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Possibilities of Applying Pickering Emulsions in Food Systems

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SUMMARY. **Pickering emulsions have received a lot of attention from academics recently because they are more physically and chemically stable than regular emulsions and offer a wide range of potential applications. Pickering emulsions can be made using a variety of techniques, and in most cases, both inorganic and organic particles are stabilized. While organic particles have a large molecular weight, inorganic ones are constrained by their indigestibility and lack of biodegradability. In order to describe the characteristic features of Pickering emulsions and the important elements impacting their quality, the paper analyzes data from the literature (wettability, particle shape, and size). The kinds of natural particles (polysaccharide particles, protein-based particles, flavonoid particles, complex particles (complexes), and solid lipid nanoparticles) utilized as stabilizers in Pickering food emulsions are taken into account. The use of Pickering's emulsion in food systems (dairy and meat products, mayonnaises) is predicted to vary in the future, according to trends. Finding a stabilizer with the required physical qualities, improved biological activity, and a secure method of modification is crucial. Research in this area will enable the development of new resource-saving technologies, a task in demand in both the economic and social spheres. Because this will provide a solution to the problems associated with extending the range of bioproducts that have a particular technological functionality and are secure for consumers.**

RESUMEN. Recientemente, las emulsiones Pickering han recibido mucha atención de los académicos porque son más estables física y químicamente que las emulsiones regulares y ofrecen una amplia gama de aplicaciones potenciales. Las emulsiones de pickering se pueden hacer utilizando una variedad de técnicas y, en la mayoría de los casos, se estabilizan tanto las partículas inorgánicas como las orgánicas. Mientras que las partículas orgánicas tienen un gran peso molecular, las inorgánicas están limitadas por su indigestibilidad y falta de biodegradabilidad. Para describir las características de las emulsiones Pickering y los elementos importantes que afectan su calidad, el artículo analiza datos de la literatura (mojabilidad, forma y tamaño de las partículas). Se tienen en cuenta los tipos de partículas naturales (partículas de polisacáridos, partículas basadas en proteínas, partículas de flavonoides, partículas complejas (complejos) y nanopartículas lipídicas sólidas) utilizadas como estabilizadores en las emulsiones alimentarias de Pickering. Se prevé que el uso de la emulsión de Pickering en los sistemas alimentarios (productos lácteos y cárnicos, mayonesas) varíe en el futuro, según las tendencias. Es crucial encontrar un estabilizador con las cualidades físicas requeridas, actividad biológica mejorada y un método seguro de modificación. La investigación en esta área permitirá el desarrollo de nuevas tecnologías ahorradoras de recursos, una tarea demandada tanto en el ámbito económico como en el social. Porque esto dará solución a los problemas asociados a la ampliación de la gama de bioproductos que cuentan con una determinada funcionalidad tecnológica y son seguros para los consumidores.

KEY WORDS: biologically active substances, food systems, Pickering emulsions, solid particles, stabilizers.

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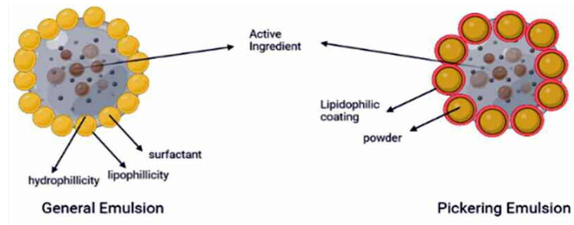
INTRODUCTION

One of the main trends in the modern food industry is the creation of environmentally friendly and energy-balanced "natural" food products that provide high-quality food. Consumer demand for functional, therapeutic, and dietary foods is also increasing [1]. Many food products are highly concentrated emulsions. Emulsions can be found in dairy, meat, confectionery, oil and fat products, and drinks. A dispersed system made up of many immiscible liquids is known as an emulsion. At the same time, it should be noted that today, stable emulsion systems with a high concentration of the dispersed phase are of particular interest to manufacturers. Such close attention to them is due to the fact that it is the dispersed phase that is the carrier of various useful applied properties, if we consider the emulsion from a technological point of view as the basis for the production of various food products [31-34]. Ordinarily, conventional emulsions stabilized with surfactants or amphiphilic macromolecules with strong solubility (such as proteins and polysaccharides) are thermodynamically unstable and have a propensity to degrade over time as a result of coalescence, flocculation, and Ostwald maturation [18]. Pickering emulsions, in which solid particles take the role of molecular surfactants, may be able to solve this issue. Emulsions stabilized by solid particles were first studied at the beginning of the 20th century by W. Ramsden (1904) and S. Pickering (1907) [24,26]. They offer many advantages over classical emulsions, such as lower toxicity, long-term stability, and economy. Therefore, they have found wide application in the pharmaceutical 3, food 34, cosmetics [30,32], chemical [5], oil [14], and other industries.

Pickering emulsions are used in the production of new materials and colloidosomes, and also often in the encapsulation and delivery of biologically active substances [2]. It should be noted that Pickering emulsions stabilized with inorganic particles are of limited use for food purposes. Literary and patent analysis of the available resources of the scientific electronic library Elibrary.ru showed that only 47 documents are identified by the key phrase "Pickering emulsions," and the existing publications relate mainly to the chemical and pharmaceutical industries. It was also revealed that work in this area of research has been carried out relatively recently (since 2013). In the international databases and citation systems Scopus and Web of Science, 33,800 scientific research documents in the field of "Pickering emulsions" were identified. The main leaders of scientific research in terms of frequency of mention are China, the USA, Great Britain, France, and Germany.

