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APPLICATION OF THE FOOD ADDITIVE *MAGNETOFOOD* IN THE TECHNOLOGY OF MOULDED MARMELADE JELLY SWEETS

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Introduction. Problem statement

Marmalade jellies have a colloidal dispersed structure, that is why it is so important to solve the problem of its stabilisation. Besides, with the fierce competition on the domestic market nowadays, manufacturers of marmalade sweets and of other fruit jelly products are looking for how to make their products more competitive. The ways to do this include improving the consumer properties of final products, making the cost of production lower and the shelf life longer [1,2].

The market trends responsible for the range of moulded marmalade jellies available are determined by

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Abstract. To expand and modernise the manufacture of fruit jelly products, it is necessary to search for simpler technologies, both resource- and energy-saving, to increase the stability of colloidal dispersed systems, and to improve the quality of finished products. In this respect, technological application of food additives of the nanometer range looks very promising due to their unique physicochemical parameters and their many functional and technological properties. In this paper, it is suggested to solve the problem of stabilising the colloidal structure of marmalade jelly products and to form their quality by using the food additive *Magnetofood* based on ferrous and ferric oxides (FeO-Fe₂O₃). *Magnetofood* is ultrafine powder with the particle size ~80 nm. It has a high functional and technological potential – a large specific surface and a number of useful qualities (the additive is surface-active, with complex-forming, sorption, and stabilising properties). This allows us to recommend *Magnetofood* as an additive with a complex action to improve the quality and extend the shelf life of fruit jelly products, in particular, moulded marmalade jellies. It has been found that addition of *Magnetofood* (in the form of an aqueous suspension at the stage of swelling and dissolution of the gelling agent) improves the product's shape, surface, and consistency, increases the moisture content by 1.15–1.16 times in agar-based samples and by 1.13–1.14 times in pectin-based samples, reduces the total acidity by 1.05–1.08 times in agar-based samples and by 1.06–1.09 times in pectin-based samples, and inhibits microbial contamination of the product's surface. Besides, it has been established that the most practical proportion of *Magnetofood* is 0.15% of the recipe mixture weight, and when storing moulded marmalade jelly sweets for 90 days, the optimum storage conditions are: relative humidity $\varphi=75\pm 2\%$, temperature $18\pm 2^\circ\text{C}$.

Key words: food additive *Magnetofood*, moulded marmalade jelly sweets, quality characteristics.

innovations in the recipe of this product. The modifications of the recipe are supposed to reduce the product's prime cost, improve its quality, and prolong its shelf life.

A problem of special importance is the year-to-year rise in raw material prices. Regretfully, this is the case of pectin and agar, the two main gelling agents traditionally used in the technology of moulded marmalade jellies. Both of these ingredients are expensive raw materials. Thus, in the period from the start of 2014 to the end of 2016, the prices of agar and food pectin rose by 3.5–4.0 times on average. This makes it a topical task to search for new domestic raw material sources that could reduce the production cost

of jellies and marmalade sweets (in particular, moulded marmalade jellies) without affecting their quality [3-6].

To stabilise the gelatinous structure of jellies and marmalade products, be able to process raw materials with different properties, and obtain storable quality products, it is promising to use various food-improving additives, in particular, nanometre-sized agents [1,2,7].

Analysis of recent research and publications

Confectionery manufacture is a branch of production most actively using food additives, stabilisers, etc. in the production technology. Numerous researchers are trying to find inexpensive structurants supposed to improve the structural, mechanical, physicochemical, and sensory characteristics of gelatinous masses and final products. Besides, scientists are looking for ways to replace, partly or fully, the traditional gelling agents, in particular, agar, pectin, and gelatine [4-30].

Development of innovative technologies of jellies and marmalade confectionery has been considered by such leading confectionery experts as V. Pertseva [4], K. Iorgachova [5], A. Dorokhovich [6], Yu. Kambulova [8], D. Gawkowska [9], N. Sanzharovskaya [10], Y. Yang [11], X. Zhang [12], A. Salieva [13], and others.

