Functional foods in the 21st century – delivering on the promise

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Introduction

Consumers in the 21st century are demanding 'miracle foods' that are not only safe and nutritious, but also natural, economical, convenient, great tasting, and enhance health and well-being – quite a challenge! The functional foods market, currently valued at >US$70b globally (Just-food.com, 2006), is growing exponentially in response to such demands. This market is becoming a lucrative outlet for bioactive ingredients (e.g. omega-3 oils, carotenoids, vitamins, and probiotic bacteria). However, food product applications for these bioactive ingredients are often restricted due to both their instability and their sometimes undesirable impact on the organoleptic properties of the final food. In addressing these challenges, cost-effective delivery systems will be critical to continuing growth in the functional foods market and in meeting consumer demands (Augustin and Sanguansri, 2007). In this regard, MicroMAX® is a novel encapsulation technology, which uses only natural food materials and standard food processing equipment, for protection of sensitive bioactives, for their successful delivery into functional foods and beverages, and potentially for their targeted delivery to particular points in the gastrointestinal (GI) tract.

Materials and methods

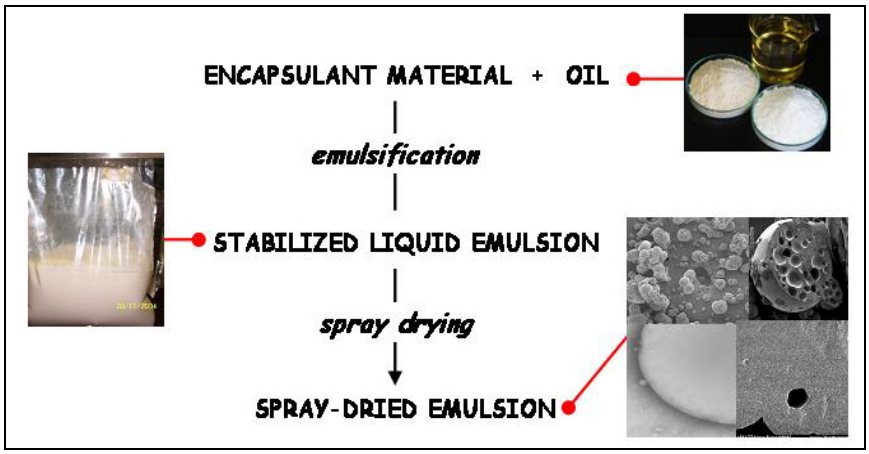

Figure 1: Schematic representation of the MicroMAX® encapsulation process involving formation of MRP (protein + carbohydrate) as the encapsulant material, a stabilised emulsion with oil, and ultimately a spray-dried emulsion powder.

MicroMAX® is a patented platform technology that relies upon the reaction between a protein or peptide (with free amino group(s)) and a carbohydrate (containing a reducing sugar) to form a very effective encapsulation matrix with exceptional film-forming and antioxidant properties (Sanguansri and Augustin, 2001; Augustin et al., 2006; Rusli et al., 2006). The technology is based upon the generation of a protein-carbohydrate conjugate (Maillard Reaction Product – MRP), and the formation of a stable emulsion with the oil of interest (e.g. omega-3 oil, other oils, oils containing dissolved bioactives) that can be heat-treated or spray-dried into a powder for stability (Figure 1). The MicroMAX® technology was initially developed and optimised for encapsulation of fish oil, but has subsequently been adapted to the protection of other oils (e.g. evening primrose oil), oil-soluble bioactives (e.g. vitamin E) (Sanguansri and Augustin, 2001; Augustin et al., 2006), and probiotic bacteria (Crittenden et al., 2005; 2006). Manipulation of the protein and carbohydrate components within the MicroMAX® encapsulation matrix and/or alteration of the order of processing can be

used to potentially control release of the microencapsulated bioactive at targeted points in the GI tract (Head et al., 2005; Crittenden et al., 2006). Experimental procedures associated with the production of encapsulated bioactives using the MicroMAX® technology have been detailed within the cited references.

