Methodological approach to the creation of functional foods enriched with encapsulated micronutrients

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Abstract. The problem of malnutrition and micronutrient deficiencies in the diets of the population of all age groups is relevant not only for Russia, but also for many countries. An effective solution to this problem is the regular inclusion in the diet of functional foods enriched with bioactive micronutrients. An urgent task in the enrichment of food products with deficient micronutrients is the preservation of their bioactive properties and bioavailability. An effective solution to the problem of maintaining the bioavailability of micronutrients is to use encapsulated micronutrients for food enrichment. We have developed the methodological approach to the creation of functional foods enriched with encapsulated micronutrients, and also formulated the basic requirements for each stage. The implementation of the developed methodological approach will make it possible to create functional food products that ensure the normalization of the nutritional status of the population of different age groups.

1 Introduction

The problem of malnutrition and micronutrient deficiencies in the diets of the population of all age groups is relevant not only for Russia, but also for many foreign countries [1-3]. Carbohydrate diet, with a predominance of refined carbohydrates, characteristic of the majority of the population, leads to the risk of cardiovascular disease, diabetes, nutritional deficiencies of macro- and micronutrients [2, 3].

An expedient and effective way to solve these negative conditions of the human organism is the regular inclusion in the diet of functional foods enriched with bioactive micronutrients [2, 4].

However, no less urgent problem of using micronutrients in food technologies is their chemical instability and low bioavailability. Currently, one of the most promising approaches to solving this problem is the encapsulation of micronutrients in the design and construction of functional food products, which allows not only to ensure the preservation of micronutrients in their native form both before and after enrichment of food products

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with them, but also to contribute to their effective assimilation by the human organism, ensuring adequate bioavailability and the manifestation of physiologically-specified functional properties [5-7].

Encapsulation of drugs and biologically active additives is widely used in medical practice, specialized and functional nutrition [8, 9]. The use of various types of encapsulation systems (liposomes, nanoemulsions, hydrogels, etc.) for the development of delivery systems for unstable compounds (for example, antimicrobial agents, flavors and biologically active substances) and the preservation of their functional properties is reflected in numerous studies [10-13].

It should be noted that, despite a significant amount of research on the use of various micronutrient encapsulation systems for food enrichment, it is necessary to develop an integrated methodological approach to their creation in order to obtain food products with proven efficacy.

2 Results and Discussion

Based on preliminary studies, as well as analysis of scientific and technical literature, we have developed the methodological approach to the creation of functional foods enriched with encapsulated micronutrients in the form of an algorithm (Fig. 1), and also formulated the basic requirements for each stage.

Stage 1: Selecting a base food for micronutrient enrichment

At the first stage of creating a food product using encapsulated forms of micronutrients, it is necessary to scientifically substantiate the choice of an object for enrichment - a basic food product.

It should be noted that it is preferable to enrich mass consumption products, such as bread, milk, drinks, salt, etc. [14], which allows reaching the largest number of consumers, and it is also possible to enrich food products intended for specific (target) population groups, such as pregnant women, school-age children, etc. [15].

One should also take into account the added value in the production of these food products, the increase of which can significantly affect their consumer attractiveness and limit their availability to a larger number of consumers.

Thus, to implement the first stage, you should:

- firstly, to analyze consumer preferences when choosing a food product in the distribution network;
- secondly, taking into account the analysis of consumer preferences, to select a basic food product as an object for its enrichment with micronutrients in an encapsulated form.

Stage 2: Selecting micronutrients for encapsulation

It is known that it is vitamins and minerals that are the micronutrients that ensure the functioning of the nervous, endocrine, immune and other systems of the human organism [16], and their regular intake in the organism in amounts due to age-related needs is necessary.

Even a slight deviation from the adequate intake of micronutrients, including macro- and microelements, in the organism leads to a significant increase in susceptibility to infections in both children and adults [17].