To improve the structural and mechanical properties of gelatinous masses and the consumer properties of jellies and marmalade confectionery, non-traditional raw materials are used. They include food production waste (from canning, winemaking, and sugar-beet processing industries) and agricultural waste (from seed farms, cotton farming, and melon cultivation) [14-16], alternative raw materials, like chitosan, vegetables, fruit, and other plants, in particular, purées from dates, feijoa, kiwi, and Jerusalem artichokes [17,18], extracts and powders obtained from aromatic herbs [19,20] and powdered vegetables, fruit, and berries (these improve the consistency and consumer properties of final products, but their gel structure is not stable enough) [21,22], sorbitol [23], such hydrocolloids as carrageenan with its sodium, potassium, and ammonium salts (including furcellaran), xanthan, tara, guar, and locust bean gums, etc. (they increase the water holding capacity and improve the resilience and elasticity of new products stored for a long time) [4,5,8-10].

Today, to make gel structures more stable, to stabilise colloidal dispersed systems, and to regulate the rheological properties and the mechanostuctural characteristics of jellies, combined systems of structure-forming agents are widely used. They include combinations of gelatine with pectin or with sulphated polysaccharides, gelatine – κ -carrageenan, gelatine – pectin LM [5,7,8], combinations of pectin with hydrocolloids (Herbagen SW-010, Ricogel 8100), pectin LM– κ -carrageenan [7,10], a combination of agar with the animal protein concentrate ScanPro [4,11]. These compositions form a stronger spatial

framework of gel than an ordinary protein stabiliser does.

There have been numerous studies of how modifying additives effect on the structural and mechanical properties of jelly masses. It has been investigated how sodium carboxymethyl cellulose (Na-CMC) and iron chloride increase the gelling power of sulphate polysaccharides [4,7], and how sodium lactate, sodium citrate, and glycerol (in the amount 0.1–0.2% of the total weight) increase the gelling power of polysaccharides, in particular, of red algae (as a result, their content is lower by 35–40%) [10,11, Patent UA 61370. Method of increasing the strength of sulphate polysaccharide gels]. It has also been studied how 0.08–0.09% of mannitol, or sodium alginate, makes jelly mass stronger by up to 40-60% and reduces the expenditure of the structure-forming agent (agar, agaroid, furcellaran) [12,13].

The nanotechnological direction of research is of interest, too. Researchers have investigated how nanoparticles Fe_3O_4 -MgO can be modified with nutmeg essential oil, and nanoparticles γ - Fe_2O_3 with apple pectin, in order to form supermagnetic nanoparticles with antibacterial and antimycotic action to be used as a bactericide [24,25], and how nanoparticles of metals and their oxides can be modified with polysaccharides, plant and animal proteins: ovalbumin, whey protein albumin, gelatine, whey protein, gliadin, proteins of legumes and soya, elastin, zein, milk protein [26,27]. A wide range of functional and technological features allows wide application of nanoparticles in technology, food industry, pharmacy, etc [28].

Magnetofood is a food additive, with the size of its particles within the nanometre range (~80nm) and with a certain functional and technical potential. It has a chemically active surface layer, is amphiphilous, and its ξ -potential is high enough (33-40mV) to make it practical in the technologies of food with a gelatinous structure, including jellies and marmalade confectionery. The food additive *Magnetofood* (FAM) corrects the surface activity of structure-forming agents and influences the effective viscosity of dispersed systems, which is a gel-forming factor. Besides, the FAM has bacteriostatic properties. That is, the additive can correct the physicochemical, sorption, sensory, and microbiological properties of marmalade confectionery and has an effect on the structure-forming agent (pectin, agar, etc.) by interacting with it chemically and electrostatically, thus intensifying its action. *Magnetofood* nanoparticles help the formation of supramolecular structures: monolayers, micelles that stabilise colloidal dispersed systems and form a certain consistency of gels [29,30]. Thus, the food additive *Magnetofood* used as a structurant, stabiliser, and improver in the technologies of jelly products and marmalade confectionery will, in our opinion, allow upgrading the physicochemical, sorption, microbiological, and sensory characteristics of jellies

and marmalade sweets. It will improve their consistency, shape, and surface, reduce syneresis in these products during storage, and extend their shelf life.

However, the effect of nanoadditives, in particular, the food additive *Magnetofood* (Patent UA 126502), on the physicochemical, microbiological, sorption, and sensory characteristics of moulded marmalade jellies needs more research since there is not enough data. All the above makes it so topical a task to study the functional and technological potential of the food additive *Magnetofood* concerning its effect on the quality and freshness retention time of jellies and marmalade confectionery.