Results and discussion

MicroMAX® and omega-3 oils

The first MicroMAX® encapsulated ingredients have been those developed for protection and delivery into foods of omega-3 fatty acids. These fatty acids are considered essential to human health but cannot be manufactured by the human body and must therefore be obtained from food. They are considered to play an important role in cognition, brain function and many other conditions such as heart disease, arthritis, elevated blood pressure, high cholesterol, diabetes, osteoporosis, and alleviating depression (Ruxton et al., 2007).

MicroMAX®-omega-3 ingredients have excellent encapsulation efficiency (>98%), oil loading capacity (≥50% loading), and stability. Data shown in Figure 2 demonstrate the exceptional stabilising effect of the MicroMAX® technology when used to encapsulate omega-3 containing fish oil. MicroMAX® powders with 50% oil loading have been shown to be stable for ≥2 years at 25°C and 35°C when packed in aluminium foil sachets (Figure 2), and UHT-treated liquid MicroMAX® emulsions with 25% oil loading have been shown to be stable for ~1 year at 25°C. The liquid MicroMAX® emulsions can also be canned and retorted to generate a sterile product. The emulsion droplet size (typically 0.3 – 0.4 μm) can be tailored in the range 0.1 – 2 μm for particular applications. MicroMAX® also masks fishy flavour in foods and beverages, and has the potential to be tailored to target release of omega-3 to specific sites in the GI tract (Head et al., 2005).

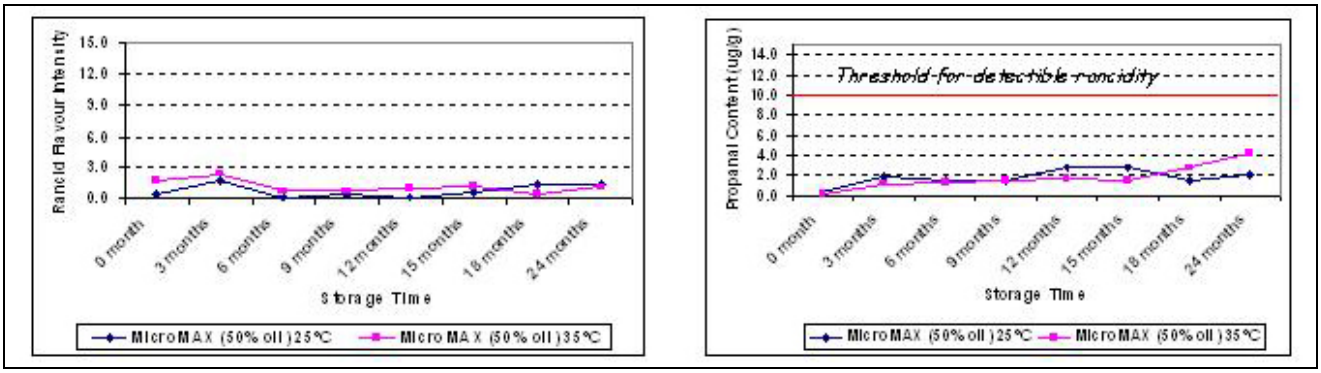

Figure 2: Stability of MicroMAX®-omega-3 powders (50% tuna oil loaded) during storage at 25°C and 35°C when packed in aluminium foil sachets, as measured by rancid flavour intensity (arbitrary scale, 1-15) and headspace propanal content (μg/g).

The MicroMAX® platform has been extended to encapsulate and deliver other oil and oil-based bioactives (e.g. vitamin E, evening primrose oil, lutein), and 'cocktail mixtures' containing both oil and water soluble bioactives in one formulation to capitalise on synergistic effects of these actives.

MicroMAX® and probiotics – synbiotic microcapsules

Probiotics are live bacteria, such as *Lactobacilli* and *Bifidobacteria*, which are consumed in foods or nutraceuticals in order to benefit human health by improving the composition of the intestinal microbiota. The scientific literature continues to report evidence for many of the health benefits associated with consumption of probiotics and their positive impact on human health (Sanders, 2003). To date however, probiotic-containing foods have largely been limited to fermented dairy

products. Widespread application of probiotics, for their health-promoting properties, in non-refrigerated foods and pharmaceutical-type products has largely been limited by the environmental sensitivity of potential probiotic strains. This sensitivity impacts on storage stability and cost of incorporation, and has restricted growth of the probiotic food market outside of dairy.

