UDC 664.681: 613.292 – 021.632 : 001.891

SYNBIOTIC ADDITIVES IN THE WAFFLES TECHNOLOGY

E. Iorgacheva, Doctor of Technical Scitnce, Professor, *E-mail*: iorgachova@gmail.com
H. Korkach, PhD**,** associate professor, *E-mail*: kor2007@ukr.net
T. Lebedenko, Doctor of Technical Sciences, associate professor, *E-mail:* tatyanalebedenko27@gmail.com
O. Kotuzaki Ph.D, associate professor, *E-mail*: elena1kotuzaki@gmail.com
Department of bread, confectionery, macaroni products and food concentrates technology
Odessa National Academy of Food Technologies

Abstract. The problems considered in the paper are the incidence of dysbiosis in the Ukrainian people, the reasons for it, and the methods of improving the diet of those suffering from microfloral disorders. Useful properties and effects of the microorganisms *Bifidobacterium* and *Lactobacillus*, and of inulin and lactulose have been studied as well as the ways in which they help to restore a person's normobiocoenosis. After a research *in vitro*, with the conditions imitating the human gastrointestinal tract, the survival rate of encapsulated cells of bifidobacteria and lactobacilli in an unfavourable environment has been determined. It has been grounded how necessary microencapsulated forms of microorganisms are in the production of confectionery – firstly, to 'protect' them against physiological and technological factors, and secondly, to help them reach the lower regions of the small intestine where their capsules are destroyed and the bacteria are released. The reasons have been given why fatty filling for waffles, as an object to be enriched with useful ingredients, should be preferred when developing healthy and wholesome confectionery. It has been shown how promising probiotics and prebiotics are if used in confectionery technology. The two synbiotic complexes SC 1 and SC 2 have been developed, and such parameters have been determined as the optimum weight fractions of inulin and lactulose in the formulation of the filling, and the number of probiotic microorganisms. It has been established that lactulose can reduce sugar in the formulation of the filling, and using inulin results in replacement of an equivalent amount of fat. To prove how practical it is to add synbiotics to waffles, and to determine the product's consumer appeal, a tasting assessment of the new types of waffle products has been made. It has been proved that adding synbiotic complexes to the formulations of waffles will result in the consistent high quality of the products, and in their better sensory characteristics. Besides, it can contribute to making the people of Ukraine healthier and fitter for work.

Key words: encapsulation, bifidobacteria and lactobacilli, inulin, lactulose, synbiotic complex, fatty filling, waffles.

СИНБІОТИЧНІ ДОБАВКИ В ТЕХНОЛОГІЇ ВАФЕЛЬНИХ ВИРОБІВ

К.Г. Іоргачова, доктор технічних наук, професор**,** *E-mail*: iorgachova@gmail.com
Г.В. Коркач, кандидат технічних наук, доцент, *E-mail*: kor2007@ukr.net
Т.Є. Лебеденко, доктор технічних наук, доцент, *E-mail*: tatyanalebedenko27@gmail.com
О.М. Котузаки, кандидат технічних наук, доцент, *E-mail*: elena1kotuzaki@gmail.com
кафедра «Технологія хліба, кондитерських, макаронних виробів і харчоконцентратів»
Одеська національна академія харчових технологій, вул. Канатна, 112, м. Одеса, Україна, 65039

Анотація. У представленій роботі розглянуто проблеми захворювання населення України дисбіозом, причини його виникнення та методи корекції раціону харчування для людей з порушенням нормальної мікрофлори. Зазначено, що для відновлення нормобіоценозу людини, доцільним є використання мікроорганізмів роду *Bifidobacterium* і *Lactobacillus*, інуліну і лактулози. Проведено дослідження в умовах *in vitro*, що імітують шлунково-кишковий тракт людини та визначено стабільність капсульованих клітин біфідо- і лактобактерій в несприятливих умовах. Доведено необхідність використання мікрокапсульованих форм мікроорганізмів для приготування кондитерських виробів для того, щоб, «захистити» їх від дії фізіологічних та технологічних факторів та для досягнення ними нижніх відділів тонкого кишківника, де відбувається руйнування їхніх оболонок з вивільненням бактерій. Обгрунтовано вибір жирової начинки для вафель в якості об'єкту для збагачення корисними інгредієнтами, для розробки кондитерських виробів, які приносять функціональну користь для здоров'я та благополуччя населення. Показано перспективність використання про- і пребіотиків в технології кондитерських виробів. Розроблено два синбіотичних комплекси СК 1 та СК 2, визначено оптимальну масову частку інуліну та лактулози, які можна вносити в рецептуру начинки, та кількість пробіотичних мікроорганізмів. Визначено, що внесення лактулози дозволяє зменшити кількість цукру в рецептурі начинки, а внесення інуліну приводить до заміни еквівалентної кількості жиру. Для обгрунтування доцільності введення в рецептуру вафельних виробів синбіотиків, визначення споживчої привабливості продукту, проведено дегустаційну оцінку нових видів вафельних виробів. Доведено, що внесення синбіотичних комплексів у рецептуру вафельних виробів дозволить одержати продукти зі стабільною якістю, покращеними органолептичними властивостями, які матимуть функціональну спрямованість для підвищення здоров'я та працездатності населення країни.

Ключові слова: капсулювання, біфідо- та лактобактерії, інулін, лактулоза, синбіотичний комплекс, жирова начинка, вафлі.

DOI: http://dx.doi.org/10.15673/fst.v13i1.1310

Introduction. Formulation of the problem

Foodstuffs, that used to be just a means of appeasing hunger, have now become rather a means that can reduce the risk of chronic diseases. This concept has opened new prospects in developing functional foodstuffs that could maintain a person's health, reduce the risk of illnesses caused by malnutrition.

