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STUDY OF FACTORS AFFECTING DEVELOPMENT OF FOOD AROMATIZATION

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Abstract. The specific understanding of food philosophy according to the facts of development of cooking technologies and growth rate of food range is given. As it has been proven by historical stages of production of flavorings, aroma is one of the important organoleptic ingredients for food developers. A review of food production based on development of nanotechnologies, as well as promising and cautioning publications on nanotechnologies in the food sector is presented. On the basis of the literary analysis, the future impact of nanotechnologies on the evolution of the aromatization process of food products is predicted. It has been determined that the peculiarity of the development mentioned above lies in the use of plant enzymes and / or flavor precursors in the nanoscale range. The example of enzymatic breakdown of polyunsaturated fatty acids of plant cell membranes as one of the ways of creating fresh flavor of many fruits, namely C₆-C₉ aldehydes and alcohols, is considered. It is noted that green fresh aromatic ingredients are needed to improve the organoleptic profile of foods from heat-treated vegetables, melons and gourds. The following factors affecting the development of food aromatization are defined: the decreased differentiation of principles of healthy nutrition and fast food, repetition of natural processes of aroma formation, application of wild green leafy vegetables, and evolution of medical nutrition. The information on food aromatization by packing with autonomous mixing and their approximate assortment is given. The innovations in food aromatization are aimed at quality nutrition, time saving, recreation and entertainment, meeting specific needs (vegetarian dishes, restrictive diets).

Key words: aromatization, nanotechnology, development, factors, food

ДОСЛІДЖЕННЯ ФАКТОРІВ РОЗВИТКУ АРОМАТИЗАЦІЇ ХАРЧОВИХ ПРОДУКТІВ

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Анотація. Наведений аналіз розвитку виробництва ароматизаторів доводить, що аромат стає одним із основних органолептичних компонентів для розробників продуктів харчування. На підставі літературного аналізу спрогнозовано майбутній вплив нанотехнологій на розвиток процесів ароматизації харчових продуктів. Представлено огляд виробництва харчових продуктів із урахуванням розвитку нанотехнологій. Досліджено фактори розвитку ароматизації харчових продуктів: зменшення диференціації між принципами здорового харчування та галуззю «фаст-фуд», повторення природних процесів формування аромату, застосування дикорослих зелених листових овочів. Наведено інформацію про способи ароматизації харчових продуктів за допомогою фасування з автономним міксингом.

Ключові слова: ароматизація, нанотехнології, розвиток, фактори, харчові продукти

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Introduction. Formulation of the problem

The growth of population and consumption is likely to contribute to the increasing global demand for food, at least during the next forty years [1]. These high growth rates require deeper understanding of the philosophy of food when using innovative technologies. The food production philosophy has been presented in the article by S. Rodgers "Technological in-

novation supporting different food production philosophies in the food service sectors" [2]. The author offers the general classification of food service sectors, namely: industrial cuisine, fast food and fresh food, and states that the difference between sectorial philosophies is gradually decreasing due to market pressure: elements of industrial cuisine are used for fast food and fresh food. There is a differentiation of the philosophy

in each sector – the elements of fresh food are transferred to fast food. One can agree with the author that the use of food production philosophy can bring some benefits such as compensating for intensive processing in industrial cuisine, counteracting the negative image of fast food roasting and improving healthy selection of fresh food. For example, functional dishes with health-improving ingredients can be developed: salad dressing with stanols (for blocking resorption and lowering cholesterol levels), pasta with dietetic fibers, dessert with silver coffee (a drink from non-roasted coffee beans with antioxidants), sauce with lupine seeds (for cancer prevention) and orange juice with probiotic bacteria [3]. Smoothie King (USA, <http://smoothieking.com>) has already suggested numerous nutritional supplements for energy, muscle mass, women's balance, caffeine charge, recovery of joints and tissues, increased immunity, as well as dietary, anti-stress, and multivitamin ones. Nowadays flavor has become a major organoleptic component for food developers; it gives attractiveness of various foodstuffs, restores food specificity lost during processing and allows developing new products of special taste.

The purpose of this paper is to study factors affecting the development of food aromatization in terms of the use of nanotechnology in the food industry, repetition of natural processes of flavor development in the nanoscale range, application of wild green leafy

vegetables in cooking as the conditions decreasing differentiation of principles of healthy eating and fast food.