Purpose and objectives of the research. The purpose of the paper is to prove how practical the food additive *Magnetofood* is when used in the technology of moulded marmalade jellies, and to improve this technology by using *Magnetofood*. To achieve the purpose, the following **objectives** were set:

- to study the effect of *Magnetofood* on the sensory characteristics (flavour, smell, colour, consistency, shape, and surface) of the test samples of moulded marmalade jellies with agar and pectin;
- to study the effect of *Magnetofood* on the physicochemical characteristics (moisture content, total acidity) of the test samples of moulded marmalade jellies with agar and pectin;
- to research the effect of *Magnetofood* on the sorption characteristics of the test samples of moulded marmalade jellies with agar and pectin during their storage;
- to research the effect of *Magnetofood* on the microbiological parameters of the test samples of moulded marmalade jellies with agar and pectin during their storage.

Research materials and methods

The food additive *Magnetofood*, or FAM (Technical Specifications of Ukraine 10.8-2023017824-001:2018. Food additive based on iron oxides *Magnetofood*), is high-dispersed brown or black powder. The size of its particles is ~80nm. The chemical composition of the FAM includes double iron oxide ($\text{FeO} \cdot \text{Fe}_2\text{O}_3$ or Fe_3O_4) obtained by chemical coprecipitation of salts of ferrous and ferric iron from aqueous solutions in an alkaline medium (Patent UA 126507.53. Method of producing the food additive *Magnetofood*); white sugar (State Standard of Ukraine (DSTU) 4623:2006); food grade agar (Gelagar CT 1.2 by the company B&V, Italy); apple pectin (DSTU 6088:2009); food grade citric acid monohydrate (DSTU 908:2006); food grade sodium lactate (Sodium L-lactate from Sigma-Aldrich, Belgium); various essences (DSTU 4716:2007); various colourants (DSTU 3845-99); starch syrup (DSTU 4498:2005).

The aqueous suspension of the FAM in 3% agar and pectin solutions was obtained by adding a

weighed portion of the FAM to a 5% polysaccharide solution at 55–60°C, stirring it continuously at $n=2.0\text{--}2.2\text{s}^{-1}$ for (5–7)×60s, and then cooling the mixture down to 18–20°C while stirring it continuously at $n=2.0\text{--}2.2\text{s}^{-1}$ [29]. The test samples of agar-based and pectin-based moulded marmalade jelly sweets were prepared, according to basic formulations No. 11 and 49 respectively (see Table 1 and [31]), on the laboratory unit at the Department of Food and Chemical Production in the Ukrainian Engineering Pedagogics Academy [29,30]. The FAM was introduced into the formulations as an aqueous suspension, with the gel-forming agent swelling and dissolving, in the amount 20g, 30g, and 40g per 1000g of the recipe mixture. This is equal, respectively, to 0.1%, 0.15%, and 0.2% of the FAM as compared to the total weight of the recipe mixture [30]. The aqueous suspension of the FAM was added to the solution of the gel-forming agent obtained by its soaking and swelling in cold water at 15–18°C for (50–80)×60s (agar) and (70–90)×60s (pectin). Then the mixture was rested at $t=95\text{--}100^\circ\text{C}$ (for agar) and $t=85\text{--}90^\circ\text{C}$ (for pectin), being continuously stirred ($n=2.0\text{--}2.2\text{s}^{-1}$), for $\tau=(2\text{--}3)\times 60\text{s}$. When the gel-forming agent dissolved completely, the prescribed quantity of sugar and starch syrup (for the agar-based marmalade sweets) was added in order to obtain jelly mass. The mixture was stirred thoroughly for (20–25)×60s (agar) and (10–15)×60s (pectin) while heating it to 95–100°C for agar and to 85–90°C for pectin, with addition of sodium lactate to the pectin-sugar syrup. After the syrup became homogeneous, it was boiled down until the mass fraction of dry matter was $75.0\pm 1\%$ for agar and $76.5\pm 1\%$ for pectin. Then it was cooled down to 55–60°C for agar and to 80–85°C for pectin, with subsequent tempering when diluted colourants, citric acid and essence were added to the formulation and the mixture was stirred thoroughly for (5–7)×60s. The marmalade jelly mass obtained was poured into moulds and cooled down to 25–30°C for further structure formation. The test samples of the moulded marmalade sweets were dried at $52.5\pm 2.5^\circ\text{C}$ for (6–8)×3600s (samples with agar) and (4–6)×3600s (samples with pectin) [29,30].