A current task of confectionery industry is widening the range of goods made with the use of raw materials of different functional purposes. This will make it possible to add the nutritional and reduce the caloric value of food, to make it more physiological, and the technology of manufacturing them more effective. Confectionery, due to its consumer appeal, is traditionally highly popular with people of all ages, so it is practical to develop confectionery of certain functional use.

Analysis of recent research and publications

It is well-known that a very important factor maintaining a person's health is microbiocoenosis, i. e. the normal microorganisms living together within the body. Strong intestines ensure high working capacity, good memory and sleep, and reduce the risk of infectious diseases and cancers. With dysbacteriosis (a disorder in the composition and amount of intestinal microflora), an abnormal growth of microorganisms can take place, resulting in overproduction of toxic metabolites (ammonia, hydrogen sulphide, phenol, indole, skatole). Some of these can cause cancers [1]. Pathogenic microorganisms cause disorders in absorption of amino acids, fatty acids, carbohydrates, vitamins. Metabolic products of opportunistic pathogenic microflora tell on the performance of the liver, inhibit the regeneration of the intestinal mucosa, cause diarrhoea [2]. Almost all people suffering from pathologies of the digestive tract have dysbacteriosis, usually accompanied by a decrease in the number of bifidobacteria, lactobacilli, and normal *E. coli*.

Dysbacteriosis can be found in practically healthy people. It can be age-related, seasonal, alimentary, professional. A lot of scientists have studied and explained the most frequent causes of colon dysbacteriosis (Fig. 1) [3-7].

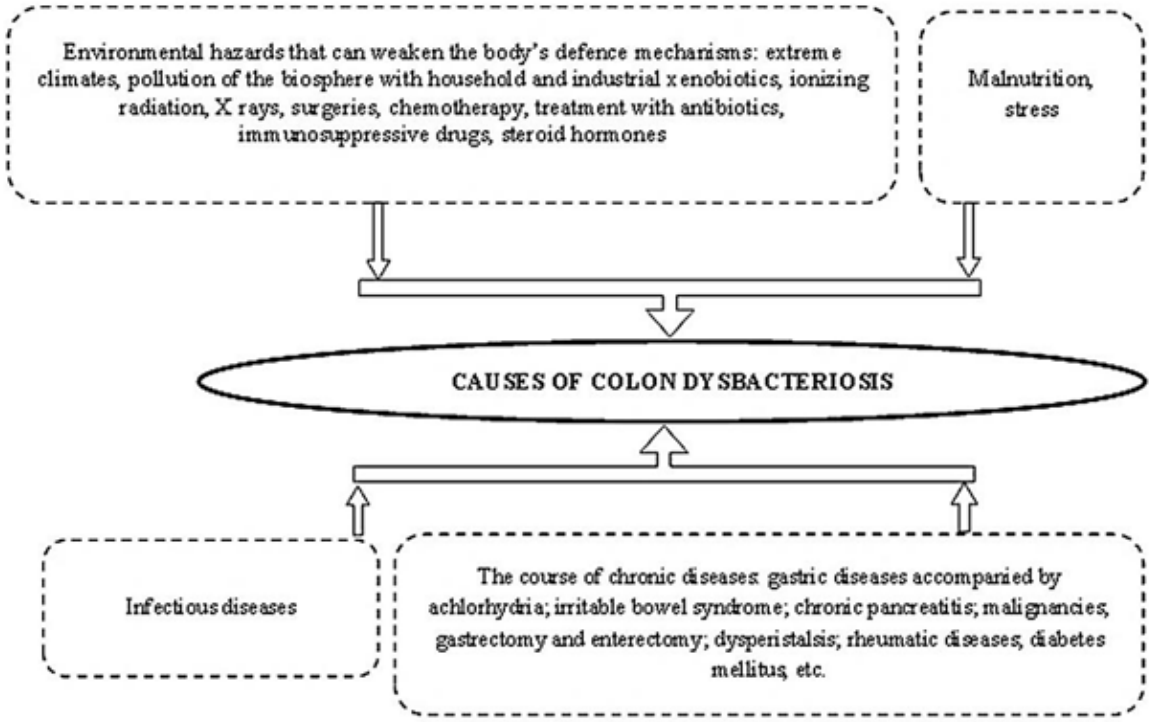

Fig. 1. Causes of dysbacteriosis

Sadly, in the last decades, the number of people ill with dysbacteriosis have kept growing steadily. According to medical statistics, today, about 90% of the Ukrainian people suffer from disorders in the microbial ecosystem. A lot of experts view the existing problem of dysbioses as an epidemical situation that requires effective methods of improving it to be developed as soon as possible [8-10].

To prevent and treat dysbiosis, today, probiotics are mostly used. They are living microorganisms and substances of microbial origin that effect positively on the body's physiological, biochemical, and immune responses by stabilizing and optimizing functionally its normal microflora. Lately, other approaches to preventing and treating dysbacteriosis have been developing, too. One of these is using prebiotics, substances purposefully introduced into food and dietary supplements, that are microbially fermented in the large intestine and activate the growth of normal intestinal microflora. Besides, synbiotics are used – complexes obtained as a rational combination of probiotics and prebiotics that reinforce each other in their effect on physiological functions and metabolic processes in the human body [11-13].

A patent search on the development of synbiotics and their introduction into confectionery technology has shown that researchers [14] have developed a synbiotic complex based on microorganisms *Lactobacillus paracasei* (a probiotic) and on prebiotics of tagatose and galactooligosaccharides. It has been established that the optimum ratio of tagatose and galactooligosaccharides is 7.5:2.5. Such aspects have

been studied as the use of probiotic cultures in chocolate mass and the effect of prebiotics on the physico-chemical and sensory characteristics of milk chocolate.

