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PROSPECTS FOR THE USE OF PROBIOTIC ENCAPSULATION PROCESS

Abstract: *This article discusses the various types, encapsulation stages, and polymers for encapsulating probiotics. The article reflects several methods of encapsulation, such as spray drying, spray freezing, emulsification, extrusion method, etc. Encapsulation allows isolating the encapsulated material from the surrounding environment until its release occurs. The structure formed by the encapsulating agent around the encapsulated material can be tailored to protect the contents and ensure their release under certain conditions. The size of capsules can range from submicron to several millimeters, and their shape can vary. The content of the capsule can be released through various pathways: mechanical rupture of the capsule, dissolution of the capsule, melting of the capsule, or diffusion through the capsule wall.*

In our time, a large number of people suffer from gastrointestinal diseases. Encapsulation of dietary supplements (BAA) will help replenish the deficiency of microelements in the human body. The article demonstrates that the use of encapsulated forms of probiotic cultures in the food industry, especially in the production of dairy products, will not only preserve the viability of the applied microorganisms but also provide favorable conditions for their development in the human body.

Key words: *encapsulation, probiotics, viability, capsule, gastrointestinal tract, polymers*

Given the significant role of gut microbiota in shaping the immunobiological reactivity of the body, the exclusive importance lies in the creation and use of functional food products based on microorganisms belonging to the normal physiological inhabitants of a healthy human intestine.

According to modern requirements imposed on these products, probiotic bacteria must be present in quantities corresponding to the therapeutic dose (no less than 1·108 CFU/g of the product), maintain viability throughout the product's shelf life, and survive in the human gastrointestinal tract [1]. However, to date, numerous studies indicate that a significant portion of probiotic cells loses its activity due to the death of microorganisms during the storage of products, as well as during the passage through the gastrointestinal tract. The reasons for this are low pH values of the stomach, the influence of gastric acid, and pepsin in the gastric juice, etc. The most promising direction for solving this problem is the use of a specific case of the bacterial cell immobilization process – encapsulation [2].

Encapsulation is a physico-chemical or mechanical process of enclosing small particles of a substance (solid, liquid, or gaseous) in a shell of a film-forming material to obtain particles with diameters ranging from several nanometers to several millimeters [3, 4].

The process of encapsulating microorganisms involves creating polymeric systems in the form of hydrogel matrices and microcapsules with immobilized microbial cells. The capsules have a dense outer shell that serves the role of a semi-permeable membrane, and an internal liquid content. Microorganism cells are localized within the matrix formed inside the capsules, where they can reproduce directly [5].

Initially, the encapsulation of biologically active substances was carried out to enhance their effectiveness, reduce toxicity, or for their stabilization, primarily – in the pharmaceutical industry and

pesticide production. Today, encapsulation is a rapidly developing technology that has found broad applications in various sectors of industry, serving as a notable example of utilizing microtechnologies in the fields of food science and biotechnology [6].

In the food industry, encapsulation of bioactive components is used to regulate oxidation-reduction reactions, adjust taste, color, and smell, and increase lifespan expiration date, etc. Currently, encapsulation of lactic acid bacteria, both starter cultures and probiotics, has become widespread to protect them in the gastrointestinal tract from acidic pH values, which makes it possible to increase the production of new technologies of functional food products [7].

The technology of encapsulation is gaining increasing interest in the field of biotechnology, because, in addition to increasing the survival rate of probiotic cultures in dairy products and in the gastrointestinal tract, it can protects cells from bacteriophages, increases their survival during drying and freezing, stabilizes quality indicators and increases expiration date of products. Moreover, encapsulated cultures provide greater stability of cells and high production of metabolites at a high agitation rate.

The encapsulating substance must be safe and capable of forming a barrier to protect probiotics.

There are various types of encapsulation, such as the «reservoir» type and the matrix type. In the first case, the encapsulating material forms a shell around the encapsulated material and, consequently, may be referred to as a capsule. In the matrix type, the active agent is dispersed in the carrier material but can also be present on the surface of the encapsulating substance. The combination of these two methods allows obtaining a third type of encapsulation – matrix, where the active agent is covered by a film [8].

The viability of encapsulated probiotic cells depends on the physicochemical properties of the capsules. For scientists conducting the encapsulation process, the following parameters are crucial: the type and concentration of the covering material, particle size, initial cell count, and the strain of certain bacteria. In the case of probiotic encapsulation, the task is not only to protect cells from adverse conditions but also to maintain them in a viable state with metabolic activity in the intestine. The obtaines capsules should be insoluble in water and stable in foods and in the upper gastrointestinal tract, and the encapsulating polymer must be allow for the gradual release of cell contents during intestinal digestion [9].

The encapsulation technology typically involves three stages.

The first stage involves incorporating bioactive components into a liquid or solid matrix. In the case where the base is a liquid, incorporation will occur through dissolution or dispersion in the matrix. If the base is a solid substance, introduction will be done through methods like agglomeration or adsorption.