The sensory parameters (flavour, smell, colour, consistency, structure, shape, surface) were evaluated by the 1 to 5 scale according to DSTU 4683:2006. When assessing the smell of the marmalade sweets, attention was paid to whether there are any or no off-odours. The physicochemical characteristics (total acidity, mass fraction of moisture) and microbiological parameters were studied by standard, commonly used methods [29,30]. The acidity of the test samples of moulded marmalade jellies was determined by titrimetry using phenolphthalein according to DSTU 5024:2008, and the mass fraction of moisture was measured according to the same standard.

Table 1 – Formulations of agar-based and pectin-based moulded marmalade jelly sweets

Raw material	Raw material expenditure per 1000 g of the final product, g							
	Test samples of moulded marmalade jellies							
	With agar				With pectin			
	Sample 1 – reference	Sample 2 – experiment with 0.1% of the FAM	Sample 3 – experiment with 0.15% of the FAM	Sample 4 – experiment with 0.2% of the FAM	Sample 5 – reference	Sample 6 – experiment with 0.1% of the FAM	Sample 7 – experiment with 0.15% of the FAM	Sample 8 – experiment with 0.2% of the FAM
Granulated sugar used as topping	86.6	86.6	86.6	86.6	86.6	86.6	86.6	86.6
Granulated sugar as a jelly component	525.6	524.6	524.1	523.6	718.9	717.9	717.4	716.9
Syrup	262.7	262.7	262.7	262.7	262.7	262.7	262.7	262.7
Agar	10.5	10.5	10.5	10.5	–	–	–	–
Pectin	–	–	–	–	18.0	18.0	18.0	18.0
Citric acid	11.8	11.8	11.8	11.8	12.0	12.0	12.0	12.0
Sodium lactate	–	–	–	–	10.0	10.0	10.0	10.0
Various essences	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Various colourants	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6
Aqueous suspension of the FAM	–	20.0	30.0	10.0	–	20.0	30.0	10.0
Water	100.7	87.7	77.7	97.7	152.3	132.3	122.3	142.3
Final product yield	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0

Storage of the marmalade sweets was modelled using plastic film (HDPE, 15 μ m). 18 hours after the test samples of the marmalade jellies (10⁻²m thick, 2 \times 10⁻²m in diameter) were moulded and cooled down, they were wrapped in the film and kept in the dark in a thermostat (air incubator TP-80-1). The storage conditions were the temperature 18 \pm 3 $^{\circ}$ C and the relative air humidity φ =40–90%, with a step of 10% (the relative humidity φ (%) was measured periodically with a psychrometer VIT-2). The storage lasted 110 days, with the interval of 10 days between strain gauge measurements, and with microbiological tests performed on the 75th and 90th days of storage.

The sorption characteristics of the samples of marmalade sweets under study were measured by the strain-gauge method [29]. When determining the optimum storage conditions, the criterion chosen was whether the marmalade's moisture content is a constant value. In freshly-made moulded marmalade jellies, this parameter is 0.179–0.181kg/kg (DSTU 4333-2004) and depends on the humidity of the environment and on the

storage duration [29,20]. The criterion looks as follows:

$$Q_{\varphi} = \sum_{i=1}^N |W_i - W_3| \rightarrow \min. \quad (1)$$

where N is the number of tests during the storage period, instances;

W_3 is the normative moisture content, which is 0.18kg/kg;

W_i is the current (instantaneous) moisture content value, kg/kg;

φ is the humidity of the environment, %.

The samples of marmalade sweets were selected and prepared for microbiological tests according to State Standard DSTU 7963:2015. The QMAFAnM (quantity of mesophilic aerobic and facultative anaerobic microorganisms) was determined according to GOST 10444.15-94, coliform bacteria according to GOST 30518-97, pathogenic microorganisms (including *Salmonella* bacteria) according to DSTU ISO 6579:2006, yeast and mould fungi according to GOST 10444.12-2013.

Results of the research and their discussion

Table 2 presents the results of sensory analysis of the test samples of moulded marmalade jellies made using different gel-forming agents.