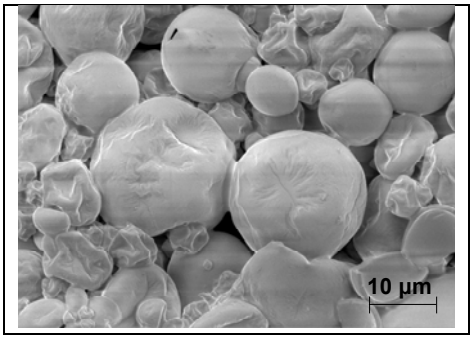

Figure 3: Dried microcapsules containing *B. infantis* as prepared using MicroMAX® technology.

MicroMAX® technology has been adapted to protect the viability of probiotic bacteria during manufacture and storage, their incorporation into foods, and their delivery to targeted points in the gut (Crittenden et al., 2005; 2006). The resulting microcapsules (Figure 3) provide an effective barrier to moisture, oxygen and gastric acid. MicroMAX® uses only safe, food-grade ingredients, and is adaptable to both freeze-drying and spray-drying. When encapsulated using MicroMAX®, probiotic strains can be efficiently encapsulated (>99%) and spray-dried with minimal loss in viability. The spray-dried powders (~40-50% w/w probiotic loading) have low water activity (<0.2) that facilitates long-term storage stability. MicroMAX® enhances probiotic stability during non-refrigerated storage, even with exposure to humidity (Figure 4). The particle size of MicroMAX® microcapsules can be finely controlled to produce small particles (10 – 200 µm) (Figure 3) with minimal impact on final food formulation and quality.

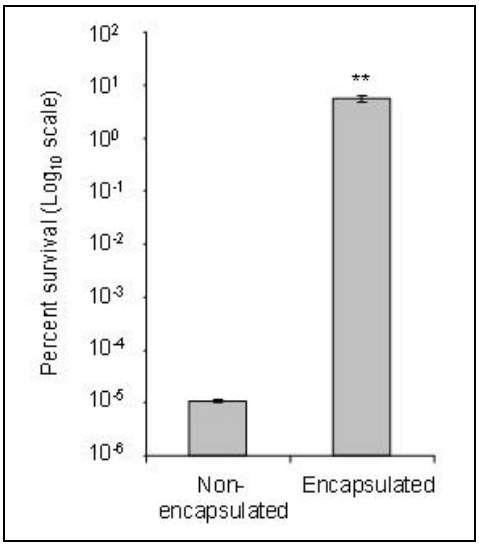

Figure 4: Comparison of the survival of a *Lactobacillus sp.* at 25°C and a_w~0.5 (50% relative humidity) when encapsulated using MicroMAX® versus non-encapsulated bacteria.

Further, *in vitro* trials have shown that MicroMAX® formulations may be tailored to rapidly release probiotic bacteria at any point in the GI tract, from the upper small intestine through to the colon (Crittenden et al., 2006). The microcapsules protect the probiotics during gastric transit, and rapidly release the bacteria at the required site of action. The flexibility of MicroMAX® technology allows a range of prebiotics (inulin, oligosaccharides, resistant starches, etc) to be incorporated into the encapsulation matrix to enhance *in vivo* biofunctionality by complementing the included probiotic and generating a synbiotic microcapsule.

Conclusions

Continuing innovation in delivery systems for bioactives, including those involving nanotechnology, will underpin expanded consumer choice in functional foods and growth strategies for food companies in the 21st century. MicroMAX® microencapsulation technology represents a revolutionary advance in the stabilisation and delivery of sensitive but efficacious bioactives, and thus forms the science foundation for application of bioactives across a spectrum of health-promoting foods and beverages for the modern consumer.

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