Development of food aromatization processes

The issue of the practical introduction of new food products is the matter of current interest; it is indirectly connected with aromatization processes. The relevant historical periods of developing aromatization processes have been presented by R. G. Berger [4]. The author has defined the following periods: old-fashioned period characterized by old-fashioned natural flavors based on natural extracts, essential oils, reaction flavors and few synthetic components (1950 – 1965); classical period of instrumental analysis and synthesis represented by natural isolates, synthetic and single natural aroma components (1965 – 1990); new age period of technology which became decisive for success of flavors in the marketplace and introduction of fashion food and food on-the-go (1990 – 1999); new century period when flavor is required to be added to food to produce taste and to make it healthy for consumers (2000-till now). Based on the analysis of the evolutionary and innovative development of the methods for obtaining aromatic components, we expect that the next period of evolution in food aromatization processes will be connected with the use of precursors (Figure 1).

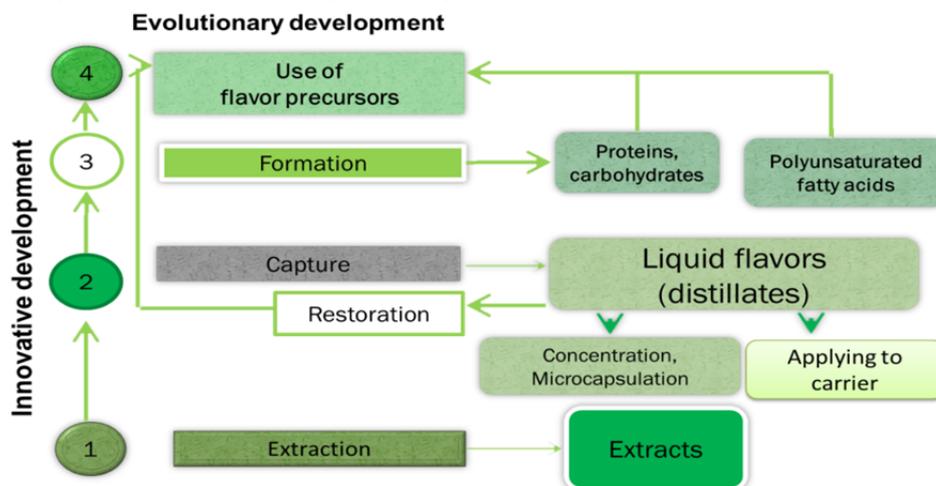


Fig. 1. Development of food aromatization methods

A precursor (from Latin *praecursor* – predecessor) is a substance that participates in the reaction resulting in the formation of the target substance. Under different conditions, flavor precursors in the plant material can be represented by amino acids, carbohydrates, and lipids [5]. Precursors of flavorings are different from flavorings and can be added to foods to create and / or modify flavors in accordance with Regulation (EC) N 1334/2008 of the European Parliament and of the Council on Flavorings and Certain Food Ingredients with Flavoring Properties. The detailed review of flavorings according to the specified Regulation

is given in the article "Use of food flavorings in accordance with the EU regulations" by S.B. Verbitsky and T.V. Sheiko (Institute of Food Resources of National Academy of Sciences of Ukraine)

A considerable amount of research has been done to define the precursors of aromatic substances in meat, cheese, fish, beer, champagne, bananas, apples, coffee, peanuts, and other products. The nature of flavor precursors has not still been defined in some fruits [6]. Over the last few years, it has been shown that many flavors exist in the form of flavor precursors that are more stable than active flavors. For example,

many flavors (especially in plant food) exist as glycoside precursors that are much more stable than the created flavor and have no taste properties. We are of the opinion that the most promising way of developing aromatization with the help of precursors is related to nanotechnology.

Application of nanotechnology in the food industry

Food products are not made by nanomachines as it is often meant while speaking about nanofood [7]. In the article "Safety of nanofood: A review", nanofood is defined as food where nanoparticles or nanotechnology techniques or tools such as microarrays of DNA, microelectromechanical systems, microfluidics are used during cultivation, production, processing, or packaging of food (Ijabadeniyi O.A., 2012). It should be noted that there are several definitions of the term "nanofood", but we think they do not significantly differ in matter.

