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Possibilities of Use of Double Emulsions in the Food Industry

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Abstract: Emulsions are becoming more and more important in the food sector. These systems allow for the targeted administration of biologically active compounds to the human body as well as the production of new generation products with desired features. It is possible to achieve renewal of the properties of the resulting products through the use of modern approaches in the technologies for creating emulsions and their implementation in the production of dual systems (improvement of organoleptic properties, preservation of freshness and high nutritional value of the product at all stages of its storage, protection of labile ingredients during the technological and digestive processes, controlled release of biologically active ingredients, etc.). An ecologically friendly technique that may be used in the food business to create new food systems that are supplemented with biologically valuable ingredients is the use of double emulsions. The creation and usage of beneficial goods made without the use of chemical substances are receiving a lot of attention right now, which makes this strategy both relevant and promising from a scientific and practical standpoint. Currently, the two-stage emulsification process is the most used technique for creating double emulsions. The biggest disadvantage of this approach of gaining is the system that is created has a poor level of stability. Therefore, current research focuses on creating novel techniques to stabilize the system of double emulsions, such as membrane emulsification, phase inversion techniques using microfluidic devices with glass capillaries, and ultrasonic therapy.

Keywords: Double emulsion, emulsifier, food system, biologically active substances

Emulsions are an integral part of the nutritional matrix of many foods. Various methods of their production, the use of new approaches in the technologies of creation and placement in the system make it possible to obtain new generation products with desired properties and targeted delivery of biologically active substances to the human body [14]. Direct and reverse emulsions, which have long been used in the food industry, are a complex disperse system consisting of microscopic drops of a liquid (dispersed phase) distributed in another

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liquid (dispersion medium). Such systems have a number of limitations for enrichment with biologically active substances that have different ratios to the phase and dispersion medium. Whereas, due to additional levels of organization, both hydrophilic and hydrophobic compounds can be encapsulated in double emulsions, since they represent a multilevel system [12, 13].

Dual emulsion systems can be used to modify the properties of the resulting products (improve sensory characteristics and shelf life), protect labile ingredients during processing and digestion processes, and control the release of active compounds. For the successful use of double emulsions in the food industry, it is necessary to take into account the factors affecting the thermodynamic instability of the system, such as the type and concentration of the emulsifier, pH, temperature, etc. [3].

The two-stage emulsification procedure shown in the figure 1 is the most common method for obtaining double emulsions [9]. The first step is to create water-in-oil (W/O) or oil-in-water (O/W) emulsions using hydrophobic or hydrophilic emulsifiers [13]. In the second step, a combination is carried out to obtain a system of double emulsions (eg water-oil-water (W1/O/W2)).

Although double emulsions are less stable than traditional ones, they have a wider range and application possibilities in targeted food system technologies, such as encapsulation of biologically active substances and subsequent fortification, development of low-calorie food products with improved sensory characteristics and texture, etc.