For *Lactobacillus plantarum* microorganisms, a group of Chinese scientists have developed a capsule made from prebiotics of sodium alginate and arabinoxylan. It has been proved that it is practical to use these materials together by prolonging the survival of the probiotic in the digestive tract. Thus, its survival rate while it passed through the stomach increased from 51 to 74%, and, when acted upon by the enzyme system, it increased from 70 to 81.6%, compared to a capsule made from sodium alginate only. The positive results of the encapsulation and microorganisms' resistance to the destructive effect of the digestive tract environment make encapsulation effective in delivering probiotics to a required location [15].

There was an idea of using the fatty filling of the probiotics Bifilact A and Bifilact D, and the prebiotic Beneo^{TM}Synergy1. The effect of the supplement on the rheological properties of the model system was established, and the optimum amount of probiotics and prebiotics was determined to obtain a high quality filling [16].

Research work was carried out on introducing probiotics, prebiotics, and synbiotics into the formulation of chocolate. The positive and negative aspects of the functional products developed were studied, compared to the traditional ones. The effect was assessed that functional ingredients had on the quality of semi-processed food. It was concluded that the results obtained needed to be confirmed by integrated studies *in vitro* and *in vivo* [17].

Thus, the above-mentioned papers suggest developing various types of synbiotics and using them in confectionery technology. However, it should be pointed out that there are practically no studies on developing synbiotics using bifidobacteria as probiotics and lactulose and inulin as prebiotics. The paper [16] suggests using probiotics, but does not take into account that they should be 'protected' against unfavourable technological and physiological factors, which considerably reduces the number of living organisms in the final product.

It should be noted that in the Ukrainian confectionery market, there is lack of dysbiosis-preventing products, i. e. those containing probiotics, prebiotics, and synbiotics. When creating confectionery for this product group, it is practical to search for and introduce ingredients with high functional characteristics, both technological and physiological.

Traditionally, the Ukrainians prefer flour confections (FC), which are important in nutrition. FC include sweet pastries, waffles, crackers, sea biscuits (hardtack), cupcakes, tortes, and cakes; sponge cakes, biscuits, Oriental sweets, rum babas. An analysis of the FC market has shown that in 2017, compared to the previous year, negative growth stopped in the Ukrainian FC market, and instead, for the first time in a long period, it grew by 8% [18]. That is why, waffles are suggested as a way of introducing synbiotics, as they belong to FC. And developing a synbiotic complex requires good reasons for the choice of probiotics and prebiotics supposed to be its constituents.

Strains of microorganisms used as probiotics must be safe for human use, resistant to gastric acid, bile, and pancreatic enzymes, highly adhesive to the epithelial cells of the gastrointestinal mucosa. They should be antimicrobial-active, inhibit the adhesion of pathogenic bacteria, be resistant to antibiotic substances, and functional physiologically and technologically [19,20]. One of the most significant groups of human synbiotic microflora is the *Bifidobacterium* genus. Its bacteria are native inhabitants of the large intestine, and a great many their species have quite a number of positive effects on their host's organism. Bifidobacteria prevent pathogenic and opportunistic pathogenic microflora from developing as they make their host resistant to infectious diseases. In the intestines, they prevent the accumulation of, and destroy harmful metabolic products of other microorganisms (indole, skatole, and carcinogenic biogenic amines). Scientists believe that intestinal bacteria's detoxicating activity is equivalent to that of the liver. These bacteria actively synthesize a number of vitamins in the body, and help the normal absorption of vitamins of the B group and K. They are active in producing some essential amino acids using ammonia as a source of nitrogen during the synthesis. By fermenting sugars, bifidobacteria create an acidic environment in the intestines, which helps calcium, iron, and vitamin D better absorb into the bloodstream [21].

Lactobacilli of the *Lactobacillus* genus are well-studied. Their biological properties make it possible to use these microorganisms widely in the composition of modern probiotics and functional products. They are integral components of heathy people's microecological systems validated as GRAS ('generally recognized as safe'). A lot of *Lactobacillus* species live, as normal microflora, in the gastrointestinal tract, all the way from the oral cavity to the colon. Lactobacilli strains can be used as chemical preservatives to inhibit the growth of pathogenic, opportunistic pathogenic, and phytopathogenic microorganisms [22]. However, one of the best-studied uses of lactobacilli-based probiotics is prevention and treatment of digestive disorders that accompany those of intestinal microflora.

Prebiotics do not contain living microorganisms, but provide ideal conditions for good bacteria's existence and development. A lot of prebiotics serve as food for bacteria. The best-studied bifidus factor is lactulose. The present-day ideas of the ways in which it works are based upon the fact that it does not decompose in the upper gastrointestinal region for lack of necessary enzymes, and goes past it directly into the large intestine, where bifidobacteria use it as a source of energy and carbon. Metabolic transformations of lactulose result in better functioning of the digestive tract, in prevention of poisoning the organism with

toxic products of protein breakdown, in a less stress on the liver and kidneys, and in the stimulation of immune responses [23]. That is why, lactulose, which has been used in different areas for over forty years, has proved to be safe and biologically valuable. The leading experts believe that in the future, it will be important in keeping people fit and socially active.

