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AN INNOVATIVE TECHNOLOGY OF WAFFLES WITH FUNCTIONAL PROPERTIES

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Abstract. The high-priority tasks of today's confectionery industry include the development and introduction of functional-purpose confections. These products are supposed to be of high technological qualities, be effective in production to the extent possible, and have physiological functional properties due to the physiologically valuable ingredients in their composition. These ingredients include the synbiotic complex composed of probiotics (bifidobacteria, lactobacilli) and prebiotics (inulin and lactulose). This complex has been studied in this research. The paper gives reasons why waffles with fatty fillings are the ones to which the synbiotic complex should be added. It has been established what mass fraction of the ingredients at what stage of fatty filling production should be added. It has been studied how the synbiotic complex affects the structural and mechanical properties of the fatty filling: its effective viscosity, adhesive strength, and critical shear stress. It has been found that the maximum shear rate that still allows obtaining a high-quality filling is 5.4 s^{-1}. The specific pull-off force of the fatty filling with the synbiotic added becomes lower compared to that of the control sample. This helps reduce the energy consumed in the course of moulding waffles. An innovative manufacturing technology for waffles with synbiotic supplements has been developed and proved practical. It includes the stages of preparing microencapsulated microorganisms and adding prebiotics, and provides the technological parameters of fatty filling preparation. It has been established that the synbiotic included into the composition of the new fatty filling decreases the maturation of waffle blocks by 40–45%, and allows reducing the layer of filling to 1–1.5 mm. It has been proven that the synbiotic complex as an ingredient in the fatty filling of waffles will allow developing and manufacturing confections that improve human microflora. These new specialised products will be socially significant, as they will help solve a topical and important task of the confectionery industry: prevent gastrointestinal diseases.

Keywords: bifidobacteria and lactobacilli, microencapsulated bacteria, inulin, lactulose, synbiotic complex, fatty filling, structural and mechanical properties, waffles.

Introduction. Formulation of the problem

The global confectionery market, despite being a niche one, is growing rapidly. Manufacturers are looking for new ways of making their products different from those produced by their competitors. Experts believe that this market will keep developing actively over the medium term, too. Functional-purpose confectionery combines food healthiness, convenience, and pleasure of eating, which is decisive in developing the manufacture of these products. A few years ago, the phrase "healthy confectionery" sounded paradoxical. However, since then, consumers have become far more focused on healthy food and lifestyle, so production of functional-purpose confectionery is becoming a strategy of most big companies. Otherwise they would lose a great part of prospective consumers, who would immediately be taken over by more farsighted competitors. So, researchers and manufacturers are now facing a topical problem of creating confections of complex raw material composition, with functional and disease-preventing properties. These products should not only be highly nutritious, but have a positive effect on the human body: maintain its natural balance and normalise the intestinal microflora.

Analysis of recent research and publications

Confections are favourite food for a lot of people, and their popularity never stops increasing. Traditionally, in Ukraine, flour confections are in great demand (fig.1), which is evidenced by the data of the State Statistics Service of Ukraine [1].

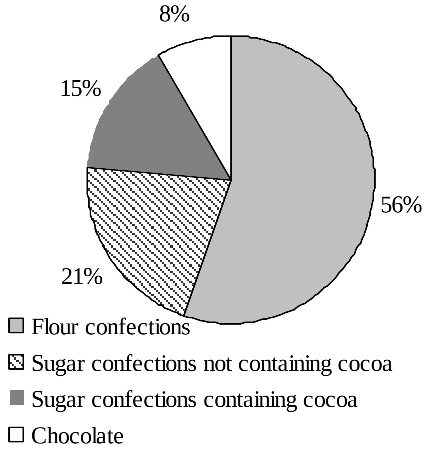

Fig. 1. Structure of confectionery production in Ukraine in 2018 by volume, %

Flour-based confectionery products are market leaders, for they are available and traditional in the diet. That is why it is relevant to develop new products of this very group and improve the existing ones.

The data of Pro-Consulting company [2] shows that in recent years, Ukrainians have been spending more and more money on sweets: Ukrainians do have a sweet tooth. Our country is among the top ten sweet-loving countries of the world, with about 15 kg of the annual per capita consumption of confectionery (whereas for the USA, this parameter is only 10 kg). Analysis of the market shows that among other directions of the Ukrainian confectionery industry, the waffle market is actively developing. There is high competitiveness on this market, a lot of large-scale manufacturers represented in all the regions, and it is quite saturated with products. However, this market still has some niches, particularly, for snack products and healthy waffle products. Thus, it should be studied what flour confections (including waffles) with health-improving dietary supplements have been developed by now.

Publications on functional-purpose waffles and patents for them have been studied and analysed. In the article [3], the authors investigated the effect of the probiotics Bifilact A and Bifilact D and the prebiotic Beneo™ Synergy1 on the rheological properties of fatty fillings for flour confections, and determined the amount of the supplements to be added.

The experimental study [4] consisted of introducing palatinose and Jerusalem artichoke powder into the fatty filling recipe. The purpose was to reduce the fat and sugar content of the filling and impart some functional qualities to it by replacing the sugar in the recipe completely and introducing prebiotics. It was determined that when sugar was excluded from the recipe, the optimum amount of palatinose added was 100%, and that of Jerusalem artichoke powder ranged within 7%. This could allow improving the chemical composition and physiological value of the product.