Table 2 makes it clear that at the stage when the gel-forming agent swells and dissolves, adding *Magnetofood*, in the form of aqueous suspension, to the recipe of moulded marmalade jellies improves the product's shape, surface, and consistency. This improvement averages 0.1–0.2 points (agar-based marmalade sweets) and 0.1–0.3 points (pectin-based marmalade sweets). The highest sensory characteristics were those of Samples 3, 4, 7, and 8 (with 0.15% and 0.2% of the FAM, compared with the reference). They were tawny or brandy-coloured, of an even consistency, vitreous and resilient, their shape was regular, sharply defined, with no deformations, their surface was smooth, elastic, and dry, and they had a pronounced pleasant smell and flavour typical of marmalade sweets. According to the organoleptic findings, the optimum content of the FAM is 0.15% of the weight of the recipe mixture. It is not recommended to raise the FAM content up to 0.2%. The better consistency and appearance (shape and surface) of the test samples of marmalade sweets are due to the structure-forming and stabilising action of amphiphilous surface-active nanoparticles of the FAM [29,30].

The moisture is mainly lost when marmalade jelly is poured into moulds and cooled down. This tells on

the quality of marmalade confections. So, the moisture content and acidity are important physicochemical parameters of marmalade sweets. Table 3 presents the data showing how *Magnetofood* effects on the acidity and moisture content of the test samples of moulded marmalade jellies.

The data in Table 3 evidence that when the FAM is added in the amounts of 0.1%, 0.15%, and 0.2% of the recipe mixture weight, it improves the physicochemical characteristics of the test samples of moulded marmalade jellies. Namely, it increases the moisture content in agar-based sweets by 1.15–1.16 times, and in pectin-based sweets by 1.13–1.14 times due to the moisture-binding and moisture retention capacities of the FAM's chemically active nanoparticles [29]. Besides, the additive reduces the total acidity by 1.05–1.08 times (in agar-based sweets) and by 1.06–1.09 times (in pectin-based sweets), due to the FAM's amphoteric properties and sorption of acidic substances on *Magnetofood* nanoparticles, as it slows down the hydrolysis of the main gelling agent (agar, pectin). The reduction in the acidity, though, has almost no effect on the gelation process [30]. Thus, the presence of the FAM in a formulation reduces moisture loss when the products cool down after pouring the marmalade mass into moulds, stabilises the acidity on a lower level, and improves the quality characteristics of moulded marmalade jellies.

Table 2 – Effect of the food additive *Magnetofood* on the sensory characteristics of the test samples of agar-based and pectin-based moulded marmalade jellies

Parameter	Test samples of moulded marmalade jellies							
	With agar				With pectin			
	Sample 1 – reference	Sample 2 – experiment with 0.1% of the FAM	Sample 3 – experiment with 0.15% of the FAM	Sample 4 – experiment with 0.2% of the FAM	Sample 5 – reference	Sample 6 – experiment with 0.1% of the FAM	Sample 7 – experiment with 0.15% of the FAM	Sample 8 – experiment with 0.2% of the FAM
Smell	5.0±0.1	5.0±0.1	5.0±0.1	5.0±0.1	5.0±0.1	5.0±0.1	5.0±0.1	5.0±0.1
Colour	5.0±0.1	5.0±0.1	5.0±0.1	5.0±0.1	5.0±0.1	5.0±0.1	5.0±0.1	5.0±0.1
Flavour	5.0±0.1	5.0±0.1	5.0±0.1	5.0±0.1	5.0±0.1	5.0±0.1	5.0±0.1	5.0±0.1
Consistency	4.8±0.1	4.9±0.1	5.0±0.1	5.0±0.1	4.7±0.1	4.9±0.1	5.0±0.1	5.0±0.1
Shape and surface	4.8±0.1	4.9±0.1	5.0±0.1	5.0±0.1	4.8±0.1	4.9±0.1	5.0±0.1	5.0±0.1

Table 3 – Effect of the food additive *Magnetofood* on the acidity and moisture content of the test samples of agar-based and pectin-based moulded marmalade jellies

Test samples of marmalade jellies	Physicochemical parameters of the test samples of marmalade jellies			
	Mass fraction of moisture, %		Total acidity, °	
	With agar	With pectin	With agar	With pectin
Sample 1 – reference	16.2±0.5	–	18.3±0.4	–
Sample 2 – with 0.1% of the FAM	18.6±0.8	–	17.0±0.3	–
Sample 3 – with 0.15% of the FAM	18.8±0.9	–	17.4±0.3	–
Sample 4 – with 0.2% of the FAM	18.8±0.9	–	17.4±0.3	–
Sample 5 – reference	–	16.6±0.6	–	18.9±0.5
Sample 6 – with 0.1% of the FAM	–	18.8±0.8	–	17.4±0.3
Sample 7 – with 0.15% of the FAM	–	18.9±0.9	–	17.8±0.3
Sample 8 – with 0.2% of the FAM	–	18.9±0.9	–	17.8±0.3