Another functional ingredient with prebiotic properties deserving particular notice is inulin. Inulin is a naturally occurring polysaccharide composed by 95% of fructose. When taken regularly, it has a positive effect on the organism. It stimulates clearing the organism from radionuclides and heavy metals, helps reduce cholesterol, acts as an immunomodulator, reduces the blood level of ammonia, improves the metabolism of bile acids, facilitates the digestion of calcium. Inulin helps the development of bifidobacteria and lactobacilli in the intestinal microflora, thus contributing to the normal functioning of the gastrointestinal tract. Besides, inulin has technological uses: it can serve as a fat substitute, a stabilizer of emulsions and air-concentrated products [24-26].

The above advantages of the selected probiotics and prebiotics made it reasonable to create synbiotic supplements based on such probiotics as lactobacilli and bifidobacteria, with inulin and lactulose used as prebiotics.

That is why, the **purpose** of the study was providing a scientific background for creating synbiotic supplements, and determining whether and how they could be used in the waffle production technology.

Objectives.

1. To develop synbiotic complexes based on the microencapsulated cells of *Bifidobacterium bifidum* and *Lactobacillus acidophilus* and on such prebiotics as inulin and lactulose.

2. To study the survival rate of the encapsulated cells of microorganisms and their equivalent liquid cultures, under conditions that simulate the human gastrointestinal tract.

3. To determine how synbiotic complexes effect on the sensory characteristics of waffles.

Research materials and methods

When experimenting to develop synbiotic supplements, the raw materials used were: inulin (manufactured by Frutabit), low-esterified apple pectin (by Felizata Ukraine Ltd), lactulose (by Fresenius Kabi), bifidobacteria (Bifidumbacterin by Biopharma), lactobacilli (Lactobacterin by Biopharma), pure cultures of lactobacilli (*Lactobacillus acidophilus Ep-317/402*) and bifidobacteria (*Bifidobacterium bifidum-1*) from the museum of microorganisms (Department of Biochemistry, Microbiology, and Nutrition Physiology, ONAFT), and calcium chloride (State Standard 450–77).

Probiotic microorganisms were cultivated by means of introducing the biomass of lactobacilli into sterilized skim milk, and bifidobacteria into a maize and lactose medium, followed by stirring for 5 minutes and leaving to rest for 24–48 hours at 37±1°C for fermentation and accumulation of biomass. As soon as the growth of lactobacilli was in its stationary phase, the fermented milk was used as a probiotic fermentation starter. After the incubation, the cells were identified by their cultural, morphological, and biochemical properties.

Determining the number of lactobacilli cells. To count lactobacilli cells, the methods were used described in State Standard 10444.11-89 (Food products. Methods of determining lactic acid organisms).

Determining the number of bifidobacteria cells. The method of counting cells of bifidobacteria is based on their ability to grow in test-tubes with a semisolid nutritional medium in the form of columns of different height, at (37±1)°C for 2–5 days, with the formation of nail-shaped colonies.

Determining the survival rate of lactobacilli and bifidobacteria in gastric juice. The obtained samples of encapsulated and nonencapsulated lactobacilli and bifidobacteria were put in gastric juice and kept in a thermostat at (37±1)°C for 3 hours. The survival was controlled every hour. Immediately after the acidification and then once per hour, 1 g portions of the sample were taken, and living cells of the microorganisms were counted. The model simulated the environment in the gastrointestinal tract.

Determining the survival rate of lactobacilli and bifidobacteria in bile. Samples of encapsulated and nonencapsulated microorganisms were put in an aqueous solution of bile, with the mass fraction 40 %. The mixture obtained was then kept in the thermostat at (37±1) °C. Right before the thermostatting, then once per hour, and, finally, at the end of the exposure time, 1 g portions of the sample were taken to count the microorganisms.

Preparing microencapsulated microorganisms. 0.4 g of low-esterified pectin was dissolved in 10 ml of distilled water, then stirred in a magnetic stirrer for 10 minutes at 36–38°C. To the dissolved pectin, lactobacilli and bifidobacteria were added, and it was stirred again. To the uniform mixture obtained, 10 ml of a 10% $CaCl_2$ solution was added, and then the whole mass was stirred thoroughly. After encapsulated microorganisms were obtained, the mixture was filtered, and the ready microcapsules were left to rest for 30 minutes.

Preparing the fatty filling. A whipping machine was loaded with powdered sugar, lactulose, inulin, and confectionery fat. The mixture was stirred until uniform. Then, crumbed waffles, an extract, and citric acid were added. The components were mixed for about 3 minutes at 36–38°C. By the end of whipping the filling, pre-prepared microencapsulated bifidobacteria were added. As the stirring bar rotates at 84–318 rpm, the plasticity and airiness of the cream are provided.

Organoleptic analysis of the waffles was conducted according to the guidelines for a degustation procedure by a group of 5–7 experts. The analysis was based on the quality parameters according to State Standards of Ukraine 4033-2001 ‘Waffles. General specifications.’

Results of the research and their discussion

Our research had an objective of creating synbiotic supplements and studying their properties for their further use in waffle technology.

To create a synbiotic complex, one needs a combination of probiotics and prebiotics. As probiotics, cells of lactobacilli and bifidobacteria were used. But, when added to confectionery recipes, they are negatively affected by technological factors. And on their way along the human stomach, the vital capacity of microorganisms is affected by physiological factors. Thus, only 3–5% of microbial cells reach the intestines. That is why, to preserve the vital activity of lactobacilli and bifidobacteria when developing a synbiotic complex, it was necessary to "protect" the microorganisms against the adverse factors. The previously conducted comprehensive study [31,32] had made it possible to develop a technology of encapsulating bifidobacteria's living cells. The method developed was now applied to 'protect' the cells of lactobacilli.