A group of researchers [5] gave reasons for their choice of dietary supplements to waffles. The products were enriched with powdered Jerusalem artichoke tubers that contained inulin (46.21%) and defatted sunflower lecithin high in phospholipids (90.29%). The effect of these supplements on the technological properties of waffle dough were studied. The optimum mass fraction of the supplements was determined.

The paper [6] developed prophylactic waffles with a fatty filling where wheat germ oil was used. The oil contained no less than 20% of vitamin E and more than 60% of polyunsaturated fatty acids. The research studied the sensory, rheological, and informational quality characteristics of the fatty filling that contained wheat germ oil. The optimum amount of the oil added ranged 2.6-3.1%. A “field of recipes” was developed for waffles with prophylactic fatty fillings that could prevent cardiovascular diseases and decelerate senescence.

The Ukrainian scientists [7] developed waffles with fatty fillings using non-traditional raw materials: powdered sage, celery and chicory roots, pollen, bee extract, powdered dried pumpkins and rosemary, pumpkin seeds, barley flour and bran, sesame seeds, powdered cumin and chicory roots. The developed products contained an increased amount of dried skimmed milk and were enriched with essential amino acids, polyunsaturated fatty acids, vitamins, and protein. As a result, new products were developed: *Kvitkovy Nektar*, *Melodiya Oseni*, *Zlakovi*.

A group of scientists [8] suggested a new waffle technology, with the addition of wheat germ oil cake, to be further used in food manufacture. The supplement *Vitazar* contains vitamins B_1, B_2, and B_6, pantothenic and folic acids, β-carotene, D, E, H, and PP. Their content was about 5 times as high as their concentration in unprocessed grain. During the experiments, it was determined that the best taste could be achieved by adding 35% of wheat germ oil cake. Higher amounts of it resulted in worse sensory qualities and higher moisture content, which led to the lower quality of the product.

The researchers [9] suggested expanding the range of healthy waffles by using hydrofat and the wholegrain amaranth flour *Krepysh* that is higher in squalene, proteins, and microelements. The effect of amaranth flour on the sensory, physical, and rheological properties of the fatty filling was studied. Based on the research, the formulation of the new filling and its production technology were developed, and its nutritive value was calculated.

The research of the works [10-12] is directed towards obtaining waffle dough with the required rheological characteristics. They involved experimental studies of controlling the consistency of waffle dough based on gluten-free flours (maize, rice, buckwheat).

The optimum moisture content of the semi-processed product depending on the flour type was determined, which made it possible to suggest adding a mixture of xanthan and guar gums. Besides, as gluten-free flours have different effects on the viscosity of dough, it is also possible to use their mixtures when inventing new formulations for wafer sheets.

The results of this analysis have shown that some developed products provide the human body with micronutrients, others improve digestion, and others are positive for the cardiovascular system and can inhibit senescence. However, there are very few products that renew the intestinal microflora.

Functional ingredients that help normalise the human intestinal microflora include probiotics and prebiotics. The prebiotics that are practical to use are lactulose and inulin due to their technological and functional properties.

Lactulose is a disaccharide consisting of galactose and fructose residues. At present, it is the best investigated bifidus factor and the world's No. 1 prebiotic. Lactulose is also used as a sweetener with unique bifidogenic properties in different prophylactic foods. For over sixty years, it has been finding its application in different spheres, has proved to be safe and biologically valuable, and the leading experts believe that in the future, too, it will remain important in keeping people healthy and socially active [13-19]. Now, lactulose is used as a dietary, baby food, prophylactic, therapeutic, gerontological, and functional-purpose nutrient. To avoid gastrointestinal and hepatic disorders and to improve the intestinal flora, its recommended doses are only a few grams a day [20].

A very important technological property of lactulose is its functional stability. This means that it can retain all of its useful qualities in a wide range of environments and technological parameters. And this allows an almost unlimited use of lactulose to manufacture functional-purpose foods. No technological treatment affects its main functions: stimulating the development of bifidobacterial flora, hepatoprotection, neuroprotection, etc.

Another common prebiotic widely used in industry is inulin. It is a polysaccharide that belongs to polyfructosides (fructans). Fructose contains 95% of inulin, the remaining 5% being D-glucose [21]. The medical, biological, and biochemical properties of inulin make it possible to use it as a functional-purpose ingredient in healthy foods [22-26]. However, in Ukraine, this practice has not become traditional yet.

Inulin's main technological feature is that, when combined with water, it forms white non-transparent creamy gel. The process involves dispersing hard inulin in water intensively using a stirring tool or a homogeniser, followed by leaving the resulting dispersion to rest for some time. Inulin breaks down into small submicron hard particles that make a three-dimensional honeycomb structure in the form of gel that has associated water in its composition. The obtained gel has neutral taste and a short structure very close to that of fat. That allows inulin to imitate the presence of fat in fat-free products, and to improve their texture and sensory qualities, thus making these parameters close to those of products with a normal fat content [26].

