Composition, physicochemical properties, preparation methods and application research status on Functional oils and fats of nanoemulsion: A comprehensive review

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Abstract. Functional oils and fats of nanoemulsion as a food nutrient transport system is considered to be effective and safe. The article expounds Composition, physicochemical properties, preparation methods and application research status on Functional oils and fats of nanoemulsion, to give more nutritional and functional of the Functional oils and fats, recommendations focus on the interaction with real food matrix between may study, optimization, explore new mechanism and preparation methods of the Functional oils and fats of nanoemulsion, in order to provide a theoretical basis for the further study of bioactive compounds or food components, and to effectively meet the urgent needs of the food industry for the high quality raw materials of the Functional oils and fats of nanoemulsion system, a wide range of bioactive compounds or food components are particularly considered.

1. Introduction

Functional fats and fats are rich in special nutrients or active substances, which have the functions of regulating body and preventing cardiovascular diseases, mainly to meet the health consumption of infants, pregnant women, middle-aged and elderly people and other special populations. But Functional oils and fats, the active ingredient not saturation is high, easy to oxidative rancidity and losing its unique efficacy, together with its hydrophobic properties and unique flavor, digest/metabolic enzymes and other factors, leading to its compatibility with food matrix variation, reduced bioavailability\textsuperscript{[1]}.

As a "near thermodynamic stability" system, Functional oils and fats of nanoemulsion in the fields of preparation technology, physicochemical properties and embedding and transport of various fat-soluble nutrients have been made\textsuperscript{[2]}. Comprehensive research has proved that Functional oils and fats of nanoemulsion can prevent functional oil nutrients was oxidized and increase its water solubility and bioavailability, increase its nutritional value and its stability, appearance, taste or quality of a material, to a certain extent, reduce its inherent odor bitterness and astringency, making it more easily accepted by consumers\textsuperscript{[3-4]}.

To promote the industrialization of Functional oils and fats of nanoemulsion exploitation and utilization, and give the functional oils and fats more nutritional and functional, the article expounds the
Functional oils and fats of nanoemulsion on constitution, physicochemical properties, preparation methods and application research status, in order to offer theoretical basis to promote its further research and effectively satisfy the food industry to the urgent needs of the nano emulsion system of high quality raw materials.

2. Functional oils and fats of nanoemulsion on constitution

Functional oils and fats of nanoemulsion is a homogeneous emulsion formed by mixing oil, water, emulsifier and co-emulsifier. The central part is filled with one or more oil phases which are composed of oil compounds as the core material. The oil-water interface layer is stacked with emulsifier as the wall material, and the outermost layer is a continuous phase mainly composed of water. The fat-soluble core material needs to choose the water-soluble wall material, and the water-soluble core material is the fat-soluble wall material, that is, the wall material can not react with the core material and immiscible.

2.1. Oil phase

In general, the shorter the length of hydrocarbon chain in the oil phase, the more stable the nanoemulsion is. Therefore, Functional oils and fats of nanoemulsion is generally selected as the carrier of nutrients, such as corn oil, soybean oil, olive oil, peanut oil and flaxseed oil with short or medium chain length, which are harmless to human body. The solubility of the core material in the oil phase can change the viscosity of the oil phase and affect the interfacial behavior of the emulsifier and the stability of the emulsion. Therefore, the solubility, polarity, viscosity, density, surface tension, refractive index and chemical stability of the core material should be considered in the preparation of the Functional oils and fats of nanoemulsion.

2.2. Aqueous phase

Based on safety and economy, food-grade emulsifiers (such as β-lactoglobulin, whey protein isolate and octenyl succinic acid modified starch, gum Arabic acid and other polysaccharides) are preferred for the preparation of the Functional oils and fats of nanoemulsion, which are safe, non-toxic, high digestibility and good emulsifying activity. The ideal emulsifier can increase the solubility of emulsifier, adjust the HLB value of emulsifier and reduce the interfacial tension of oil and water, which is beneficial to the stability of nanoemulsion and make the emulsion form smaller drops, but can not improve the stability of nanoemulsion at low temperature storage. General aid emulsifier includes short chain alcohol, organic ammonia, single and double amino acid glyceride, etc., and the most used is short chain alcohol, commonly used aid emulsifier has ethanol, ethylene glycol, propylene glycol, propylene triol and poly glyceride, etc.