Science and technology related to nanoparticles are the new frontiers of this century, so food nanotechnology is a new area. The application of nanotechnologies in the food sector is relatively new compared to their use in medicine, in particular when transmitting drugs and pharmaceuticals to the body [8]. Despite the fact that successful application of nanotechnology in food is still somewhat limited, some main concepts based on the nanoscale have been unambiguously established [9]. In the food industry, nanotechnology is associated with two main applications: alteration of food products to nanosizes and providing of food matrix ingredients with nanostructures. Nowadays, food quality and safety assessment in the area of food production can be improved through nanotechnology. Food industry can be greatly enhanced in terms of smart nutrient intake by the body, protein bioseparation, rapid sampling of biological and chemical contaminants, nanocapture of nutraceuticals, solubilization, flavor and color in food systems. This is an incomplete list of new nanotechnology topics for food production and agriculture [10]. However, food nanotechnology as a new area requires consideration of both potentially adverse effects and many positive ones. The authors of the paper "Nanotechnology applications in food and food processing: innovative green approaches, opportunities and uncertainties for global market" have described some developments in nanotechnology and their application in nutritional and nutraceutical systems; they have also identified a number of unsolved issues [11]. The review considers some of the nanoscale structures standing along in the food industry and various food production techniques that can be beneficial due to nanotechnology, as well as during the use of nanotechnologies in development and storage of food. Nanotechnology in the area of functional nutrition finds potential application of biological molecules thanks to the properties that are substantially different from those ones they have in nature [3]. The

scientists discuss the examples of malignant and healing effects of nanoobjects on the human body confirming that the final effect doesn't depend on the nanotechnology itself, but on the ability to use it for own benefit [12].

The specific character of food nanotechnology is defined by both the tasks of food raw material processing and the characteristics of the raw material itself. The article "Energy analysis of food nanotechnology" states that food nanotechnology can be developed in three directions. The first one is manipulation with nanoscale elements for composition of artificial foods (milk, meat, etc.). These technologies are based on the bottom-up mechanism. The first direction can be attributed to modification of individual complexes and providing them with new properties. The second direction involves managing transfer processes at the level of nanoscale objects of food raw materials, improvement of traditional manufacturing processes, food and their application through the full use of quantum properties and surface phenomena on the nanoscale. The third direction is a combination of the mentioned two ones so as to create unique patterns [13].

The increased funding possibilities and considerable interest in this area leads to more frequent and mainly liberal use of the term "nano" arousing some criticism in the scientific community. An ethical debate in the area of nanoscience, nanotechnology and its methods reflects NEST-ethics (ethics of new and emerging science and technology) [14]. Whether justified or not, one should understand that the entire area of nanosciences is essentially an eclectic derivative from the established disciplines such as chemistry, physics, microtechnology, etc. However, the use of the term "nano" allows researchers to emphasize the fact that processes (for example, nanomanufacturing) or material structures (e.g., nanomaterials) are designed and optimized in order to use specific properties and behaviors in the range of 10^{-7} to 10^{-9} m [3].

The functionality of many raw materials and successful food processing are determined by the presence, modification and generation of self-organizing nanostructured forms [15]. The examples include cellulose fibril accumulation in the walls of plant cells, crystalline starch structures, and processed starchy products that influence gelatinization and cause food benefits during digestion. Fiber structures are responsible for melting, gluing and texture of gels. Two-dimensional (2D) nanostructures formed at the interfacial water-water and air-water segregation and controlling stability of food foam and emulsions also illustrate the statement mentioned above [16]. Specifically, creation of foam or emulsions (sauces, creams, yoghurts, oils, margarine) involves formation of bubbles of gas or drops of fat or oil in a liquid medium. This process requires formation of interfacial air-water or oil-water segregation; the molecules involved in this process determine its stability. Similar structures have one-molecule thickness being the examples of two-

dimensional nanostructures. When there are mixtures of proteins and other molecules close to the nanoscale range in size, such as surfactants (soap-like molecules or lipids), the instability source potentially blocked by nanotechnology occurs in most food products at the interface [2]. New raw materials with new molecular structures and properties identified by nanotechnology require the permission for use in food. The discussion of ELSE issues (context of ethical, legal, social and environmental) of nanoscience and nanotechnology has already started in some developed countries [17].