As probiotics, it is reasonable to use cultures of bifidobacteria and lactobacilli, which make the basis of useful human microflora. By now, it has been conclusively established that microbiota responds to mental, emotional, and health changes in people, and produces mediators that affect the body's specific and nonspecific resistance. According to the WHO, the number of people with reduced immune system functionality is growing. This results in higher occurrence of chronic, particularly, opportunistic diseases. Thus, the question of restoring the optimum microflora, i.e. the microbial ecology and endoecology of a macroorganism, has arisen [27].

That is why the **purpose** of the research was developing an innovative technology of manufacturing fatty fillings for waffles using a synbiotic complex to normalise the body's microbiota.

The research objectives.

To achieve the above purpose, the following objectives were solved:

– to give theoretical reasons for the advantages of using probiotics (microencapsulated bifidobacteria and lactobacilli) and prebiotics (inulin and lactulose) as functional ingredients to enrich waffles;

– to study the effect of the synbiotic complex on the structural, mechanical, and sensory properties of the waffle filling;

– to develop a functional technology of manufacturing the newly-developed waffles with a fatty filling;

– to evaluate the consumer properties of waffles with the synbiotic complex.

Research materials and methods

In the experiments to develop a fatty filling for waffles, the following raw materials were used: wheat flour (State Standard of Ukraine 46.004-99), chicken eggs (State Standard of Ukraine 5028:2008), salt (State Standard of Ukraine 3583:2015), baking soda (State Standard 2156:76), granulated sugar (State Standard of Ukraine 4623-2006), shortening (State Standard of Ukraine 4463:2005), flavouring essence (State Standard of Ukraine 4716:2007), citric acid (State Standard of Ukraine 908:2006), inulin (by Frutabit), lactulose (by Fresenius Kabi), Bifidumbacterin (by Biofarma), Lactobacterin (by Biofarma), pure cultures of the bifidobacteria *Bifidobacterium bifidum-1* and the lactobacilli *Lactobacillus acidophilus Ep-317/402* (from the collection of the museum of microorganisms at the Department of Biochemistry, Microbiology, and Nutrition Physiology, ONAFT), drinking water (State Standard of Ukraine 7525:2014), pectin (State

Standard of Ukraine 6088:2009), calcium chloride (State Standard 5973-2014).

The object of research was the fatty filling for waffles.

Determination of the density of the fat and the filling. The density of the filling (fat) was determined volumetrically by the ratio between the mass of the object under study and the volume of the container [28].

Determination of the evenness of the component distribution in the filling. The heterogeneity coefficient of the mixture (K_m) is the ratio between the mean square deviation of moisture to its mean value in a mass fraction of the mixture.

$$\hat{E}_m = \frac{100 \bullet s}{x} = \frac{\pm n \bullet 100 \sqrt{\sum_{i=1}^{n} (\tilde{o}_i - x)^2 \bullet \frac{1}{n-1}}}{\sum_{i=1}^{n} x_i}, \quad (1)$$

where s – mean square deviation;

x – arithmetic mean value;

n – number of measurements.

The inverse value, the homogeneity coefficient P (%), is calculated by the formula:

$$Ð = (100 - \hat{E}_m) \quad (2)$$

The effective viscosity, adhesive properties, and strength of the fatty filling were determined by the methods described in [28].

The moisture content of the fatty filling was determined with a Chizhova moisture meter [28].

The mass fraction of fat in the filling and in the final products was determined by refractometry [29].

The sensory analysis of the waffles was carried out by a taste panel of 5–7 people. The analysis complied with the methodology of tasting and was based on the quality parameters according to State Standard of Ukraine 4033-2001 "Waffles. General technical specifications."

Results of the research and their discussion

The previous research [30] developed and scientifically substantiated two synbiotic complexes SC1 and SC2 to be included in the recipe of a fatty filling for waffles. The present work studies the effect of the synbiotic complex SC2 on the quality parameters and possible functional properties of the fatty filling. The fatty filling is chosen for waffles because it has almost no free moisture, so waffles can remain crispy for a long time. Their main disadvantage is a high caloric and low physiological value. So, it is practical to enrich them with functional ingredients.

The synbiotic SC2 is composed of a mixture of prebiotics (inulin and lactulose) and a probiotic (a mixture of microencapsulated lactobacilli and bifidobacteria). It was developed at the Department of the Bread, Confectionery, Macaroni, and Food Concentrates Technology, in Odessa National Academy of Food Technologies. The formulation of the waffles *Ananasni* was taken as the control sample. The supplements were added at the stage of mixing the fatty filling.

In this work, the mass fractions of the ingredients and the stage of adding them during the manufacture of the fatty filling have been determined. Doctors recommend a daily intake of 2 to 10 g of lactulose, so the research considered adding 15%, 30%, and 45% of it to replace sugar. Inulin was added to the filling in the amount 10% to 40%, to replace the equivalent amount of fat. The samples with 40% of fat replaced with inulin had a dense consistency and viscous structure, which prevented them from being evenly spread over the wafer sheets. That is why it was decided that the mass fraction of inulin introduced into the formulation of the waffle filling would be 10, 20, and 30%.