3. Functional oils and fats of nanoemulsion on physicochemical properties

3.1. Average drop size (ADS)

The type and content of emulsifier have important effects on the formation and particle the average drop size (ADS) of nanoemulsions, while temperature and rotation speed are not the main effects. ADS affects the stability, appearance, and digestive properties of nanoemulsions. Small droplet size usually results in improved stability, gravitational separation, and aggregation. Studies showed that the effects on ADS of ultrasonically prepared green tea seed oil and fractioned coconut oil nanoemulsion tea seed oil and special oil nanoemulsion were, in descending order, emulsifier content > ultrasonic time > ultrasonic power [4]. The influencing factors of Shea Butter nanoemulsion ADS were oil concen>NaCl concen> emulsifier concen, additive had significant influence, while the influence of oil type did not have significant regularity [5]. Protein α-helix (P < 0.01) and β-spin (P < 0.05) are related to corn oil nanoemulsion ADS (< 245nm) [6].
3.2. Polydispersity index (PDI)
Polydispersity index (PDI) represents the size distribution of nanoemulsion, which is an important index and parameter for the identification and evaluation of nanoemulsion. The PDI value between 0.2 and 0.5 indicates that the distribution of nanoemulsion is more concentrated, the dispersion effect is better, and the stability is higher. The larger the PDI, the more dispersed the particle size distribution of the emulsion, indicating that the nanoemulsion is prone to delamination or precipitation. The smaller the particle size of nanoemulsion, the larger the surface area, the lower the stability; Under the same particle size, the smaller the dispersion index, the stronger the stability [7]. Liang-hong Chen[5] found that when oil was 14% and emulsifier was 5%, NaCl increased from 0% to 0.5%, and the PDI value of shea Butter nanoemulsion decreased from 0.268 to 0.177. NaCl had a significant effect on the PDI value, both oil and emulsifier were small, and the influence of oil type did not show significant pattern.

3.3. Zeta-potential values
The zeta-potential was used to characterize the surface charge properties of the nanoemulsion, it was generally believed that the absolute value of zeta-potential was less than 30mV, indicating that the emulsion was less stable, while the absolute value of zeta-potential >30mV indicated that the emulsion was more stable. The results showed that the random coil of protein (P <0.05) was related to the zeta-potential value of corn oil nanoemulsion[6]. The zeta-potential value of Antarctic krill oil nanoemulsion prepared with whey protein isolate as wall material was -4.25 ± 1.91 mV, and the mutual repulsion was weak, the stability was poor, and the aggregation and precipitation were easy. However, the nanoemulsion with sodium caseinate, stearic acid and zein as wall materials had a smaller particle size and a zeta-potential of -22.65 ± 3.32mV, -61.95 ± 0.49mV and -32.3 ± 3.39mV, respectively, indicating good stability and no accumulation[8].

3.4. Stability
Stability is an important index for the evaluation of nanoemulsion, the formation and stability of nanoemulsion depend on the physical and chemical properties of oil phase, water phase and emulsifier, and its stability is closely related to the composition and concentration of each phase and the added composition. In addition, the oil phase with medium chain length is easier to form nanoemulsion, and the oil phase with low water solubility is more stable than the oil phase with high water solubility. Therefore, in order to adjust the physical and chemical stability of nanoemulsion, different oil and water phases and different emulsifiers, thickeners and antioxidants should be selected and added to them in some cases[5, 9-11].