The most discussions on nanotechnology and food have been caused by accidental or deliberate introduction of prepared nanoparticles into food products. These debates mainly concern risks and benefits, given the lack of knowledge about potential bioaccumulation and toxicity of nanoparticles. The report "Nanofood" published by Helmut Kaiser Consultancy (2004) evaluates the development of nanotechnology and patent applications related to food [18]. The number of nanofoods is growing rapidly. According to P. Ravichandran, the examples are as follows [11]:

- nanoparticles of carotenoids that can be scattered in water, which allows them to be added to fruit drinks, which provide improved bioavailability;
- nanosized micellar systems containing canola oil, which are claimed to provide a number of materials such as vitamins, minerals or phytochemicals;
- a spectrum of nano-products containing nanoclusters (as a means of formation, for example, a chocolate drink);
- mineral-based additives based on nanoparticles, such as Chinese nanoscale manufacturers, claim to improve selenium uptake by an order;
- patented nanodrop supply systems for encapsulating materials.

We believe that this list is not complete; it will be extended on a continuous basis in the long term.

The potential benefits of the food products made through nanotechnology are impressive. In the world where thousands of people starve every day, the necessity to increase manufacturing is the main reason to support nanotechnology worldwide [19].

Over the last few years, the food industry has invested millions of dollars in research and development in the area of nanotechnology. Some of the world's largest food producers, including Nestl'e, Altria, H.J. Heinz and Unilever, pioneer the way for nanofood, while hundreds of small companies follow them. But in spite of the potential benefits, nanofood is not very popular compared to other nanotechnology areas. Continuous disputes on security and regulations in the field of nanotechnology have slowed introduction of nanofood; but the research and development are being continued. It is interesting that most large companies work behind the scenes (when you look for the term "nano" or "nanotechnology" on the websites of

Kraft, Nestl'e, Heinz and Altria companies, you will have no results) [11]. Although the risks associated with nanotechnology in other areas, such as cosmetology and medicine, are the same, the public is much less likely to jump on the nanotechnology platform when it comes to food [20].

A great number of scientific works has been devoted to the research on nanotechnology in food manufacturing. In particular, the authors of the article "Acceptance of nanotechnology foods: a conjoint study examining consumers' willingness to buy" point out that consumers attribute negative benefits to nanotechnology food, even when the food products have had a discernible advantage for them. The results show that consumers are interested in food with additional healing effects only when this effect is caused by natural additives. Public perception of nanotechnology will be crucial for technological advances in the field of food science. The change in the description of nanotechnologies in food manufacturing can lead to more positive consumer ratings [21].

Summarizing, one can agree that nanofood is indeed a global phenomenon [3]. In Australia, for example, nanocapsules are used to add omega-3 fatty acids to one of the country's most popular white bread brands. According to the manufacturer, nano-caps of tuna oils added to TipTopBread provide valuable nutrients, while encapsulation prevents bread from being tasting. NutraLease, a start-up company at the Jewish University in Jerusalem, has developed new carriers for nutraceuticals in food systems [11].

In literary sources, the negative link between cheap highly processed food and obesity, poor health has been repeatedly demonstrated [22,23]. Of course, there is no substitute for healthy natural food; but if nutritional nanotechnology could make the processed food less harmful to health, it would be a huge success for nanotechnology [20]. Designing and producing food products through formation of molecules and atoms is a promising future for the food industry globally.

Flavor formation in the nanoscale range

A review of scientific publications has shown that manipulations with aromatic components are not a direct object of nanotechnology. For example, filters that can sift out or let pass certain molecules according to their shape, not size, have been developed; this makes the aroma control process possible [24]. Nanotechnology can provide a unique advantage to food products processed in various ways. The programmed food considered to be the ultimate consumer's dream will have built-in design food, so the consumer will be able to create the food product of the desired color, flavor and texture with the help of specially programmed microwave ovens. The idea is to make this food at the production plant while providing it with millions of nanoparticles of different colors, flavors and nutrients; the consumer will be able to program an oven to acti-

vate only selective particles of the food according to his/her preferences, whereas others remain inert, thus achieving the desired food profile [11]. The leader of nanotechnology and development of the nanoscale industry is Kraft Foods Nanotek Consortium. The consortium focuses on "interactive" foods and drinks. These food products will fit into the individual consumer needs and tastes. The foods being developed include beverages that change colors and flavors, as well as foods that can recognize and adapt to consumer allergies or nutrition needs [24].