The quantity of microorganisms introduced into the formulation was determined taking into account that their physiologically active level in functional-purpose products should be 10^6-10^7 CFU/g to the contents of the intestine. The ratio between the contents of bifidobacteria and lactobacilli was varied according to the demands of the target audience. The quantity of living cultures of microorganisms has no effect on the course of the technological process.

The following fatty filling samples were suggested as objects of research: 1 – the control sample; 2 – the sample containing 15% of lactulose and 10% of inulin; 3 – the sample containing 30% of lactulose and 20% of inulin; 4 – the sample containing 45% of lactulose and 30% of inulin. The compositions of all the samples under study were enriched with a mixture of microencapsulated bifidobacteria and lactobacilli in the amount 10^7 CFU/g.

The quality criteria of the fatty filling for waffles are the granulation level of the solid particles, the evenness of distribution of the recipe components in the product, and the density of the filling itself. Preparation of the filling involves mixing, which is the mechanical process of distributing particles of individual components evenly throughout the whole volume of the mixture under the action of external forces to achieve the required consistency. The quality of mixing can be estimated by the homogeneity of the obtained mixture, and for its quantitative assessment, the heterogeneity coefficient is used. A mixture is homogeneous if the content of its components in any volume of it is the same as their content in the whole mixture. The quality of mixing depends on the density of the recipe components, the parameters of the component particles in the mixture (their shape and size, and for non-uniform components, the dispersive distribution by their fineness), their moisture content, the surface state of the particles, the forces of friction, cohesion, and adhesion of the surface particles, etc.

The homogeneity was determined by the moisture content (W) of the filling in different points of the whipping machine. Each ingredient has a certain amount of moisture which is constant. So, when the components are distributed evenly, the amount of moisture in different points of the filling remains unchanged. If it does not, this means that the quantitative composition of the components is uneven.

The homogeneity coefficient P (%) has been determined (Table 1). The higher *P*, the more homogeneous the mixture is. This is a effectiveness characteristic of the mixers: with *P>90%*, mixing is considered to be good. If there is a significant difference in the density of the components and in the parameters of their particles, it becomes much harder and takes far longer to achieve the necessary level of mixing.

Table 1 – Coefficients of distribution of the recipe components in the filling

Sample	P (distribution coefficient), %
control	96.0
15% of lactulose, 10% of inulin, bacterial mixture	95.0
30% of lactulose, 20% of inulin, bacterial mixture	93.4
45% of lactulose, 30% of inulin, bacterial mixture	91.5

As evidenced by the experimental data, in the fatty filling formulation with SC2 included, the distribution coefficient is lower than in the control sample. It can be seen from the table that the more lactulose and inulin a sample contains, the lower the distribution coefficient is. This results from the fact that the experimental recipe mixtures contain solid particles of different sizes: the less uniform the mixture is by the size of the particles, the less evenly the recipe components are distributed in the finished filling. However, in all the experimental samples, *P* is higher than 90%, which is evidence of the mixer's effectiveness and the homogeneity and high quality of the obtained filling with a synbiotic complex.

It was necessary to study how the synbiotic influences the effectiveness of the cream formation process that is indirectly characterised by the density of the filling after whipping.

Fig. 2 presents the experimental results that show how the filling density depends on the amount of lactulose, inulin, and microencapsulated microorganisms.

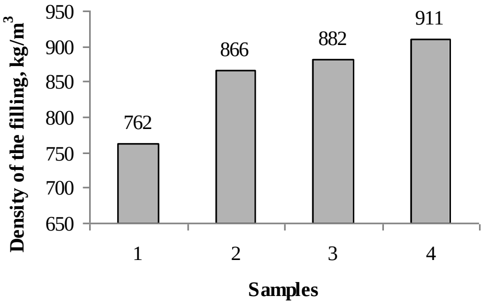

Fig. 2. The effect of the synbiotic complex on the density of the fatty filling

The obtained results show that a synbiotic supplement in the fatty filling composition makes it denser compared to the control sample. This tendency is due to the fact that fat promotes the aerification of the mass, and in the experimental samples, some of the fat is replaced with inulin, which results in less air in the filling and its higher density.

The effectiveness of preparing a fatty filling can be determined after it acquires the required structural and mechanical characteristics: viscosity, adhesion, and strength. That is why, at the second stage, it was analysed how the structural and mechanical characteristics changed with the addition of the synbiotic complex.

One of the rheological characteristics determining the quality of a filling is viscosity (the internal frictional force), which is a measure of the resistance of a flow. Viscosity directly depends on the temperature of a mixture under study. The changes in the effective viscosity η according to the shear rate gradient D were studied in the control and experimental samples (Fig. 3). The temperature of the filling was 30°C.