It was found that the increase of olive oil significantly improved the stability of nanoemulsion and hindered the maturation of Ostwald, and more aromatic compounds were retained in olive oil nanoemulsion [12]. Fish oil nanoemulsion was stable at both 4℃ and 25℃ for 30 days, with good resistance to certain concentration of Na+, unstable under acidic conditions and stable under alkaline conditions [11]. ADS(162 ~ 839 nm) and zeta-potential (9 ~ 40μmV) significantly affected the stability of high oleic acid palm oil nanoemulsion, and caused instability through Ostwald maturation mechanism [13]. The optimal storage temperature of kenaf seed oil-in-water nanoemulsion was 4 ℃, and the bioactivity stability and antioxidant activity were maintained at 8W, with VE and phytosterol retention rates of 90% and 65%, respectively[14]. High temperature and low temperature have great influence on the stability of peony seed oil nanoemulsion, which needs to be stored at room temperature of 25 ℃. Under the condition of high speed centrifugation, the particle size and zeta-potential of the crystal were little changed, with uniform appearance, no delamination, and good stability [15].

3.5. Bioavailability
Functional oils such as DHA algal oil are rich in polyunsaturated fatty acids and have the effect of preventing cardiovascular diseases. However, they are highly unsaturated and easily rancidity due to oxidation. Therefore, the construction of nanoemulsion can improve oxidative stability and bioavailability. Palm oil nanoemulsion is the best system for improving the bioaccessibility and stability
of lipid-soluble active substances such as β-carotene. The fatty acid DHA nanoemulsion can increase the release of omega-3 fatty acids. MCTS nanoemulsion can improve lipid digestibility and bioaccessibility of rosiderene. Nanoemulsions prepared using long-chain triglycerides (corn or fish oil) were most effective in increasing the bioavailability of vitamins.

4. Preparation of the Functional oils and fats of nanoemulsion

Nanoemulsions are non-equilibrium systems that do not spontaneously form, and the choice of the appropriate method for preparing nanoemulsions depends on the properties of the compounds (especially the oil phase and emulsifiers) that need to be homogenized, as well as the physical and chemical properties and operational qualities (including rheological, optical, release and stability properties) required for the final product. Including through mechanical equipment to provide energy method called high-energy emulsification method, using the method of potential chemical structure called a low-energy emulsification method.

4.1 High-energy emulsification method

High-energy emulsification is the most commonly used method for preparing nanoemulsion. Generally, there are three methods, namely high-pressure homogeneous emulsification, phacoemulsification and micro-jet emulsification. High pressure homogenizing emulsification method is mainly suitable for the preparation of emulsion systems with medium or low viscosity. The most widely studied products include Seabuckthorn fruit oil nanoemulsions, Shea Butter nanoemulsions, Perilla oil nanoemulsion, Sacha inchi oil nanoemulsions, Deep-sea fish oil nanoemulsion, Fish oil nanoemulsion, etc. Phacoemulsification is a kind of practical, it is commonly used in Oil-tea camellia seed oil, Sunflower seed oil nanoemulsion, Crab oil nanoemulsion, Algal oil nanoemulsion, etc. Microfluidization can produce adverse effects under certain circumstances, which can lead to the recoalescence of emulsion droplets. In addition, there are disadvantages such as high production cost, high requirement of equipment construction precision, and high operating conditions and difficulties.

4.2 Low-energy emulsification method

The low-energy emulsification method includes spontaneous emulsification method and phase transfer method. Gulotta A et al. prepared optically transparent nanoemulsion using polyunsaturated (omega-3) fish oil as raw material by spontaneous emulsification. Zhong Jinfeng et al. used the self-emulsification method to prepare nano-emulsions with uniform particle size, stable non-delamination and low turbidity, which can improve the solubility and bioavailability of nano-emulsions, and prevent inflammation by combining with nano-emulsification. Yukuyama et al. obtained Olive oil nanoemulsion with 275nm ADS by high pressure homogenization and DPE. Jian-run Zhang prepared nanoemulsion with sodium caseinate as wall material and emulsified solvent evaporation method, which could better retain the good functional components of Antarctic krill oil.

5. Application research status on Functional oils and fats of nanoemulsion

Study found that the Functional oil and fats microemulsions can build optical transparent system, increase the solubility, activity increase coating hydrophobic compounds bioavailability of nutrients and improve its stability, and therefore as lipotropy sexual material conveying carrier in functional foods, dairy beverage, food additives, medicine and cosmetics, and other fields are closely watched application prospect.