While investigating the issue of the reactions causing formation of aromatic components in plants, it is necessary to establish whether aromatic substances or components producing them are in over the range of nanosized units. The subject of research in food nanotechnologies are microorganisms, nanoporous and nanocapillaries of plant material, cell membranes, protein, polysaccharides, and water molecules [13]. Nutritional proteins are often globular structures 1-10 nm in size. Most polysaccharides and lipids are linear polymers less than nanometers in thickness. Synthesis of aromatic components of plant material is carried out on the basis of enzymes (size 10 – 100 nm), polysaccharides (size 1 – 10 nm), etc. Therefore, synthesis of fruit flavor *in vivo* is a sequence of certain reactions occurring in the nanometer range. The precursors of aromatic substances (proteins, carbohydrates, lipids) are not just a set of nanoscale objects: atoms and molecules are organized into hierarchical structures and dynamic systems, which are the result of experiments of nature for millions of years. Ions with a diameter of tens of nanometers, such as potassium and sodium, regulate the behavior of important biomolecules, including sugars, amino acids, hormones and DNA; they reside in the nanometer range. Most of the molecules of proteins and polysaccharides are of the nanoscale size. Each living plant exists due to the presence, absence, concentration, location and interaction of these nanostructures [3].

Among all nanofoods, enzymes are the most widely used ones in the manufacturing of food and beverages, since an enzyme is a nanosized protein molecule that acts as a catalyst for a chemical reaction. Nanotechnology also has the potential to improve the nutritional processes that use enzymes to gain health benefits while eating. For example, enzymes are often added to food to ensure hydrolysis of anti-nutritional components and increase bioavailability of essential nutrients, such as minerals and vitamins. To make these enzymes highly active and cost-effective, nanomaterials are used for enzyme support systems today [25].

Precursors of taste and flavor do not necessarily turn into aromatic substances *in situ* (even despite the presence of specific flavorase bienzyme [26]), since these reagents can be physically separated from each other by cellular microstructures. The significance of cell integrity destruction for the biochemical changes

in vegetables and fruit cannot be overestimated [27]; this destruction affects formation of taste and aroma, off-flavors and smells. We have investigated the impact of destruction of cell integrity to nanoparticles during vacuum heating (temperature 32 ± 2 °C, dilution 6 ± 1 kPa) on membrane-bound enzymes in suspended plant homogenates resulting in the increased duration of the production of aromatic components [28].

At first sight, it seems that in the case of nanoparticles, which are enzymes and precursors in this study, the same forces as in the classical problems of colloidal chemistry operate in the biological system. Indeed, it has been noted that Van der Waals forces, electrostatics, the influence of the solvent, and the hydrophobic effect act here. However, scientists point out that it is necessary to significantly adjust the preconditions with consideration of the nanoscopic scale of the ongoing processes and the presence of biological objects in the system. The peculiarity of nanosystems is that they contain a relatively small number of atoms; the nature of the interaction between particles will essentially depend on their mutual orientation and dielectric permeability [12]. We have shown that the value of the hydrodynamic diameter of particles and zeta potential, the effect of disjoining pressure are also of great importance for the interaction of aroma-forming precursors and enzymes in the nanoscale range [28].

The estimated values of usefulness of the information about flavor have shown that flavor naturalness is the most important consumer factor for this characteristic [11]. One of the ways of adding natural flavor to food is repetition of natural processes of its formation. Enzymatic degradation of polyunsaturated fatty acids is one of the methods to create fresh flavor of many fruits. The precursors of various aromatic compounds can be lipids, polyunsaturated fatty acids (PUFA). The reactions of α -, β -oxidation and enzymes of the lipoxygenase type are the main achievements in the study of the mechanisms of aroma formation in fruit *in vivo* [4]. Biosynthesis of aroma compounds by lipoxygenase takes place in tomatoes, cucumbers, olives, bell peppers, apples, citrus, and strawberries. This particular way is used for microbial synthesis of C_6 - C_9 aldehydes, alcohols – flavorings of the specific green and fresh aroma Green Leaf Volatiles (GLVs) made from oil waste on industrial scale. Scientific literature does not reveal systematic studies on food aromatization by lipoxygenase *in vitro*. The implementation of food aromatization with the help of a complex of enzymes of plant raw materials has been shown in our works [29,30].