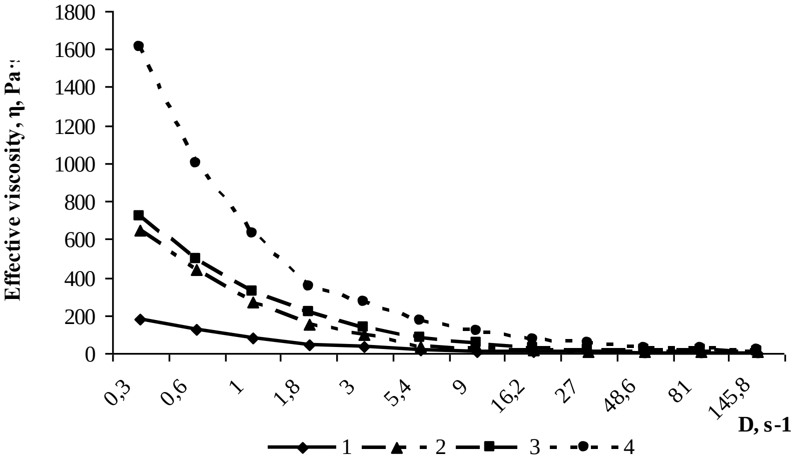

Fig. 3. Dependence of the effective viscosity of the filling η on the shear rate gradient D, with different mass fractions of lactulose, inulin, and microencapsulated microorganisms

The experimental data makes it clear that with an increase in the shear rate gradient, the effective viscosity decreases down to 5.4 s^{-1} (the decrease is especially rapid within the range of shear rates). With a further increase in the shear rate, the effective viscosity changes but insignificantly. The horizontal regions in the curves correspond to the viscosity of a mixture with the structure completely destroyed. This means that fillings should be obtained at the shear rates that do not destroy the structure of the material. The maximum shear rate that allows obtaining a good filling corresponds to the point where the curve starts smoothly proceeding into the destroyed structure region. Practically, the total time of obtaining a high-quality filling is about 15–20 min. The duration of mixing depends on the nature of the mixture components, the frequency of stirring, the construction of the machine, and the temperature.

The experimental data shows that the frequency of stirring is limited, as at a rate higher than 9 s^{-1} in samples 1, 2, and 3 and higher than 16.2 s^{-1} in sample 4, the structure of the filling is destroyed. The increase in the effective viscosity of the experimental filling samples may be explained by the fact that the coagulation structure in a dispersion medium is formed due to the adhesion of the prebiotic fibre particles of inulin, lactulose, and powdered sugar through the thin layers of the dispersion medium (fat). The less fat in the filling, the thinner the fatty layer is between the particles, the stronger the structure and the coagulation contacts are. Thus, the effective viscosity of the mixture increases with the addition of the synbiotic complex.

The physical and chemical properties of a waffle filling are characterised by the value of the critical shear stress in the filling during a cone penetrometer test. It is an objective characteristic that shows a material's resistance to crushing and displacement. So, the qualities of a material that are revealed by the penetration test are related to its structural strength. The latter can be assessed according to the critical shear stress τ_o.

The results of the experimental studies of the critical shear stress of the filling with a synbiotic complex are shown in Fig. 4.

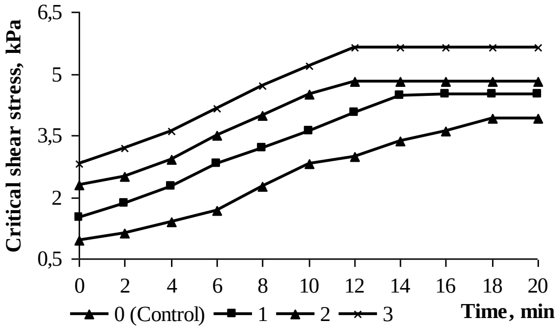

Fig. 4. Changes in the critical shear stress (τ_0) in the samples with different mass fractions of lactulose, inulin, and microencapsulated microorganisms

The fatty filling for flour-based confectionery is a two-phase structured dispersed system that belongs to lyophobic compact high-concentration dispersed systems. Its hydrophilic dispersed phase with solid particles is powdered sugar, and the hydrophobic dispersion medium is shortening. The structure of the fat mass is formed due to adhesion of microparticles through the thin layers of the fat phase. The data analysis has shown that probiotics and prebiotics included in the fatty filling formulation significantly increase the level of structure formation, as compared to the control sample. This is most likely due to the fact that, with the addition of the synbiotic supplement, the concentration of the solid phase in the fluid medium increases. The phase interface increases correspondingly, which results in higher molecular cohesion of the particles. The increased strength of the experimental filling samples, as can be seen in Fig. 4, leads to a shorter resting time of the wafer sheets. Thus, for the control sample, this time is 18nmin, but for experimental samples 2, 3, and 4, it is 14, 12, and 10 min., respectively.

When making a filling, the level of its adhesion to the surfaces of moulding machines is rather important. Adhesion, or sticking, is the ability of some materials to interact, more or less strongly, with another material or with the surfaces that enclose them. The strength of joining two bodies made of different materials depends on the area and the condition of the contact surface between them.

For the experiments, an adhesion tester was used based on the method of pulling a plate off the bulk of food. In the confectionery industry, the forming rollers of spreading machines are most commonly made of steel, and are of the 3rd grade of finish. Thus, in the experiments, the enclosure surface was a plate made of Steel 3. The temperature of its surface was 29±2°C in all the experiments. The results of the studies on the dependence of the specific pull-off force T of the plate on the mass of the SC2-containing filling are presented in Fig. 5.