Analysis of the physicochemical parameters of the test samples of moulded marmalade jellies has shown that the FAM's optimum content is 0.15% of the recipe mixture weight. When the mass fraction of the FAM is further increased to 0.2%, these parameters do not change. This is due to the peculiar properties of nanoparticles, in particular, their large specific and chemically active surface and their ability to produce the required effect even at low concentrations [29,30].

To establish how to store moulded marmalade jellies, the kinetics of sorption of their test samples containing the FAM in the amount 0.15% of the recipe mixture weight has been studied. This proportion of the FAM is the optimum, which has been proved in the earlier studies [30] and confirmed by analysing the sensory and physicochemical parameters presented in this paper. The data from studying the sorption characteristics are shown in Fig. 1 (a, b, c, d).

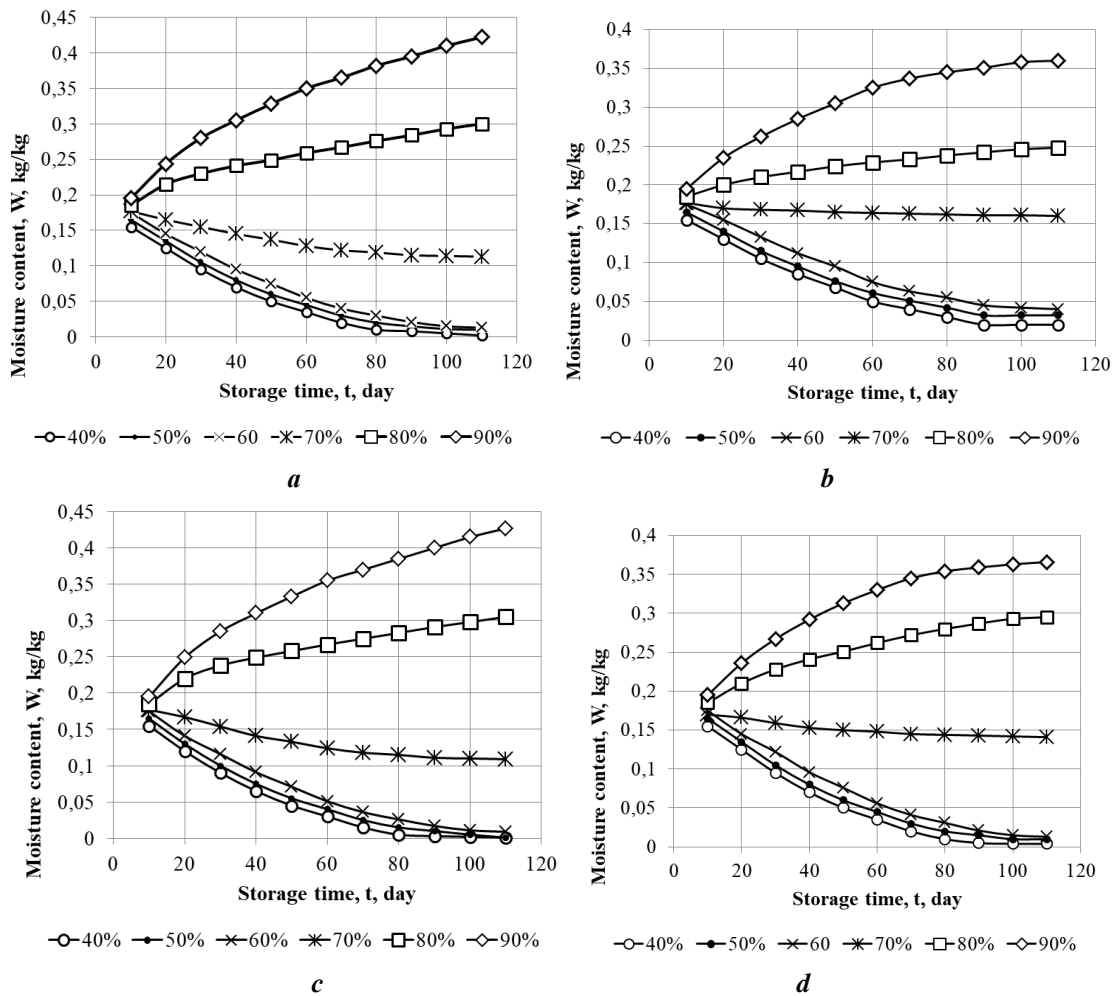


Fig. 1. Kinetics of sorption in the test samples of moulded marmalade jellies at different air humidity: a – reference sample 1 (agar-based marmalade); b – Sample 3 (agar-based marmalade); c – reference sample 5 (pectin-based marmalade); d – Sample 7 (pectin-based marmalade)

Analysis of the curves in Fig. 1 makes it clear that with the relative humidity $\varphi=70-80\%$, during all 110 days of storage, the moisture content changes but slowly in all the marmalade jelly samples under study, which is shown by the respective sorption curves. At $\varphi=75\pm 2\%$, adding the FAM slows down the moisture loss by 11-18% in the agar-based samples and by 10-17% in the pectin-based samples, as compared with the reference samples. The moisture content in the samples of marmalade sweets remains constant throughout the storage period. At $\varphi=90\pm 2\%$, the moisture content of the sweets increases gradually.

When the air humidity is below $70\pm 2\%$, the sorption curves are directed downwards. This indicates that the moisture content becomes lower, the product dries out gradually and loses its sensory qualities: its shape and structure change, and its texture hardens. Comparison with reference samples 1 and 5 shows that the moisture content in Samples 3 and 7 changes more slowly by 1.08-1.1 times (samples with agar) and by 1.04-1.08 times (samples with pectin). This results from the ability of polar *Magnetofood* nanoparticles to bind and hold moisture by forming complexes with water and polysaccharide macromolecules (those of agar, pectin).