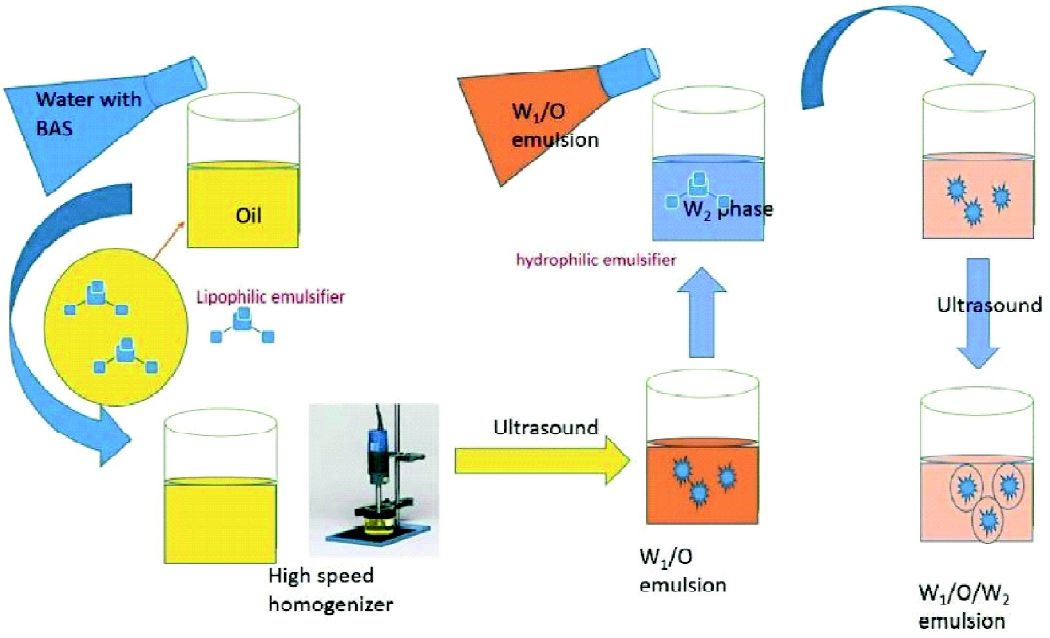

Figure 1: Generalized scheme for obtaining double emulsions

A fairly large number of scientific papers (see table 1) are devoted to research in this area, which indicates its attractiveness for the real sector of production.

The presented studies show that the creation of double emulsions is an effective emulsification process for obtaining a wide range of natural food products.

It should be noted that the use of double emulsions is a «clean» technology, environmentally friendly, which can be used in the food industry when obtaining new food systems enriched with biologically active substances. Currently, special attention is paid to the development and use of useful products obtained without the use of chemical ingredients, which makes this approach relevant and promising both in scientific and practical terms.

Table 1: Characteristics of developments in the field of application of double emulsions in the food industry

Namedevelopment	*Mode of production*	*Results*	*Source*
Iron encapsulation	Two-Step Emulsification Method	High bioavailability of the substance and encapsulation efficiency; sufficient emulsion viscosity to allow iron to be encapsulated in ice cream and whipped cream	Ilyasoglu Buyukkestellи El [6]
Microencapsulation of calcium and vitamin D_3	Two-stage emulsification method withusing ultrasound	Increased bioavailability of vitamin $D_{3;}$ increase in the rate of releaseCa^{2+}	Dima [5]
Folic acid nano-encapsulation	Two-stage emulsification method after spray drying	Encapsulation efficiency – 88.3%, the ability to encapsulate in all food products	Assadpour [2]
Encapsulation Vitamin C	Two-Step Emulsification Method	Encapsulation Stability –79.75%; encapsulation efficiency– 95%, which decreases to 79 % when heated. Can be used for drinks	Kheynoor [7]
Encapsulation Probiotic *Lactobacillus reuteri*	Two-Step Emulsification Method	Viability of bacteria – 98%; survival - from 7.59 to 7.23 CFU / ml. Stability of storage of strains – up to 30 days	Marefati [11]
Encapsulation of glycyrrhizin in double nanoemulsions	Two-Stage Ultrasonic Emulsification Method	Encapsulation efficiency – 92%, emulsion storage stability – up to 7 days	Maghamian [10]
Encapsulation Riboflavin	Two-Step Emulsification Method	Encapsulation Efficiency – 85.4% (in chia oil), stability up to 8 days	Bou [4]
Encapsulation of biologically active substances	Two-stage method for obtaining Pickering emulsions using ultrasound	High values of antioxidant activity of yogurt with emulsion – 5,120 DPPH, %, consistency stability in storage	Potoroko [1]

Modern studies focus on the development of new approaches to stabilize the system of double emulsions, for example, the use of ultrasonic treatment, methods of phase inversion of microfluidic devices with glass capillaries, membrane emulsification, etc. However, a number of researchers [3, 8, 10, 11, 13] note that the long-term stability of double emulsions is still a critical factor for the final product, which somewhat limits their use on an industrial scale.

Thus, the interest in developments in the field of double emulsions is very relevant, as it allows creating a food system of a new format.

Conclusions

Double emulsions have a lot of promise as compartmentalized systems to encapsulate various components for safeguarding actives, disguising flavor, and precisely administering and controlling the release of medications. To obtain the best therapeutic effectiveness for pharmaceutical applications, precise control of each component's encapsulation properties is essential. By creating monodisperse double emulsion droplets utilizing microfluidic techniques, such controlled encapsulation may be achieved.

Double emulsions' inner and outer drops, with carefully regulated structures and compositions, provide distinct compartments for efficient and controllable encapsulation of different or incompatible components. These microfluidic double emulsions are potent templates for compartmental microparticles that can encapsulate several components for delivery and controlled release. Since double emulsions are metastable multiphase systems, surfactants must be found to stabilize them for prolonged shelf life. These experiments would improve.

Double emulsions can make low-calorie meals, pharmaceutical encapsulation, and other high-value goods. Shear sensitivity makes it hard to manage double emulsion production. Membrane emulsification uses modest shear forces, making it ideal for double emulsion formation.

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