5.1 Functional foods

Functional oil and fats nanoemulsion is especially suitable for the encapsulation of lipophilic nutrients. Research shows that: The total α-tocopherol bioavailability of kenaf seed oil nanoemulsion was 1.7 and 1.4 times higher than that of kenaf seed oil and kenaf seed oil macroemulsion prepared by conventional methods, respectively. Curcumin flaxseed oil nanoemulsion rich in alpha-linolenic acid can increase the concentration of DHA in serum, liver, heart and brain lipids, which is beneficial to meet the needs
of vegetarian population\cite{23}. Zhang Y et al.\cite{24} Preparation of kiwifruit linolenic acid oil nanoemulsion (ADS of 60±10nm) by high speed shear emulsification or high pressure homogenization technology has broad application prospects in the field of nutrition and health care. Algae oil is rich in omega-3 long-chain polyunsaturated fatty acids and is prone to lipid oxidation and unpleasant fishy smell. omega-3 algal oil nanoemulsion (ADS=258nm) improves DHA absorption rate, absorption amount and bioavailability of strawberry yoghurt\cite{25}. The temperature-sensitive seaweed oil nanoemulsion with phytochemical structure has a low fishy smell and good oxidation stability and can be used in the combination of functional food and liquid food systems such as beverages and condiments\cite{26}.

5.2 Milk products, beverages, food additives

Functional oils and fats of nanoemulsion encapsulation system can minimize the appearance and taste of food, deliver bioactive ingredients to improve bioavailability, and improve the general characteristics of traditional food. The study confirmed: Bioaccessibility of carotenoids is improved by enhancing the physical and oxidative stability of Flaxseed oil nanoemulsion\cite{27}. The physicochemical indexes, trace element content and microorganism indexes of orange juice beverage obtained by adding Eucommia seed oil nanoemulsion as functional raw material meet the requirements of national standard\cite{28}. When DHA or EPA nanoemulsion was added to apple juice, it was found that there was no obvious influence on the fruit juice reducing sugar content, titratable acid content, pH, soluble solids and other indicators, but there was a certain influence on the color, turbidity and odor and other apparent indicators\cite{29}. Silva W, et al.\cite{30} Gallic acid and quercetin O/W type nanoemulsions in the oil phase of olive oil, linseed oil and fish oil are used as potential fat substitutes in various food formulations. Jarzbski M et al.\cite{31} used Hemp seed oil nanoemulsion as a potential carrier for food additives (such as spices).

5.3 Drugs

Functional oils and fats of nanoemulsion has the advantages of good solubility, Cheong et al.\cite{32} proposed Kenaf seed oil nanoemulsion as a natural alternative to synthetic hypocholesterolemic drugs for the prevention and treatment of cardiovascular disease and fatty liver disease. Shen Q et al.\cite{33} prepared Sea-buckspine oil nanoemulsion (O/W type, ADS 52.2±4.8 nm, average drug loading 0.24 mg/mL) as a potential delivery system for skin treatment. Walia N et al.\cite{34} prepared Fish oil nanoemulsion using ultrasonic technology (ADS= 300-450nm, VD encapsulation rate 95.7-98%), which can be used as a carrier for drug delivery of various lipophilic compounds.

6. Conclusion

In this paper, the research and application of Functional oils and fats of nanoemulsion are reviewed based on many published research results, and the summary analysis shows that it will definitely have a broader application prospect in the future. Suggested that the future focus on the Functional oils and fats of nanoemulsion and other large molecules that exist in the real food matrix (such as proteins, carbohydrates, fiber) the study of the possible interaction between, continuous optimization and explore new Functional oils and fats of nanoemulsion mechanism and preparation methods. On the one hand, the physicochemical properties, stability and bioavailability of the Functional oils and fats of nanoemulsion are improved, in order to better avoid the existing limitations and have universality, versatility and versatility, and determine the appropriate operation mode and production scale to facilitate the food industry mass production.

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