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STUDY ON MICROENCAPSULATED FOOD FOR HUMAN NUTRITION

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Abstract

Microencapsulation is a new technology that has been used in various fields: food industry, cosmetics, detergents, textiles, photography, chemical, medical and pharmaceutical, agricultural, electronics, drawing and painting, waste treatment and biotechnology.

Microencapsulation offers a variety of opportunities, such as: labile compounds protection (lipid and vitamin protection against oxidation processes, probiotic protection), facilitation of handling (intelligent and interactive packaging), mixing the immiscible components (the microencapsulation of essential oils and their introduction as microcapsules in a liquid medium),transforming a liquid component in a powder (powders are obtained from liquid components by microencapsulation in cyclodextrin), masking the unpleasant taste and smell (the unwanted smell of fish or the bitter taste of amino acids, the strong odour of allyl isothiocyanate) and providing a controlled slow release of bioactive substances (the aroma compounds microencapsulation).

The general objective of the authors is consulting a database required to establish a work plan needed to achieve the project research and the thesis.

The authors hope that the scientific information presented in this paper could be useful for food industry specialists, and other professionals who want to know and to strengthen their scientific framework regarding the benefits of microencapsulation.

***Keywords**: microencapsulation, food industry, human nutrition, encapsulant, encapsulated, flavour*.

1. Introduction

Encapsulation is a process that involves the coating and enclosing a core (*encapsulated*) in a membrane (*encapsulant*), until the core is losing it's identity [1, p. v]. Encapsulation is focused on isolation, protection, transport and controlled release of the active substance (*encapsulated*) [1, p. 2; 2, p. 3]. Nowadays, the dietary habits of the world's population are in a state of permanent change. To satisfy consumer requirements, the *microencapsulation* of food ingredients has become a topic of current interest for the products availability, to providing nutrients, ensuring innocuity, energy supply and products packaging. *Microencapsulation* is applicable on a broad spectrum of food and drinks, ranging from the health aspect, for creating specific taste and *flavour*, to the range of possible interactions and food packaging [3, p. 543]. The general objective of this paper is consulting a database required to establish a work plan need it to achieve the research project and the doctoral thesis. The authors hope that the scientific information presented in this paper could

be useful for food industry specialists, and other professionals who want to know and to strengthen their scientific framework regarding the benefits of microencapsulation.

2. Applied methods and materials

Method applied was a descriptive exploratory research. Operational objectives were (i) to provide a better knowledge about the phenomenon of microencapsulation, (ii) the clarification of certain concepts, (iii) suggesting some research directions through the establishment of the work plan. The used instrument was the existing data analysis via exploitation the results obtained by other researchers from different sources, such as: ISI or BDI online journals, books, chapters in books, doctoral thesis.

3. Results and discussions

3.1. Aspects concerning microencapsulation and its role in industry

In the scientific literature, the term encapsulation is often confused with immobilization, the encapsulation is considered by some researchers to be an immobilization technique. The difference between those two processes is concerned with the relationship between the active substance and the *encapsulant* material. Through encapsulation the core is totally covered by the *encapsulant* material, while by immobilisation the active substance is adsorbed on the support material, so the nutrient can leave the system and distroy it [4, p. 295; 5, p. 31].

The term microcapsules covers several configurations that differ by morphology and size (Table 1).

Table 1: The main types of products obtained by *microencapsulation* operation

Products type	Characteristics	Schematic illustration
Microcapsules	They are obtained by coating a core liquid with a solid membrane. They have micrometric dimensions.	
Nanocapsules	They present the same structure as microcapsules, but are smaller, they have nanometric dimensions.	
Microspheres or microparticles	These are products that possess both a solid core and solid membrane. Mostly, there is no clear distinction between the core and the membrane. The membrane acts as a porous matrix by absorbing the active substances. They have micrometric dimensions.	
Nanospheres or nanoparticles	They present the same structure as microspheres, but are smaller, they have nanometric dimensions.	
Liposomes	Products represented by a lipid membrane, consisting most often of phospholipids and cholesterol. They are represented by two subtypes: unilamellar and multilamellar, and they have micrometric dimensions.	
Niosomes	Products with a similar structure to liposomes, but witch differ by the membrane composition, which is made of synthetic amphiphilic molecules. It have nanometric sizes.	