To determine the survival rate of the encapsulated cells of bifidobacteria and lactobacilli in the gastrointestinal tract (GIT), *in vitro* studies have been carried out, under conditions simulating the human GIT. To this end, the survival rates of encapsulated *Lactobacillus acidophilus* and *Bifidobacterium bifidum* and liquid cultures equivalent to them have been studied and compared, the exposure time being 3 hours in gastric juice media, and 2 hours in bile media (Fig. 2, 3).

After the unprotected cells of bifidobacteria stayed for 3 hours in a medium with pH=2, a large part of them died, and the number of viable cells decreased by 50 %, compared to the initial value, and was now $5 \cdot 10^4$ CFU/g. By contrast, the number of encapsulated cells only decreased by 12% and was $3 \cdot 10^7$ CFU/g. The same results were for the bile medium. The number of nonencapsulated cells was 60% lower, and that of encapsulated ones only 20%. The encapsulated cells of bifidobacteria were resistant to low pH due to their pectin capsules.

Similarly, the survival rate of the encapsulated cells of *Lactobacillus acidophilus* have been studied under conditions simulating the human GIT (Fig. 3).

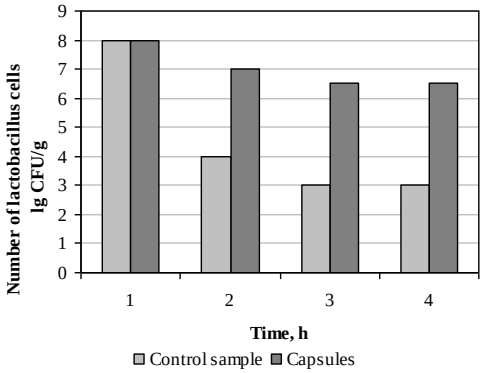

Fig. 2. Survival rate of *Bifidobacterium bifidum* cells under adverse conditions that simulate the GIT: 1 – prior to their introduction into the model GIT, 2 – 3 hours after the introduction into gastric juice, 3 – 1 hour, and 4 – 2 hours after the introduction into bile

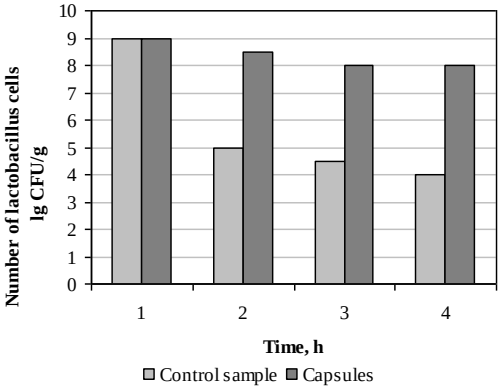

Fig. 3. Survival rate of *Lactobacillus acidophilus* cells under adverse conditions that simulate the GIT: 1 – prior to their introduction into the model GIT, 2 – 3 hours after the introduction into gastric juice, 3 – 1 hour, and 4 – 2 hours after the introduction into bile

So, the advantages of the microencapsulated forms of bacteria, compared to their free forms, are evident. The experimental data show that their survival capacity in the digestive tract is 70–90%. Their increased stability is, firstly, due to the fact that the microcapsule shells are formed of a polymer resistant to hydrochloric acid contained in gastric juice. This is the dominant property of the microcapsules that are supposed to reach the lower region of the small intestine, where their shells are destroyed, and the bacteria are released and then colonize the mucosa of the large intestine. Secondly, a microencapsulated form, when introduced into the body, is destroyed but gradually, thus making it possible for the bacteria to penetrate into the environment over quite a long period. That is why, to create a synbiotic supplement to be used in confectionery technology, one should use the microencapsulated forms of probiotic bacteria.

As prebiotic, lactulose and inulin were used. That is why, the research included the development of two synbiotic complexes: synbiotic complex 1 (SC 1) consisting of different mass fractions of lactulose and microencapsulated bifidobacteria, and synbiotic complex 2 (SC 2) based upon a mixture of lactulose and inulin and microencapsulated lactobacilli and bifidobacteria.

Adding synbiotic supplements to waffles with fatty filling has been suggested. As a control sample, waffles *Ananasni* were used. According to the recipe, their filling is composed of 35–40% of fat and 45–50% of powdered sugar. The supplements were added at the stage of mixing up the fatty filling. The task was to determine the mass fraction of the ingredients and the stage when the supplements should be added to the

formulation. Lactulose was introduced into the filling, in an amount of 10–50%, and replaced sugar. The results were quite satisfactory, and, in theory, more of it could have been added. But doctors recommend that its daily intake should not exceed 2–10 g. Overdosing can have a laxative effect. So, it was decided to add lactulose to the recipes in the amounts 15%, 30%, 45%.

Inulin was introduced into the filling in the amount 10–40%, replacing the equivalent amount of fat. The samples where 40% of fat was replaced with inulin were thick and viscous, which made it difficult to spread the filling on wafer sheets. So, the mass fraction of inulin in waffle filling was decided to be 10, 20, and 30%. The samples of fatty filling were obtained that contained synbiotics and were low in calories.

During the experiments, the following optimum ratio of lactulose and inulin was determined for SC 2: 30% of lactulose, and 20% of inulin. When prebiotics with this ratio of components were added to the fatty filling, its structure and taste improved.

The number of microorganisms introduced into the formulation was determined considering the fact that their physiologically active level in functional products should be 10^6–10^7 CFU/g of the intestinal content. For SC 1, only encapsulated bifidobacteria, and for SC 2, encapsulated bifidobacteria and lactobacilli were introduced. Depending on what target consumers need, the ratio of bifidobacteria and lactobacilli can be varied, or, if necessary, only one of these can be introduced. The technology remains unchanged, though.