In the second stage, the liquid matrix is dispersed, and the solution is sprayed onto the solid matrix.

Various materials are used for encapsulation, such as alginate, gellan gum, chitosan, pectin, etc.

Alginate hydrogels are widely used in cell encapsulation, and calcium alginate is preferred for encapsulating probiotics due to its simplicity of use, non-toxicity, biocompatibility, and low cost. The use of coating microcapsules with alginate during encapsulation is a popular research direction in the field of probiotic encapsulation. In addition to providing additional cell protection, such coatings can possess other beneficial properties, such as controlling the release of probiotic cells. The most popular material used for coating is the polysaccharide chitosan. Research has shown that a multilayer coating of chitosan on capsules enhances protective properties and can be applied to improve the survival of probiotic cells in highly acidic food systems, such as pomegranate juice.

Pectic substances, or pectins, are polysaccharides formed primarily from residues of galacturonic acid. They are present in all higher plants, especially in fruits, and some seaweeds. Serving as a structural element in plant tissues, pectins contribute to maintaining their rigidity, enhancing the resistance of plants to wilting, and the stability of vegetables and fruits during storage. Used in the food industry – as structuring formers (gelling agents), thickeners, as well as in the medical and pharmaceutical industries as physiologically active substances with beneficial properties for the human body. On an industrial scale, pectic substances are primarily obtained from apple and citrus pomace, sugar beet pulp, and sunflower husks.

Gelatin is a product of the destruction of collagen, the connective tissue protein in animals. The production of gelatin can be carried out through the following methods: acid, alkaline, enzymatic,

and steam extraction under high pressure. In the USA, food-grade gelatin is produced using acidic treatment of frozen pig skin, while in domestic food industry gelatin is obtained through alkaline treatment of bones and skins from pigs and cows.

Thus, the use of hydrophilic polymers for the encapsulation of probiotics is promising and contributes to the high viability of cells under the influence of aggressive conditions in the gastrointestinal tract.

An important aspect in the encapsulation process is the selection of the encapsulation method. Choosing the encapsulation method allows selecting the encapsulating material based on the morphological characteristics of the obtained capsules.

There are several encapsulation methods, such as spray drying, spray-freeze drying, emulsification, extrusion methods, and etc.

Spray drying is one of the oldest and most widely used methods of encapsulation employed in the industry. The use of this method provides flexibility and continuity in the process and contributes to obtaining capsules of high quality with a particle size of less than 40 micrometer. However, despite the widespread use of spray drying in the food industry, this method has several drawbacks, such as the need for complex and expensive equipment, uneven drying conditions in the drying chamber, as well as difficulties in controlling particle sizes.

Figure 1 shows a scheme for obtaining microcapsules.

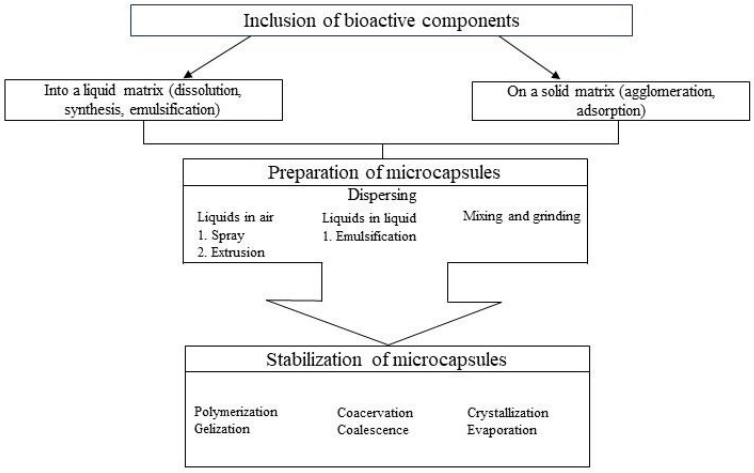

Figure 1 – Basic diagram describing the stages of obtaining microcapsules [11]

Vacuum or sublimation drying is very similar to the process of spray drying; however, it is faster and more cost-effective, as it occurs at a temperature above the freezing point of the solvent. The main drawback of sublimation drying is high energy consumption and the duration of the process.

Another commonly used method of encapsulation is emulsification. It is employed for encapsulating water-soluble components, is easily scalable, and ensures high cell survival for bacterial cultures. Capsules obtained through this method have a small diameter, but a major drawback is the production of capsules with a wide range of sizes and shapes.

The extrusion method is widely used in laboratory research. Extrusion is a physical method of encapsulating living probiotic cells using hydrocolloids (aqueous solutions of polymers) as encapsulating materials. The essence of the method is to obtain capsules by squeezing the polymer through a nozzle under pressure. The chosen method is simpler and cheaper, and also uses a gentle mode of operation and does not cause damage to probiotic cells and ensures their high vitality. However, this encapsulation method does not involve the use of harmful solvents and can be used both in aerobic and anaerobic conditions [12].