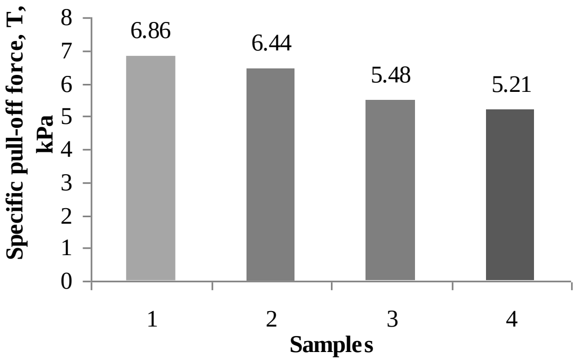

Fig. 5. Dependence of the specific pull-off force T on the content of the synbiotic complex

The obtained data shows that the specific force the synbiotic-containing fatty filling is pulled off with is lower compared to the control sample. Thus, in the control sample, it is 6.86 kPa, but with higher lactulose and inulin contents (in samples 2, 3, and 4), it is lower by 8, 20, and 25%, respectively. This may be due to the fact that in the filling with fat and powdered sugar partially replaced with lactulose and inulin, solid particles become larger, which results in strengthening the structure of the fatty filling. Besides, the presence of particles different by their nature and physical and chemical properties (sucrose and lactulose) has a different effect on how the aggregative forms in the filling structure are joined together and how strong they are. The binding energy of particles in coagulation contacts depends on the nature of the dispersed phase substance and on the dispersion medium. The higher the polarity of one of them, the higher the superficial tension in their interface is. The more different the polarities of the dispersion medium and the particles are, the more the particles tend to aggregate. The surface of lactulose particles is more hydrophilic and has a higher capacity of forming lyophobic bonds. So, adding it strengthens the contacts, which results in structure strengthening. This, in turn, leads to a decrease in the forces of adhesion of the filling to the enclosure surface.

To manufacture waffles with synbiotic properties, innovative technological chart has been improved and adjusted to include the stage of adding microencapsulated probiotics and prebiotics of lactulose and inulin. The process flow chart of making functional-purpose waffles with synbiotic properties is shown in Fig. 6. The technological parameters of manufacturing the new waffle filling are presented in Table 2.

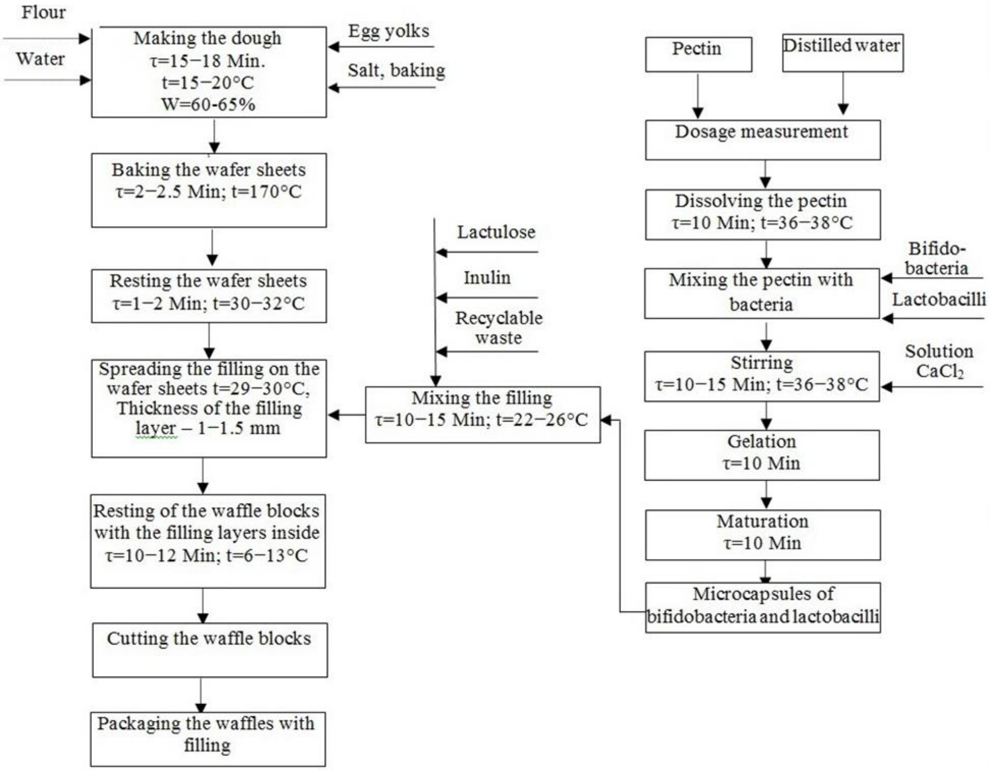

Fig. 6. Process flow chart of manufacturing waffles with the synbiotic complex

Table 2 – Technological parameters of waffle production

	Parameters of the technological process of waffle production	
	Control	***Harmoniya Smaku***
Duration of mixing the filling, min.	15–18	15–18
Temperature of the filling before spreading, °C	29–31	29–31
Thickness of a filling layer after spreading, mm	1.5–2.5	1–1.5
Resting duration of the waffle blocks, min.	15–20	10–12
Resting temperature, °C	6–13	6–13
Resting duration, min.	18–20	10–12