Sources: [1, p. 2; 6, p. 8]

Microencapsulation has a wide application spectrum in industry [1, p. 3; 7, p. 221] (Table 2).

Table 2: Fields and examples of industrial applications of *microencapsulation*

Field	Examples
Food industry	Flavours, essential oils, colorants plant extracts, antioxidants, minerals, preservatives, essential fatty acids, amino acids, enzymes, microorganisms, vitamins
Agriculture	Insecticides, acaricides, nematicides, herbicides, fungicides, pheromones, fertilizers, micronutrients, microbial bioinsecticides
Biotechnology	Immobilized enzymes, complex multienzymatic, microorganisms living cells, cell complex hybrid tissue, culture mononuclear antibodies, markers, ADN and ARN, nutritional compounds, food for aquaculture, chromatographic materials
Chemical industry	Catalysts and enzymes, oxidants and reductants agents, fireproof materials, adhesives, dyes, perfumes, lubricants, hygroscopic and chromatographic materials
Detergent industry	Perfumes, enzymes, chelating agents, decolouring agents, bleaching activators, antistatic, bleaches, abrasives
Textile industry	Materials that can be subject to phase transition, dyes, pigments, perfumes, waterproofing agents, color stabilizers
Drawing and painting	Dyes, revelatory, pigments, perfumes, organic solvents, adhesives, photosensitive compounds, heat-sensitive compounds, toners, liquid crystals
Photo	Silver halides, pigment colorants photographic emulsions, photopolymerizable compounds, film-potting compounds, colors, plasticizers
Waste treatment	Microorganisms, substrates, enzymes, catalysts, detoxifying, liquid waste, radioactive waste, industrial waste with high perceived risk
Electronics	Liquid crystal materials that can be subject to phase transition, semiconductor materials, adhesive agents, drying agents, fireproofing agents, antistatic agents, repellent substances
Pharmaceutical and medical industry	Antibiotics, analgesics, sedatives, prostaglandin inhibitors, contrast substances, hydrocortisone, cytostatics, alkaloids, detoxifying, hemoglobin, contraceptives, insulin
Cosmetics	Perfumes, antiperspirants, essential oils, agents humectants, bronzing agents, sunscreens, capillary dyes, depilatory substances

Sources: [6, p. 9; 8]

The capsules are cell-like. The cell membrane plays a decisive role in the existence of the cell by the delimitation of extracellular and intracellular space, protecting cell components from external aggression, allowing permanent communication with the outside environment through the transfer of mass, energy and information [1, p. v].

The same functions need to be activated also on the encapsulation of active substances in food systems: the capsule core delimitation from the external environment via stabilization and protection from external factors, such as (oxygen, moisture, light, chemical hazards, biochemical and microbiological) and the membrane's permeable property and to provide a controlled release of the active substance with a controlled speed in the right place and at the right time [1, p. v].

In the *food industry*, encapsulation is used for the stabilization of food ingredients and to increase their bioavailability; to prevent the evaporation and degradation of volatile components; to mask the undesirable taste and odour; mixing immiscible compounds; for preventing the reaction between biocomponents and various substances from the food matrix during storage; converting a powder compound into a liquid; providing a slow, controlled release of the active substance and

it's protection against the aggressiveness of physical factors such as temperature, *p*H, oxygen, enzymes, light, and moisture [4, p. 293, p. 300; 5, p. 3, p. 4].

3.2. Aspects concerning the use of microencapsulated food in *human nutrition*

Because of the convenience or the lack of time resources required for food preparation, consumers are focused on foods that do not require so much time and energy to cook. By using *microencapsulation* techniques, a whole range of products ready to eat (RTE), food and drinks, are offered on the market [9, p. 42; 10, p. 3]. In the poultry meat industry, *microencapsulation* accomplishes the improvement of food security, mainly through controlled delivery of salts of organic acids in meat, such as lactate and sodium diacetate, substances that determine an increased resistance against the bacteria growth of the genus *Listeria*, *Clostridium*, *Salmonella* and *Lactobacillus* [3, p. 543]. In the case of raw fish such as salmon RTE, through *microencapsulation* the controlled release of astaxanthin pigment for ensuring the reddish-orange colour and providing the antioxidant activity can be accomplished [11, US Patent 2010/0319077A1].