Prototypes of final products have been made, with the use of synbiotic complexes: the waffles *Fantasia* containing SC 1, and the waffles *Harmonia Smaku* containing SC 2. Consumers find it important that new products that appear on the market should have the same sensory characteristics as the traditional products they are used to. So, to prove the introduction of synbiotics into the waffle recipe, the first thing done was tasting evaluation of the new waffles. To determine the sensory characteristics the consumer appeal of the product depends on, a systematic approach was applied. The parameters (descriptors) used to evaluate the products were developed as a result of discussing the matter by the tasting committee. The object of research was decided to be the taste of the product. The degustation results were plotted in a profile diagram of the tastes of the products (Fig. 4). The following profile diagram is based on the sensory assessment of the fatty filling (Fig. 5).

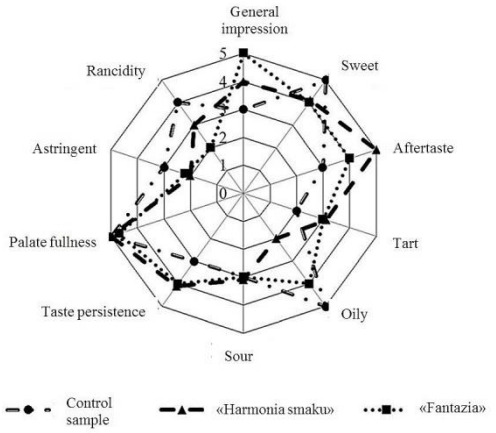

Fig. 4. Profile diagram of the taste of the waffles

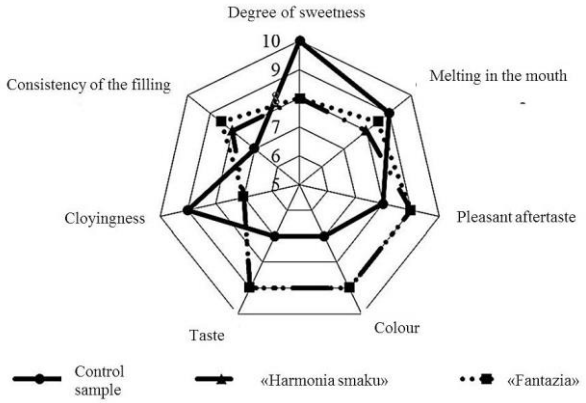

Fig. 5. Profile diagram of the sensory evaluation of the fatty filling of the waffles, with SC 1 and SC 2 added

The data obtained show that the experimental samples have far better sensory characteristics than the control one. The study has proved that synbiotics in the composition of the fatty filling provides sustained high quality of the final product. Inulin and lactulose used as wholesome ingredients allow manufacturing waffles with functional properties, low in calories, and of excellent taste. Besides their prebiotic qualities, these ingredients have a number of technological advantages. Lactulose can be, to some extent, a substitute for sugar. When used, it makes waffles taste sweetish, but not cloying, with no off-taste. Inulin can partially or completely replace fat due to the formation of creamy gel with water, tasting neutral, and with a texture very close to that of fat. So, adding inulin and lactulose to fatty fillings for waffles can reduce fat and sugar in them, thus making them healthier and less fattening, with no loss of their consumer qualities. And the introduction of encapsulated microorganisms into fatty filling will add probiotic qualities to the products.

Conclusion

The search through the literature on the problem made it possible to give theoretical reasons for the choice of ingredients to develop synbiotic complexes SC 1 and SC 2, basing on their technological and physiological characteristics. *In vitro* studies have been carried out under conditions simulating those in the human gastrointestinal tract (GIT). The survival rates of encapsulated cells of bifidobacteria and lactobacilli in the GIT have been determined. It has been established that when bifidobacteria were passing the gastric juice medium, their encapsulated cells decreased in number by 12%, and the unprotected ones

by 50%. When acted upon by the enzyme system, the number of the nonencapsulated cells reduced by 60%, and that of the capsulated ones by 20%. Similar results have been obtained for lactobacilli cells: after they were incubated in the gastric juice medium, the encapsulated cells were fewer by 44% than they originally were, whereas the protected ones remained viable. When put into bile, the number of the unprotected cells reduced by 55%, and that of the encapsulated ones by 11%. It has been proved that adding the obtained synbiotic complexes to the formulation of the fatty filling allows manufacturing waffles with high sensory qualities, low in calories, and of excellent taste. The waffles obtained have certain functional qualities. When included into the diet, they, rather than providing the body with energy and plastic material, control and optimize certain physiological functions and biochemical reactions, keep a person fit, reduce the risk of diseases, and speed up the recovery process.

List of references:

1. Храмцов А.Г., Харитонов В.Д., Евдокимов И.А. Лактулоза и функциональное питание // Молочная промышленность. 2002. Вип. 5. С. 41-42.
2. Ким В.В., Харитонов Д.В., Щербаков Э.Г. Зарубежный опыт использования пребиотиков // Молочная промышленность. 2001. Вип. 2. С. 31-32.
3. Role of the gut microbiota in immunity and inflammatory disease / Kamada N. та ін. // Nature Reviews Immunology. 2013. Вип. 5. С. 321-325. DOI: 10.1038/nri3430.
4. Бондаренко В.М., Мацулевич Т.В. Дисбактериоз кишечника как клинико-лабораторный синдром: современное состояние проблемы. Москва: ГЭОТАР-Медиа, 2007. 304 с.
5. Littman D.R., Pamer E.G. Role of the commensal microbiota in normal and pathogenic host immune responses // Cell Host &Microbe. 2011. Вип. 10. С. 311-323.
6. Sorokulova I. Recombinant Probiotics: Future Perspectives in Disease Treatment // Journal of Probiotics Health. 2014. Т. 2, вип. 2. С. 1000e109. DOI: 10.4172/2329-8901.1000e109.
7. Fava F., Danese S. Intestinal microbiota in inflammatory bowel disease: friend of foe? // World Journal of Gastroenterology. 2011. Т. 17, вип. 5. С. 557-566. DOI: 10.3748/wjg.v17.i5.557.
8. Некоторые замечания относительно тактики использования пробиотиков в неонатологии и педиатрии / Лукьянова Е.М. та ін. // Современная педиатрия. 2005. Т. 3, вип. 8. С. 230-240.
9. Янковский Д.С., Дымент Г.С. Микрофлора и здоровье человека. Киев: ТОВ «Червона Рута-Турс», 2008. 552 с.
10. Янковский Д.С., Моисеенко Р.А., Дымент Г.С. Место дисбиоза в патологии человека // Современная педиатрия. 2010. Т. 1, вип. 29. С. 154-167.
11. Roberfroid M.B. Prebiotics and synbiotics: concepts and nutritional properties // British Journal of Nutrition. 1998. Вип. 4. С. 197-202.
12. Schrezenmeir J.0., Vresse D.M. Probiotics, prebiotics and synbiotics – approaching a definition // The American Journal of Clinical Nutrition. 2001. Вип. 2. С. 361-364.
13. Kearney S.M., Gibbons S.M. Designing synbiotics for improved human health // Microbial Biotechnology. 2018. Т. 11, вип. 1. С. 141-144. DOI: 10.1111/1751-7915.12885.
14. Development of Synbiotic Milk Chocolate Enriched with Lactobacillus paracasei, D-tagatose and Galactooligosaccharide / Rad A.H. та ін. // Applied Food Biotechnology . 2018. Т. 5, вип. 2. С. 59-68.
15. Wu Y., Zhang G. Synbiotic encapsulation could boost probiotic survival rate // LWT - Food Science and Technology. 2018. Т. 93. С. 135-141. DOI: 10.1111/jam.12762.
16. Красина И.Б., Хашпакянц Е.А., Джахимова О.И. Влияние пробиотиков и пребиотиков на реологические свойства структурированных дисперсных систем // Фундаментальные исследования. 2014. Вип. 6. С. 1149-1153.
17. Konar N., Toker O., Sagdic O. Improving functionality of chocolate: a review on probiotic, prebiotic, and/or synbiotic characteristics // Trends in Food Science & Technology. 2016. Т. 49. С. 35-44.
18. Анализ рынка кондитерских изделий Украины: [Веб-сайт]. 2017. URL: https://pro-consulting.ua/issledovanie-rynka/analiz-rynka-konditerskih-izdelij-ukrainy-2017-god (дата звернення: 02.08.2018).
19. Bifidobacteria: history, ecology, physiology and applications / Biavati B. та ін. // Annals of Microbiology. 2000. Вип. 50. С. 117-131.
20. Shah N.P. Characteristics and potential for application in fermented milk products // Milchwissenschaft. 1997. Т. 52, вип. 1. С. 16-20.
21. Утебаева А.А., Бурмасова М.А., Сысоева М.А. Перспективы использования бифидобактерий в продуктах функционального питания и лекарственных средствах // Известия вузов. Прикладная химия и биотехнология. 2016. Т. 6, вип. 4. С. 100-109. DOI: 10.21285/2227-2925-2016-6-4-100-109.
22. Coudeyras S., Forestier C. Microbiota and probiotics: effects on human health // Canadian Journal of Microbiology. 2010.Вип. 8. С. 611-615. DOI: 10.1139/w10-052.
23. Рябцева С.А. Технология лактулозы: учебное пособие. Москва: ДеЛи принт, 2003. 232 с.
24. Application of inulin in cheese as prebiotic, fat replacer and texturizer: a review / Karimi R. та ін. // Carbogydrate polymers. 2014. Вип. 11. С. 85-100. DOI: 10.1016/j.carbpol.2014.11.029.
25. Inulin: Properties, health benefits and food applications / Shoaib M. та ін. // Carbogydrate polymers. 2016. Вип. 4. С. 444-454. . DOI: 10.1016/j.carbpol.2016.04.020. DOI: 10.1016/j.carbpol.2016.04.020.
26. Miremadi F., Shah N. P. Applications of inulin and probiotics in health and nutrition // International Food Research Journal. 2012. Вип. 4. С. 1337-1350.
27. Коркач А.В., Крусир Г.В., Егорова А.В. Обоснование метода иммобилизации микроорганизмов и их применение в технологии кондитерских изделий // Пищевая наука и технология. 2013. Вип. 1. С. 35-38.
28. Korkach A., Krusir G. The development of innovative technologys fondant candies with synbiotics // Technology audit and production reserves. 2017. Вип. 1/3. С. 50-55. DOI: https://doi.org/10.15587/2312-8372.2017.93806.

References:

1. Khramtsov AH, Kharitonov VD, Evdokimov IA. Laktuloza i funktsionalnoe pitanie. Molochnaia promyshlennost. 2002; 5: 41-42.