The study has allowed establishing the stages when probiotics and prebiotics should be added. Besides, reasons have been given for the sequence of feeding the ingredients into the whipping machine: 85% of total partially crystalline fat (t=22°C), the total amount of inulin, and half the amount of powdered sugar and lactulose, which is mixed for 2–3 minutes. The whipping tool speed changes from 84 to 318 rpm. Then, the rest of the powdered sugar and lactulose is added, together with a pre-prepared emulsion containing flavor essence, acid, recycled ingredients, and fat (15%). The mixing lasts 11–13 min. Two minutes before the filling is ready, the rotational speed is reduced from 318 to 84 rpm, and microencapsulated bifidobacteria and lactobacilli are added. After the mixing, the temperature of the filling is 22–26°C. The microencapsulated cells of microorganisms must be added at the very end of mixing, because of their low survivability: if the working tools of a whipping machine act upon the cells for a long time, even the ones protected with a coating can die.

Microencapsulated microorganisms are prepared as follows. The required amount of low-esterified pectin is fed, in certain doses, into a tempering machine, where distilled water with the temperature 36–38°C is added. The mixture is stirred for 10 min. At the same time, a lyophilised bifidobacteria and lactobacilli culture is dissolved in distilled water. The dissolved bacteria are added to the dissolved pectin, and the resulting mixture is stirred for 10–15 min. A 10% solution of $CaCl_2$ is added into the obtained homogeneous mixture, then the mixture is stirred thoroughly for 10 min. so that a gelling process can take place. The obtained suspension of microencapsulated microorganisms is left to rest for 10–20 min. Then, the prepared microcapsules are dosed to be used in mixing the fatty filling.

The finished filling is pumped into the tempering machine, where it is tempered at 29–30°C.

The wafer sheets are supplied to the spreading machine where they are interlaid with the fatty filling. Then the resulting waffle blocks are placed into a refrigerating cabinet where they are cooled down at the constant air temperature 6–13°C. The resting time of the waffle blocks is reduced to 10–12 min. The hardened waffle blocks are supplied to a string-type cutting machine and cut in two perpendicular directions into rectangular pieces. The finished waffles are packaged in portions ready for sale, put in corrugated boxes, and directed to storage.The data shows that adding a synbiotic in the formulation of a fatty filling for waffles reduces the duration of the technological process. The resting duration of the waffle blocks before cutting becomes 40-45% less, as the structure in the synbiotic-containing filling forms more quickly.

The next stage of research was comprehensive assessment of the consumer properties of the developed waffles and determining the optimal synbiotic amount.

The following characteristics have been considered in the research: the structural and mechanical properties of the fatty filling samples with different amounts of lactulose and inulin, the process of spreading the filling on the wafer sheets, the thickness of its layer, the ratio between a wafer sheet and the filling, and the sensory qualities of all the samples. After studying and evaluating the above parameters, it has been established that adding 30% of lactulose, 20% of inulin, and microencapsulated bifidobacteria and lactobacilli to the fatty filling formulation produces a filling of a semifluid, fluffy, homogeneous, and tender consistency, which melts in the mouth. When applied on a wafer sheet, the filling spread evenly and did not flow beyond its edges. After resting, the waffle blocks were strong, did not break down into separate layers, and the filling prevented displacement of the sheets. The new waffle type containing a synbiotic was given the name *Harmoniya Smaku* (Flavour Harmony).

Table 3 presents the physical and chemical quality parameters of the newly-developed waffles compared to the control sample.

Table 3 – Physical and chemical parameters of the waffle quality

Parameters	Control	*Harmoniya Smaku*
Moisture content, %	1.5	1.7
Ratio of the mass fraction of fat to the dry matter, %	38.9	37.5
Ratio between a wafer sheet and the filling	20:80	30:70

The data shows that the main physical and chemical parameters of the newly-developed waffle not only differ from, but exceed the control sample due to a lower fat content. In the sheet to filling ratio, the proportion of the wafer sheet increased, because the filling has become more plastic, so it can be applied in a thinner layer.

The sensory characteristics of the new waffle with a synbiotic complex are given in Table 4.

Table 4 – Sensory characteristics of the waffle quality

Parameter	Control	*Harmoniya Smaku*
Taste	Excessively sweet, no off-taste	Less sweet, no fatty off-taste, pleasant aftertaste.
Smell	Characteristic of this sort of products, no off-flavour	Characteristic of this sort of products, no off-flavour
Colour	A sheet is light yellow, in the cross-section is of combined colour. The filling is evenly white.	A sheet is light yellow, in the cross-section is of combined colour. The filling is evenly white.
Cross-sectional structure	A layered product composed of wafer layers with the filling between them. The wafer sheets are in close contact with the filling. The filling is evenly spread and does not go over the edge of the sheets.	
Exterior and surface	The surface has a clear pattern, with the edges cut straight, no drippings. The filling does not go over the edges.	
Consistency of the filling	The filling is of homogeneous consistency, free of lumps, oily, does not allow the wafer sheets to be displaced.	The filling is of tender homogeneous consistency, plastic, melts in the mouth, finely dispersed. In the finished product, is dense, does not allow the wafer sheets to be displaced.