The main applications of *microencapsulation* for *human nutrition* are shown in Figure 1.

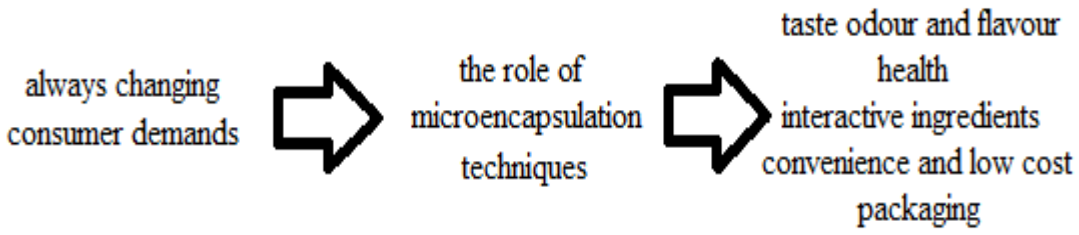

Figure 1: The main applications of *microencapsulation* for *human nutrition*
Source: [3, p. 543-546]

New *microencapsulation* technologies have led to a whole series of industrial applications in terms of enhancing the *flavour*, the introduction of odour masking, maintaining the *flavour* for a longer period of time, or release rapid onset and stabilization *flavour* [3, p. 545]. In the case of hot drinks the lipid matrices with a high melting point are used to ensure the capture and the *flavour* protection, but to low enough melting points for release only after the application of hot water, especially for coffee products, tea, milk or chocolate.

Other uses of the techniques of *microencapsulation* are based on the *p*H value, using alginate especially calcium alginate, by coacervation of the polyelectrolytes with different electrical loads, in which case it will release the flavour after it has been exposed to certain *p*H conditions. Some researchers, like Nedovic and his team, Deepak and his collaborators have developed *microencapsulation* technologies to mask unpleasant tastes and aromas. The microcapsules are designed to protect the active substance so that it does not come into contact with taste receptors on the tongue [12, p. 108; 13, p. 1806]. Another application of *microencapsulation* of flavouring

compounds is with regards to its release over a long period of time, in particular gum, sweets and bakery products. There are certain brand of chewing gum which have the capacity to release aroma during mastication, or at the breaking moment, as well as nutrient and medical substances (e.g. teeth whitening agents) [14, p. 678; 15, p. 323; 16, p. 546; 17, WO Patent 2012/145611; PCT/US Patent No. 2012/034427]. In general, the compounds used must have a high solubility in organic solvents and poor solubility in water (*e.g.* ethyl cellulose), which are capable of the slow release of *flavour* [3, p. 545]. Other researchers, like Ko and his colleagues investigated the applicability of allyl isothiocyanate (AITC) to increase the validity period and maintaining the quality of Kimchi. AITC is a very useful antimicrobial agent, but its use in foods is limited because it has a strong odour and high volatility. *Microencapsulation* is used to decrease the volatility and mask the undesirable odour, but also increase product validity. The *encapsulated* materials that were used are arabic gum and chitosan. By adding the microencapsulated AITC (<0.1%), Kimchi has a longer shelf life, whilst maintaining its quality [18, p. 92]. The new trend in health refers to functional foods. Through *microencapsulation*, the active substances were introduced into foods easily, especially for teas made ready-to-drink, drinks for athletes, beverages based on milk, water and fortified snacks, baked products, foods with a low sodium level, dietary supplements, chewing gums, candies [3, p. 545]. *Microencapsulation* techniques allows for the protection of probiotics and also for oxidation susceptible compounds, such as: vitamins, unsaturated lipids and other functional active substances [19, p. 3; 20, US Patent 2011/0217410 A1, p. 1; 21, US Patent 2011/0020520A1, p. 5; 22, p. 126; 23, US Patent 2012/0195868 A1; 24, US Patent 2012/10120156330 A1; 25 p. 214]. The *microencapsulation* of omega-3 fatty acids plays an important role in reducing lipid oxidation and permit its use for a form easy to assimilate. Complex coacervation and spray-drying are the most commonly used methods [26, p. 1]. Nicolo Della Rosa et al studied the feasibility of fortified fish snacks with seaweed extract as a natural antioxidant and polyunsaturated fatty acids long-chain (n-3 LCPUFAs) as a source of high quality lipids as cod liver oil and fish oil. The samples enriched with omega-3 fatty acid showed oxidation levels higher than the controls and by *microencapsulation* of fish oil the oxidation process was greatly diminished. The products quality was not affected by adding algae extracts. The sensorial properties did not change. The lipid quality and its oxidation were determined by chemical analysis namely peroxide value (PV), the test thiobarbituric acid (TBARS) and by sensory analysis (descriptive analysis) after a storage period of 28 days in refrigeration conditions [27, p. 746]. The sensitive ingredients microencapsulated in functional food include caffeine, taurine, D-ribose, vitamin B, aroma compounds, essential electrolytes (sodium, potassium, chloride, calcium, phosphate and magnesium salts), antioxidants, colorants, sweeteners, prebiotics and probiotics, stabilizers, fruit extracts, and whey protein hydrolyzate.