We have formulated the main requirements and principles that should be followed when choosing encapsulated micronutrients:

- as encapsulated micronutrients, are used those micronutrients, the deficiency of which has been identified and is most common in the nutritional status of the population;
- the selected micronutrients must exhibit scientifically validated and established physiological effects;

- in the case of using several micronutrients in the encapsulation system, it is necessary to have reliable experimental data on the absence of antagonism;
- micronutrients must have accurate physical and chemical characteristics, reliably determined by special methods of analysis;
- micronutrients should not reduce the consumer properties of the food product and, above all, significantly change its organoleptic properties and reduce the shelf life.

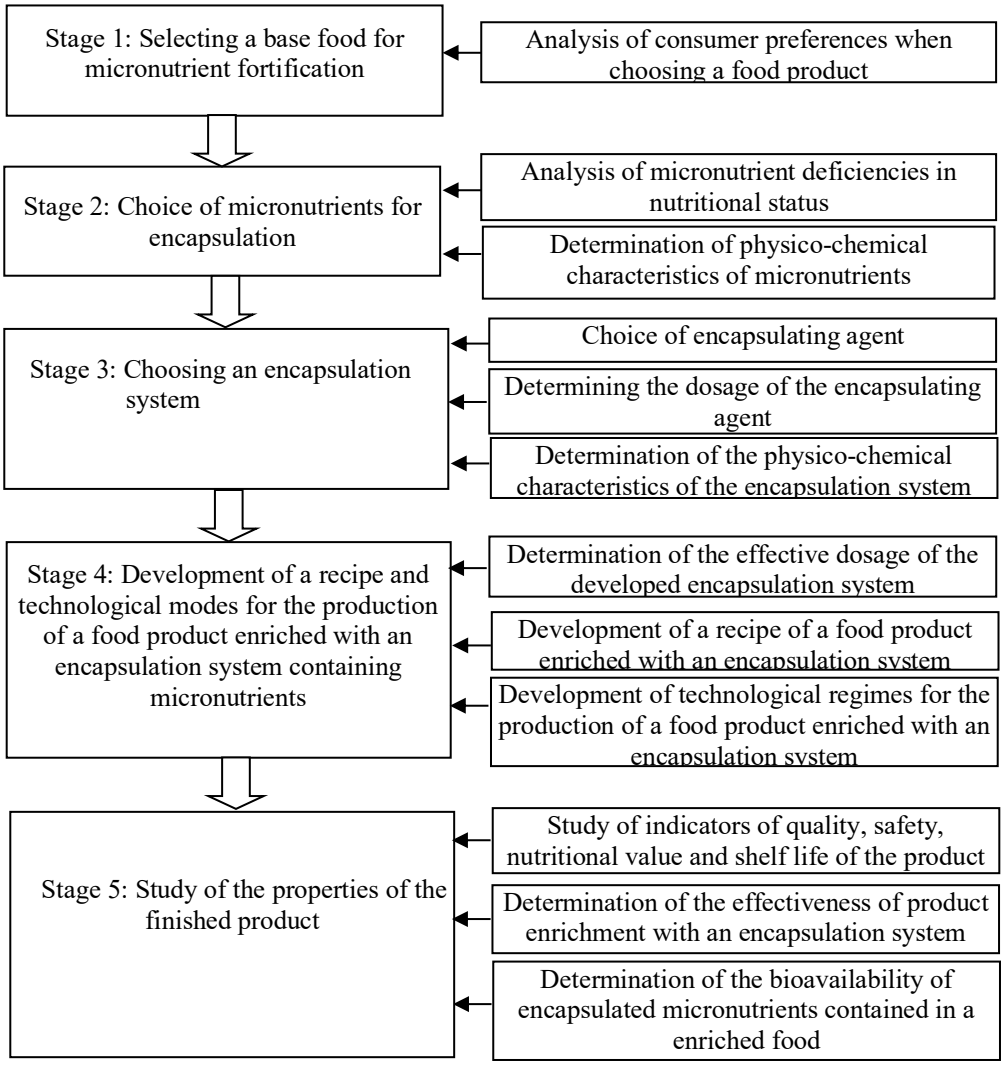

Fig. 1. The algorithm for creating functional foods using encapsulated forms of micronutrients

Stage 3: Choosing an Encapsulation System

The choice of encapsulation system determines the stability and bioavailability of the encapsulated micronutrient in the food product. In addition, the choice of encapsulation system depends on the physical structure of the enriched food product, as well as on the solubility of the encapsulated micronutrient in water, since approaches to the encapsulation of hydrophilic and hydrophobic (lipophilic) ingredients are different [18-20].