In recent years, interest in Pickering emulsions has been growing due to their specific properties that are attractive to manufacturers. The difference between conventional emulsions and Pickering emulsions lies



in the different mechanisms of their stabilization. The major methods for stabilizing traditional emulsions include a mixture of electrostatic stabilization, interfacial tension reduction, and steric stabilization using surfactants or soluble macromolecules. Concurrently, conventional emulsifiers' adsorption at the oil-water interface in conventional emulsions is often reversible. Particles deposited at the oil-water interface for Pickering emulsions provide a physical barrier (Fig. 1) that can prevent droplet contact and interfacial interaction due to volume exclusion. This adsorption of particles is thought to be irreversible. Emulsions are given distinct interfacial features by various stabilization methods. Pickering emulsions have a larger surface load and thickness than traditional emulsions because of the adsorption of particles 10 (Fig. 1).

Figure 1. Typical appearance of oil-in-water emulsion - ordinary and Pickering, as well as various forms of particles of the Pickering stabilizer.

Application of Pickering emulsion

Based on how hydrophobic the particles are, simple Pickering emulsions can be categorized as either oil-in-water (O/W) or water-in-oil (W/O) [5]. Water-in-oil-in-water (W/O/W) and oil-in-water-in-oil (O/W/O) On the basis of this hypothesis, Pickering double emulsions were developed, which are more intricate. Two-stage emulsification is often the foundation of common methods for creating Pickering double emulsions [12]. Insoluble solids serve to stabilize Pickering emulsions. The stability of emulsions is primarily influenced by wettability and particle size. Only particles having dual wettability, which must stay stable in both the oil and water phases, can be utilized as stabilizers for Pickering emulsions [22]. The size of the solid stabilizing particles is also an important factor in determining the stability of Pickering emulsions. If the particle size is not much smaller (at least 10 times smaller) than the droplet size of the fractions in the emulsion, the particles won't be able to adsorb at the oil-water interface for stabilization [36]. The particles form a steric barrier that prevents the aggregation of the dispersed phases at the oil-water interface due to their appropriate wettability and size.

Kind of particles		Particle size	Particle shape	Source
Polysaccharide particles	modified cassava starch	5-100 nm	spherical	6
	modified quinoa starch granules	1-2 μm	spherical	16
	cornstarch particles	500-700 nm	elliptical	15
	nanocrystals of starch	79-95 nm	polygonal	25
	nano cellulose fibrils	33-49 nm	fibrous	11
	chitosan particles	100-500 nm	rod-shaped	7
	nanocrystals of chitin	20-250 nm	rod-shaped	33
	with upracolloids lignin	90-600 nm	spherical	21
Protein Particles	hours of soy protein	60-130 nm	polygonal	13
	soy protein ash	0.2-160 μm	spherical	17
	whey protein microgels	250-300 nm	spherical	27
	to azeic nanogels	180 nm	spherical	4
	gelatin nanoparticles	250 nm	spherical	31
	peanut protein particle	178-260 nm	spherical	20
Particles of flavonoids	tiliroside /rutin/naringin	500-1000 nm	unknown	8
	flavonoid glycoside particles from Ginkgo biloba extract	0.8-1 μm	unknown	37
With false particles (complexes)	particles to complex a alginate-chitosan	230-1100 nm	spherical	19
	β-cyclodextrin-glucan complex particles	105 nm	spherical	9
	particles of whey protein complex and curcumin	0.2 μm	rod-shaped	38
Solid lipid nanoparticles	β-cyclodextrin	unknown	unknown	29
	crystalline tripalmitin nanoparticles _	130 nm	spherical	23
	to crystalline nanoparticles of tripalmitin	100-350 nm	spherical	28

Pickering emulsion stability is significantly influenced by particle shape as well. Spherical, fibrous, polygonal, ellipsoidal, and rod-shaped particles are among the several particle morphologies.

Pickering emulsions can be stabilized by using particles with a wider contact area because they can wet both phases [10]. The absence of surfactants makes it possible to use Pickering emulsions in the food industry. According to numerous studies, a wide variety of solid particles with natural origins can be used as stabilizers. Polysaccharide particles, protein-based particles, flavonoid particles, complex particles (complexes), and solid lipid nanoparticles are the basic groups into which these solid particles can be divided. Table 1 presents data on the use of these particles as stabilizers for Pickering emulsions.

Table 1. Particles used as stabilizers for Pickering food emulsions.

While information on their usage in food systems has not been discovered, the quantity of scholarly works on the topic of choosing solid particles as stabilizers of Pickering food emulsions and the research of their stability has expanded tremendously recently. Due to their high stability, physical properties, and health benefits, Pickering's emulsions can be a promising alternative to conventional emulsions and act as an innovative approach to the creation of a new line of "health" food products. According to. Xia [35], the use of Pickering food emulsions can replace butter in the production of multicomponent confectionery products and cream in the preparation of yogurt and ice cream. Ultrasonic treatment has been used to obtain a bioactive colloidal Pickering emulsion system using brown algae and flax cellulose polysaccharides as structuring components. This work shows that ultrasonic treatment can be an effective tool for obtaining highly stable emulsion-type food systems with bioactive effects [39]. However, before the industrial use of Pickering's food emulsions, it is necessary to solve a number of problems related to the selection of a stabilizer as well as develop a safe method for its modification.

CONCLUSION

In recent years, Pickering emulsions have become a popular topic of discussion due to their widespread use in a variety of fields, including medicine, cosmetics, food technology, and material engineering. The current movement in the food business to reduce the amount of artificial additives being used is the primary factor contributing to their rising popularity. Future research will be aimed at developing new technologies for obtaining physically and chemically stable Pickering emulsions for placement in the food matrix of mayonnaise, dairy, and meat products.

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