The use of green leafy vegetables in cooking

The following factor in the development of food aromatization processes is the potential benefits of the use of green leafy vegetables for health and dietary nutrition. This area has been recognized as an important sphere in the research of the use of green leafy vegeta-

bles, generally non-cultivated (wildlife). The use of wild plants in a daily diet based on local cuisine is potentially of considerable interest to research scientists in the field of nutrition because these plants are important as local products and have the potential to be the sources of new nutraceuticals [31]. Nutrition is a manifestation of belonging to the region; at the same time, it is often viewed as an opportunity for local enterprises to get profit working with small producers, sellers and, above all, restaurants offering specialized products. In addition to health benefits, these food products are also important elements for determining local or regional identity [32]. We consider the use of green leafy vegetables in cooking to be the factor contributing to the introduction of the principles of healthy nutrition into the fast food industry. The following advantages of application of the innovative aromatization approach for fast food have been defined:

- consumers flavor food independently by using plant concentrates with the increased flavor in/on food. It enriches the organoleptic profile of dietary dishes. This is an alternative way of industrial aromatization when the determined quantity of flavorings is added to the raw material;
- for products with a modified recipe (without fat, salt, sugar, or with their reduced content);
- consumption of clean label food (0 % fat, 0 % salt, sugar 0 %, 0 % colors, 0 % flavorings).

For example, in the fast food preparation technology we have proposed to use potato juice (for people with hyperacidity, ulcer, and other diseases) with flavor of green leafy vegetables, mashed melons and gourds with renewed fresh flavor, mashed cabbage (homogenized) with cucumber flavor.

The implementation of the innovative approach in the manufacture of flavored foods was able due to

packaging with autonomous mixing; it is the original Push-Top technology, which has world-wide novelty and is represented by healthy drinks in separate packaging (the inventor of the development is S. V. Savinskyi, patent #41921 "Packing-closing machine for containers of autonomous mixing"). Autonomous mixing is based on separate packaging of beverage components in a two-chamber container. Before consuming food, you need to press the top of the cap and destroy the membrane between a container chambers; whereupon the plant enzyme extract and the fruit mixture with aroma nanoprecursors are autonomously blended and converted into the ready-to-use flavored food. But when this happens the container remains hermetically sealed.

Conclusions

Innovations in aromatization continue to evolve focusing on quality nutrition (natural flavorings), time saving (fast food preparation of flavored food), recreation and entertainment, meeting specific needs (vegetarian dishes, restrictive diet).

The following factors affecting development of food aromatization have been investigated: decreased differentiation of principles of healthy nutrition and fast food; development of nanotechnologies in the food industry; repetition of natural processes of aroma formation; use of green leafy vegetables.

The recommendations to enrich the organoleptic profile of food are especially needed for people who for some (long) time consume dietary foods or have a uniform menu due to life circumstances, including the military, the elderly, consumers with chronic diseases or after surgery, tourists, and lovers of food without nutritional supplements (among other things, religious restrictions).

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ИССЛЕДОВАНИЕ ФАКТОРОВ РАЗВИТИЯ АРОМАТИЗАЦИИ ПИЩЕВЫХ ПРОДУКТОВ

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Аннотация. Проанализировано развитие производства ароматизаторов показывающее, что аромат становится одним из основных органолептических компонентов для разработчиков продуктов питания. На основании литературного анализа спрогнозировано влияние нанотехнологий на развитие процессов ароматизации пищевых продуктов. Представлен обзор производства пищевых продуктов с учетом развития нанотехнологий. Исследованы факторы развития ароматизации пищевых продуктов: уменьшение дифференциации между принципами здорового питания и отраслью «фаст-фуд», повторение природных процессов формирования аромата, применение дикорастущих зеленых листовых овощей. Приведена информация про способ ароматизации пищевых продуктов с помощью упаковки с автоматным миксингом.

Ключевые слова: ароматизация, нанотехнологии, развитие, факторы, пищевые продукты

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