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ПРОБИОТИКТАРДЫ ИНКАПСУЛДЕУ ПРОЦЕСІН ҚОЛДАНУ КЕЛЕШЕГІ

Бұл мақалада инкапсулдеудің әртүрлі типтері, стадиялары, сонымен қатар пробиотиктерді инкапсулдеуге арналған полимерлер қарастырылған. Мақалада инкапсулдеудің бірнеше әдістері көрсетілген, олар мыналар: бүріккіш кептіру, спрей-тоңазыту, эмульгирлеу, экструзионды және т.б. әдіс. Капсулаланатын материалдың айналасында капсулалық агент түзетін құрылым қабырғалар мазмұнын қорғайтын және белгілі бір жағдайларда оның босатылуын қамтамасыз ететін етіп таңдалуы мүмкін. Капсулалардың мөлшері субмикроннан бірнеше миллиметрге дейін өзгеруі мүмкін. Пішіні де әртүрлі болуы мүмкін. Капсуланың мазмұнын әртүрлі жолдармен шығаруға болады: капсуланың механикалық бұзылуы, капсуланың еруі, капсуланың еруі немесе капсула қабырғасы арқылы диффузия арқылы.

Қазіргі уақытта көптеген адамдар асқазан-ішек жолдарының ауруларымен ауырады. Диеталық қоспаларды капсулалау адам ағзасындағы микроэлементтердің жетіспеушілігін толтырады. Мақалада тамақ өнеркәсібінде, әсіресе ашытылған сүт өнімдерін өндіруде

пробиотикалық дақылдардың капсулаланған түрлерін қолдану қолданылатын микроорганизмдердің өміршеңдігін сақтап қана қоймай, олардың адам ағзасында дамуы үшін қолайлы жағдайларды қамтамасыз ететіндігі көрсетілген.

Түйін сөздер: *инкапсулдеу, пробиотиктер, тіршілік қабілеттілігі, капсула, асқазан-ішек жолы, полимерлер.*

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ПЕРСПЕКТИВНОСТЬ ПРИМЕНЕНИЯ ПРОЦЕССА ИНКАПСУЛИРОВАНИЯ ПРОБИОТИКОВ

В данной статье рассматриваются различные типы, стадии инкапсулирования, а также полимеры для инкапсулирования пробиотиков. В статье отражены несколько способов инкапсулирования, такие как распылительная сушка, спрей – заморозка, эмульгирование, экструзионный метод и т.д. Инкапсулирование позволяет отделить капсулируемый материал от окружающей среды до тех пор, пока не произойдет его высвобождение. Структура, которая образуется капсулирующим агентом вокруг капсулируемого материала стенки могут быть подобраны таким образом, чтобы защитить содержимое и обеспечить его высвобождение при определенных условиях. Размер капсул может варьировать от субмикронного до нескольких миллиметров. Форма также может быть различной. Содержимое капсулы может быть высвобождено различными путями: механическим разрушением капсулы, растворением капсулы, расплавлением капсулы, либо путем диффузии через стенку капсулы.

В наше время большое количество людей страдают болезнями желудочно-кишечного тракта. Капсулирование БАДов позволит восполнить нехватку микроэлементов в организме человека. В статье показано, что использование капсулированных форм пробиотических культур в пищевой промышленности, особенно при изготовлении кисломолочных продуктов, позволит не только сохранить жизнеспособность применяемых микроорганизмов, но и обеспечить благоприятные условия для их развития в организме человека.

Ключевые слова: *инкапсулирование, пробиотики, жизнеспособность, капсула, желудочно-кишечный тракт, полимеры.*

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ИССЛЕДОВАНИЕ И ПРИМЕНЕНИЕ ТЕХНОЛОГИИ МИКРОДУГОВОГО ОКСИДИРОВАНИЯ ДЛЯ ВОССТАНОВЛЕНИЯ РАБОЧИХ ПОВЕРХНОСТЕЙ ПОРШНЯ ГРУЗОВЫХ ТРАНСПОРТНЫХ СРЕДСТВ

Аннотация: *Научная статья посвящена исследованию и применению технологии микродугового оксидирования для восстановления рабочих поверхностей поршней грузовых транспортных средств. Исследование включает в себя анализ физико-химических процессов, происходящих во время микродугового оксидирования алюминиевых сплавов, из которых изготовлены поршни. Физическое воздействие МДО способствует формированию прочного и стойкого оксидного слоя, приводя к улучшению морфологии поверхности и закрытию микротрещин. Полученные результаты подтверждают, что данная технология способствует формированию твердых покрытий. Отмечается наличие микротрещин и поверхностных дефектов на исходной поверхности алюминиевого сплава, вызванных эксплуатацией. После применения процедуры микродугового оксидирования видна значительная улучшенная морфология поверхности, уменьшение*