To mask the unwanted smell of fish or the bitter taste of amino acids, microencapsulationof aroma compounds is used [3, p. 545]. Wen-Ching Ko and his team have studied an optimum method of curcumin *microencapsulation*, a compound soluble in the oil phase using ɣ polyglutamic acid, a natural polymer, water soluble, biodegradable and non-toxic. The use of Span80 (sorbitanoleate) increased the efficiency of encapsulation [28, p. 497]. Nowadays, via *microencapsulation*, the consumers can be pampered with a lot of new products, foods and beverages with interactive properties. For example, in the case of candies, high pressure CO_2 is encapsulated in a glassy polymer matrix food. After the introduction of the candy to the mouth, there is a sharp noise as the CO_2 is released [29, US Patent 7,122,215B2]. In the case of candies for children, when the microcapsules come into contact with saliva, the tongue changes colour, it turns to green, blue,

yellow or red. With some breakfast cereals when the grain oatmeal is introduce into milk, a change of colour also occurs [3, p. 546]. In the beverage industry, gas infusion or the injection of microcapsules which are capable of causing the product to begin foaming when it is combined with water, milk or other suitable liquid is used. The suitable products for this type of *microencapsulation* are instant soft drinks, instant cappuccino, coffee mixes, or instant milkshake [30, US Patent 2010/0278995 A1; 31, US Patent 2010/0092629 A1, p. 1; 32, US Patent 7,713,565B2]. The introduction of the microcapsules which respond to movement in a drink has also been carried out [29, US Patent 7,122,215B2]. Norris and his collaborators studied a delivery system with a small explosion with a very intense *flavour* when drinkers come into contact with the beverage container [33, US Patent 8,042,356B2]. Concerning packaging, *microencapsulation* technologies are focused on creating intelligent and interactive packaging. Specially designed intelligent packaging are incorporating nanoparticles with a role in the relationship between both with the external environment and also with the food. Thus, the packaging contributes to improving food safety, to preservation of the food and an increase in food consumption [34, p. 496]. Edible films, increasingly being a new trend used, incorporates the *flavour* compounds and let them become free upon contact with saliva by total dissolution. The main constituents of soluble edible films are pullulan, starch, cellulose derivates, proteins and derivatives resulting from different mixtures [3, p. 546]. In the case of telescopic straws, the active ingredient, such as a probiotic is suitably mounted in an adherence agent on the interior wall of the straw. The fitobiotic is consumed when the water or drink is drawn through the straw. By the same principle, the bioactive compound is protected by a thin aluminum foil which is situated on the lid of the drink. By unscrewing the lid of a bottle of water, the aluminum foil is broken and the active substance is released into the water. Through this method the products can be enriched with moisture-sensitive functional ingredients, such as *flavour*, colour compounds or, probiotics, because the active ingredient is protected and released immediately during use [3, p. 546].

The general objective of the authors is consulting a database required to establish a work plan necessary to achieve the project research and the thesis.

