported by high quality research on taxonomic, functional and clinical data, have been submitted at European Food Safety Authority (EFSA), no favourable opinion have been issued. However, the same situation is ongoing. With regard to foods, according to the European Commission, a health claim means “any claim that states, suggests or implies that a relationship exists between a food category, a food, or one of its constituents and health” (Reg. CE 1924/2006). From 2005 to 2013, the EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA) have evaluated more than 100 proposals for the substantiation of a health claim related to probiotics consumption, publishing as many dossiers where the health effects of probiotics were analysed and judged as beneficial, possibly beneficial and or non-beneficial to human health. Binnendijk and Rijkers (2013) overviewed all EFSA panel on NDA evaluations of claimed effects of probiotics in the years comprised from 2005 to 2013 (gut microbiota, supported by 46 published opinions, gut health 26, immune health 28, metabolic health and obesity 19 and other health effects 15). They pointed out that most of them (about 80%) were considered to be beneficial or possible beneficial, even thought they concluded that EFSA and other regulatory authorities, collectively express negative opinions on health claims. The same situation occurred in the United States, where the US Food and Drug Administration (FDA) has not yet approved any health claim for probiotic strains or products. Certainly, the scientific data to support health claims for probiotic products are often difficult to be collected and, consequently, to be provided (Farnworth, 2008). It is also worth underline that the lack of proper evidence-based studies might be related to fact that clear guidelines to be followed by scientific research groups during the preparation of clinical trials are not still available. Instead, probiotic foods received FOSHU approval (Food for Specific Health Use) in Japan, thus they are regularly considered as products having beneficial effects on the physiological functions of the human body in maintaining and promoting health, and improving health-related conditions. In particular, foods carrying beneficial bifidobacteria and LAB have been included in the segment of foods helping the modification of gastrointestinal conditions. Health claims on FOSHU correspond to other function claims of the Codex Alimentarius or structure/function claim in the United States (Yamada, Sato-Mito, Nagata, & Umegaki, 2008) and, in alignment with foreign jurisdictions, claims on reduction of disease or disease risk are not allowed for probiotics.

About the dose of assumption, no specific cell load is recognized to guarantee a health effect even thought a dose of 10^9 CFU/die is generally recommended. At this regard, it is paramount that cell probiotic load and composition comply with food labels. In fact, a serious weakness in the field of probiotic products is that the viability of the bacterial strains involved does not reflect what is reported on the label about the live microorganisms assumed with the food. From an exploration of the global market it raised that the currently employed probiotic strains exhibit little or no survival in final goods, showing cell loads lower than they are labelled, so the quality of the foods that carry them are still scarce (Corona-Hernandez et al., 2013).

3. Microencapsulation: a possible tool to overcome technological hurdles

A wide range of foods including fermented and non-fermented dairy products, ice creams and frozen desserts, fruit juices, peanut butter, cereal-based products, reduced fat (bio)spread have been enriched in probiotics to be evaluated as possible carriers of these beneficial microorganisms and to be placed on the market. To date, among the probiotic foods available on the market, fermented and non-fermented dairy products are still the most consumed by population. Most common probiotic strains added to foods are belonging to several species of *Lactobacillus* and *Bifidobacterium,* but also a yeast, *Saccharomyces cerevisiae* (*boulardi*), is used. However, other genera (*Enterococcus*, *Bacillus,* and *Escherichia*) include strains recognized as probiotics but their main use is for food supplement production (Douglas and Sanders, 2008). Different factors that could affect microorganism behaviour and robustness into the different food environments have to be considered because