It has been established that the new waffle *Harmoniya Smaku* are of better sensory qualities compared to the control sample. The *Harmoniya Smaku* waffle with the synbiotic complex no longer has the unpleasant fatty off-taste, is not excessively sweet, and has a pleasant tender aftertaste. The filling is melty, with a tender oily texture.

The sensory analysis has shown that the experimental waffle samples are better than the control sample and comply with State Standard of Ukraine 4033-2001 "Waffles. General technical specifications."

Approbation of results

The obtained results have been tested in an industrial environment at the SP *Turevska*, the *Pishchanska* bakery, and have been recommended for industrial application.

Conclusion

The research has allowed to conclude the following. The generalised theoretic principles were the basis for choosing the functional ingredients used in developing a synbiotic complex (SC2) added to the fatty filling formulation. Its composition includes probiotics (microencapsulated bifidobacteria and lactobacilli) and prebiotics (a lactulose and inulin mixture). This synbiotic will have a good physiological effect on the host organism and help the introduced living bacteria acclimatise in the intestine where they will promote the growth and activity of the body's own beneficial microflora. This will allow to create a new functional-purpose fatty filling for waffles. It will be able to restore the body's normal microflora and prevent dysbacteriosis.

The synbiotic complex included in the composition of the fatty filling for waffles will not only make the products more wholesome, but will also improve the structural and rheological properties of the fatty filling. The study has shown that a synbiotic complex in the composition of a fatty filling improves its viscosity and strength, thus accelerating the cooling of the waffle blocks. The specific pull-off force of a synbiotic-containing fatty filling is lower than that of the control sample. This allows using the existing waffle-making equipment to manufacture the new types of waffles, and reduces the energy consumption of the technology.

An innovative technological chart of manufacturing synbiotic-containing waffles has been developed, which includes preparing micro-encapsulated microorganisms. The choice of the stage of their adding to the product has been explained. The technological parameters of preparation of the synbiotic-containing filling have been improved.

The optimal amount of the synbiotic has been established. The sensory qualities and the physical and chemical characteristics of the obtained products have been evaluated. The assessment has proven that the obtained products are of high quality, taste excellent, contain less fat, and the percentage of the wafer sheet can be increased in the sheet to filling ratio.

Thus, the innovative technology of waffles with a synbiotic complex will not only make the confections with functional ingredients attractive due to their sensory characteristics, but will also improve their technological properties. This will allow to expand the range of health-maintaining products, and make it possible for confections that can normalise the human intestinal microflora to appear on the Ukrainian consumer market.

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ІННОВАЦІЙНА ТЕХНОЛОГІЯ ВАФЕЛЬНИХ ВИРОБІВ З ФУНКЦІОНАЛЬНИМИ ВЛАСТИВОСТЯМИ

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Анотація. До пріоритетних завдань сучасної кондитерської галузі відноситься розробка і впровадження кондитерських виробів функціональної спрямованості, що володіють високими технологічними властивостями, забезпечують максимальну ефективність виробництва і проявляють фізіологічно функціональні властивості, завдяки наявності в своєму складі фізіологічно цінних компонентів. До таких інгредієнтів належить синбіотичний комплекс, що складається з пробіотиків – біфідо- та лактобактерії, та пребіотиків – інуліну та лактулози, який вивчали у данному дослідженні. У роботі обгрунтовано вибір вафель з жировими начинками в якості об'єкту для внесення синбіотичного комплексу. Визначено масову частку інгредієнтів і стадію внесення їх при виробництві жирової начинки. Досліджено вплив синбіотичного комплексу на структурно-механічні властивості жирової начинки: на ефективну в?язкість, адгезійну міцність та граничну напругу зсуву. Встановлено, що максимальна швидкість зсуву, при якій можна отримати начинку хорошої якості, склала 5,4 $с^{-1}$. Питома сила відриву жирової начинки з добавкою синбіотику знижується порівняно з контрольним зразком, що сприяє зниженню енергетичних витрат при формуванні. Розроблена та обгрунтована інноваційна технологічна схема виробництва вафельних виробів з синбіотичним комплексом, в якій передбачено стадії приготування мікрокапсульованих мікроорганізмів, введення пребіотиків, наведені технологічні параметри приготування жирової начинки. Встановлено, що внесення синбіотику до складу нової жирової начинки сприяє скороченню процесу вистоювання вафельних пластів на 40–45% та дозволить зменшити шар начинки до 1–1.5 мм. Обґрунтовано, що внесення синбіотичного комплексу в рецептуру жирової начинки для вафель дозволить розробити і випускати кондитерські вироби, які сприятимуть нормалізації мікрофлори людини, тобто нових соціально значущих спеціалізованих продуктів для профілактики шлунково-кишкових захворювань, що на сьогоднішній день представляється актуальною і важливою задачею кондитерської галузі.

Ключові слова: біфідо- та лактобактерії, мікрокапсульовані бактерії, інулін, лактулоза, синбіотичний комплекс, жирова начинка, структурно-механічні властивості, вафлі.

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