4. Conclusions

Microencapsulation is a process that involves the coating and potting of a core in a membrane until the *encapsulated* loses its identity, and it has applications in many fields, in many industries. In this study we summarized some aspects of *microencapsulation* and its role in the industry, and some aspects concerning the use of microencapsulated food in *human nutrition*. *Microencapsulation* is not the same with immobilisation. The relationship between the active substance named also *encapsulated* material and the *encapsulant* material make the difference between those two processes. A database about the actual situation in *microencapsulation* for *human nutrition* was created. The studies have been being focused in two directions, such as: (i) microencapsulation of citrus essential oils and bring flavour for cocktails published on 1st International Conference named Essential Oils in Aromatherapy – Food Industry – Cosmetic, which took place on March, 2016, in Galati, Romania and (ii) microencapsulation of oregano oil for fish nutrition in recirculating aquaculture systems. There have been several preliminary tests with different coloured capsules which indicated that the red colour was preferred and the *Great sturgeon* need wet capsules, while *Nile tilapia* preferred dry capsules.The authors hope that the

scientific information presented in this paper could be useful in the *food industry* by specialists, and other professionals who want to know and to strengthen the scientific framework regarding the benefits of *microencapsulation*.

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Rezumat

Microîncapsularea este o nouă tehnologie, utilizată în varii domenii: alimentar, cosmetic, al detergenților, textil, al fotografiei, chimic, medical și farmaceutic, agricol, electronic, pentru desen și pictură, tratarea deșeurilor și biotehnologic.

Microîncapsularea oferă o varietate de oportunități, cum ar fi: protecția compușilor labili (protecția lipidelor și a vitaminelor împotriva proceselor de oxidare, protecția probioticelor), facilitarea manipulării (ambalajele inteligente și interactive), amestecarea componentelor nemiscibile (microîncapsularea uleiurilor esențiale și introducerea acestora sub formă de microcapsule în mediu lichid), transformarea unui component lichid într-o pulbere solidă (prin microîncapsularea în ciclodextrine a componentelor lichide se obțin pulberi), mascarea gustului și mirosului neplăcut (mirosul nedorit de pește, gustul amar al aminoacizilor, mirosul neplăcut și puternic al izotiocianatului de alil), oferind o eliberare lentă și controlată a substanțelor bioactive (prin microîncapsularea compușilor de aromă).

Obiectivul general al lucrării este consultarea datelor științifice actuale în vederea întocmirii unei baze de date bibliografice necesară pentru derularea planului de lucru obligatoriu proiectului de cercetare și realizării tezei de doctorat.

Autorii speră că informațiile științifice prezentate în această lucrare ar putea fi utile studenților, tinerilor cercetători dar și specialiștilor din industria alimentară și altor categorii de profesioniști care doresc să cunoască și să-și consolideze informațiile științifice cu privire la beneficiile tehnicilor de microîncapsulare.

***Cuvinte-cheie**: microîncapsulare, industria alimentară, alimentație umană, încapsulat, încapsulant, aromă*.

Аннотация

Микроинкапсуляция это новая технология, используемая в различных областях: пищевой, косметической, моющих средств, текстиля, фотографии, химической, медицинской и фармацептической, сельскохозяйственной, электронной, рисования и живописи, обработки отходов и в биотехнологии.

Микроинкапсуляция предоставляет многообразие возможностей, таких как: защита лабильного соединения (защита липидов и витаминов от процессов окисления, защита пробиотиков), облегчение

обработки (интеллектуальная и интерактивная упаковка), смешивание несмешиваемых компонентов (микроинкапсуляция эфирных масел и их внедрение в виде микрокапсул в жидкую среду), превращение жидкого компонента в твердый порошок (путем микрокапсулирования жидких компонентов в циклодекстрин получают порошки), маскировку неприятного вкуса и запаха (запаха рыбы, горького вкуса аминокислот, сильного и неприятного запаха аллилизотиоцианата), медленное и контролируемое высвобождение биологически активных веществ (через микрокапсулирование ароматических соединений).

Основная цель данной работы заключается в исследовании актуальных научных достижений для составления базы библиографических данных, необходимых для надлежащего выполнения рабочего плана по исследовательскому проекту и реализации диссертации.

Авторы надеются, что научная информация, представленная в данной работе, может быть полезна студентам, молодым ученым и специалистам в области пищевой промышленности и другим категориям специалистов, заинтересованных в углублении своих научных познаний о преимуществах методов микроинкапсуляции.

Ключевые слова: *микрокапсулирование, пищевая промышленность, продукты питания, инкапсулированный, инкапсулянт, аромат.*

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