The main requirements and principles that should be followed when choosing a micronutrient encapsulation system:

- the encapsulation system must be compatible with the food being enriched;
- the encapsulation system must be stable to the processes of coagulation and coalescence;
- the encapsulation system must have a high resistance to oxidation;
- the encapsulation system should have a positive impact on the technological properties of raw materials and semi-finished products for food production;
- the encapsulation system should, to the maximum extent, ensure the preservation of the content of thermolabile micronutrients in the process of food production;
- the encapsulation system should not reduce the consumer properties of the food product and, above all, significantly change its organoleptic properties and reduce the shelf life.

In our opinion, micro- and nanoemulsions are the most promising encapsulation systems for including both hydrophilic and lipophilic micronutrients in functional foods. Due to the smaller particle size of the dispersed phase, i.e. higher degree of dispersity, and, consequently, the specific surface of particles, the bioavailability of encapsulated lipophilic micronutrients in nanoemulsions is much higher compared to emulsions with large particles [20].

In addition, due to the smaller particle size, nanoemulsions are considered to be more stable to the processes of sedimentation and particle aggregation compared to macroemulsions [21].

Another advantage of nanoemulsions is the possibility of combining chemically incompatible food substances in a complex product [21].

It should be noted that the efficiency of micronutrient encapsulation and the stability of the encapsulation system are affected by the encapsulating agent.

When choosing an encapsulating agent to create an encapsulation system, the following requirements and principles should be considered:

- the encapsulating agent must have accurate physical and chemical characteristics, reliably determined by special methods of analysis;
- the encapsulating agent must show the established physiological effects;
- the encapsulating agent should show high emulsifying and encapsulating ability;
- the encapsulating agent should not reduce the consumer properties of the food product and, above all, significantly change its organoleptic properties and reduce the shelf life.

As encapsulating agents, it is possible to use such biopolymers as natural gums (gum arabic, alginates, carrageenans, etc.), proteins (milk or whey proteins, soy proteins, etc.), starches, and natural phospholipids [22].

Stage 4: Development of recipes and technological modes for the production of a food product enriched with an encapsulation system containing micronutrients

The fourth stage involves the development of a recipe and technological modes for the production of a food product enriched with an encapsulation system containing micronutrients.

Implementing this stage requires:

- firstly, determining the effective dosage of the developed encapsulation system based on the study of its effect on the organoleptic and physico-chemical properties of the enriched food product;
- secondly, the development of a food product formulation enriched with an encapsulation system containing micronutrients;
- thirdly, the development of technological modes of food production based on the study of the influence of individual technological stages on the change in the content of encapsulated micronutrients during the production of an enriched product.

Stage 5: Research the properties of the finished product

The fifth stage involves the study of the consumer properties of the developed food product and its effectiveness in the consumption of the product by the population.

The implementation of this stage requires:

- firstly, the study of indicators of quality, safety, nutritional value and shelf life of the product enriched with the developed encapsulation system;
- secondly, to establish the effectiveness of the enrichment of the developed product with the encapsulation system by determining the degree of satisfaction of the physiological needs of the population of certain age groups in encapsulated micronutrients during its consumption;
- thirdly, determining the bioavailability of encapsulated micronutrients contained in a enriched food product in vitro and in vivo experiments.

3 Conclusions

Thus, the implementation of the developed methodological approach will make it possible to create functional food products that ensure the normalization of the nutritional status of the population of different age groups.

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