2. Kim VV, Kharitonov DV, Shcherbakov EH. Zarubezhnyy opyt ispolzovaniia prebiotikov. Molochnaia promyshlennost. 2001; 2: 31-32.
3. Kamada N, editors. Role of the gut microbiota in immunity and inflammatory disease. Nature Reviews Immunology. 2013; 5: 321-325. DOI: 10.1038/nri3430.
4. Bondarenko VM, Matsulevich TV. Disbakterioz kishechnika kak kliniko-laboratornyy sindrom: sovremennoe sostoyanie problemy. Moskva: HEOTAR-Media; 2007.
5. Littman DR, Pamer EG. Role of the commensal microbiota in normal and pathogenic host immune responses. Cell Host &Microbe. 2011; 10: 311-323.
6. Sorokulova I. Recombinant Probiotics: Future Perspectives in Disease Treatment. Journal of Probiotics&Health. 2014; 2(2): 1000e109. DOI: 10.4172/2329-8901.1000e109.
7. Fava F, Danese S. Intestinal microbiota in inflammatory bowel disease: friend of foe? World Journal of Gastroenterology. 2011; 17(5): 557-566. DOI: 10.3748/wjg.v17.i5.557.
8. Lukianova EM, editors. Nekotorye zamechaniia otnositelno taktiki ispolzovaniia probiotikov v neonatolohii i pediatrii. Sovremennaia pediatriia. 2005; 3(8): 230-240.
9. Yankovskii DS, Dyment HS. Mikroflora i zdorove cheloveka. Kiev: TOV «Chervona Ruta-Ture»; 2008.
10. Yankovskii DS, Moiseenko RA, Dyment HS. Mesto disbioza v patolohii cheloveka. Sovremennaia pediatriia. 2010; 1(29): 154-167.
11. Roberfroid MB. Prebiotics and synbiotics: concepts and nutritional properties. British Journal of Nutrition. 1998; 4: 197-202.
12. Schrezenmeir J0, Vresse DM. Probiotics, prebiotics and synbiotics – approaching a definition. The American Journal of Clinical Nutrition. 2001; 2: 361-364.
13. Kearney SM, Gibbons SM. Designing synbiotics for improved human health. Microbial Biotechnology. 2018; 11(1): 141-144. DOI: 10.1111/1751-7915.12885.
14. Rad AH, editors. Development of Synbiotic Milk Chocolate Enriched with Lactobacillus paracasei, D-tagatose and Galactooligosaccharide. Applied Food Biotechnology. 2018; 5(2): 59-68.
15. Wu Y, Zhang G. Synbiotic encapsulation could boost probiotic survival rate. LWT - Food Science and Technology. 2018; 93: 135-141. DOI: 10.1111/jam.12762.
16. Krasina IB, Khashpakiants EA, Dzhakhimova OI. Vliianie probiotikov i prebiotikov na reolohicheskie svoystva strukturirovannykh dispersnykh sistem. Fundamentalnye issledovaniia. 2014; 6: 1149-1153.
17. Konar N, Toker O, Sagdic O. Improving functionality of chocolate: a review on probiotic, prebiotic, and/or synbiotic characteristics. Trends in Food Science & Technology. 2016; 49: 35-44.
18. Analiz rynka konditerskikh izdelii Ukrainy: [Veb-sayt]. 2017. URL: https://pro-consulting.ua/issledovanie-rynka/analiz-rynka-konditerskih-izdelij-ukrainy-2017-god (data zvernennya: 02.08.2018).
19. Biavati B, editors. Bifidobacteria: history, ecology, physiology and applications. Annals of Microbiology. 2000; 50: 117-131.
20. Shah NP. Characteristics and potential for application in fermented milk products. Milchwissenschaft. 1997; 52(1): 16-20.
21. Utebaeva AA, Burmasova MA, Sysoeva MA. Perspektivy ispolzovaniia bifidobakterii v produktakh funktsionalnoho pitaniia i lekarstvennykh sredstvakh. Izvestiia vuzov. Prikladnaia khimiia i biotekhnolohiia. 2016; 6(4): 100-109. DOI: 10.21285/2227-2925-2016-6-4-100-109.
22. Coudeyras S, Forestier C. Microbiota and probiotics: effects on human health. Canadian Journal of Microbiology. 2010; 8: 611-615. DOI: 10.1139/w10-052.
23. Riabtseva SA. Tekhnolohiia laktulozy: uchebnoe posobie. Moskva: DeLi print; 2003.
24. Karimi R, editors. Application of inulin in cheese as prebiotic, fat replacer and texturizer: a review. Carbogydrate polymers. 2014; 11: 85-100. DOI: 10.1016/j.carbpol.2014.11.029.
25. Shoaib M, editors. Inulin: Properties, health benefits and food applications. Carbogydrate polymers. 2016; 4: 444-454. DOI: 10.1016/j.carbpol.2016.04.020.
26. Miremadi F, Shah NP. Applications of inulin and probiotics in health and nutrition. International Food Research Journal. 2012; 4: 1337-1350.
27. Korkach AV, Krusir HV, Ehorova AV. Obosnovanie metoda immobilizatsii mikroorhanizmov i ikh primenenie v tekhnolohii konditerskikh izdeliy. Pishchevaia nauka i tekhnolohiia. 2013; 1: 35-38.
28. Korkach A, Krusir G. The development of innovative technologys fondant candies with synbiotics. Technology audit and production reserves. 2017; 1/3: 50-55. DOI: https://doi.org/10.15587/2312-8372.2017.93806.

Отримано в редакцію 18.09.2018
Прийнято до друку 06.03.2019

Received 18.09.2018
Approved 06.03.2019

Цитування згідно ДСТУ 8302:2015

Iorgacheva E., Korkach H., Lebedenko T., Kotuzaki O. Synbiotic additives in the waffles technology // Food science and technology. 2019. Vol. 13, Issue 1. P. 19-26. DOI: http://dx.doi.org/ 10.15673/fst.v13i1.1310

Cite as Vancuver ctyle citation

Iorgacheva E, Korkach H, Lebedenko T, Kotuzaki O. Synbiotic additives in the waffles technology. Food science and technology. 2019; 13(1): 19-26. DOI: http://dx.doi.org/ 10.15673/fst.v13i1.1310