Besides, this is due to the FAM's cluster-philic property and ability to form an extra spatial grid that stabilises the dispersed system (this is especially important for agar, which is less stable) [29,30].

Table 4 shows the criterion Q calculated for the samples of marmalade sweets.

The data in Table 4 evidence that using 0.15% of the FAM slows down changes in the criterion Q. In the agar-based samples, Q changes (compared with the normative moisture content at $\varphi=70\%$) by 1.79-3.42 times (Sample 1) and by 1.03-2.87 times (Sample 3). In the pectin-based samples, it changes by 1.66-3.33 times (Sample 5) and by 1.00-2.90 times (Sample 7). Analysis of this criterion allows establishing the

smallest total value by which the moisture content (W_i) of the marmalade jelly samples under study deviates from the standard $W_s=0.180$ kg/kg, with the air humidity being $\varphi=70\%$. The latter is another proof that the temperature and humidity found from the kinetic sorption curves (Fig. 1) are optimal for storing the product: relative air humidity $\varphi=75\pm 2\%$, temperature $18\pm 2^\circ\text{C}$.

The microbiological characteristics of the test samples of moulded marmalade jellies have been studied, too. Table 5 shows the microbial contamination of the surface of the samples: when they are freshly-made and after 90 days of storage at $\varphi=90\pm 2\%$ and $\varphi=75\pm 2\%$.

Table 4 – Criterion Q for the samples of marmalade sweets at the specified humidity of the environment (φ)

Relative air humidity, φ , %	Values of the criterion Q for the samples of marmalade jellies under study			
	Sample 1 – reference	Sample 3 –with 0.15% of the FAM	Sample 5 – reference	Sample 7 – with 0.15% of the FAM
40	1.405	1.257	1.392	1.237
50	1.304	1.139	1.289	1.105
60	1.179	0.990	1.136	0.869
70	0.490	0.480	0.471	0.461
80	0.876	0.492	0.789	0.459
90	1.679	1.378	1.571	1.354

Table 5 – Effect of *Magnetofood* on the microbiological characteristics of the test samples of moulded marmalade jellies

Parameter	Standard (DSTU 4333:2004)	Test samples of moulded marmalade jellies at $\varphi=(90\pm 2)\%$			
		Sample 1 – reference	Sample 3 – with 0.15% of the FAM	Sample 5 – reference	Sample 7 – with 0.15% of the FAM
QMAFAnM, CFU/g: in freshly-made samples/after 75 days of storage/after 90 days of storage	not more than 1.0×10^3	not detected/ $1.0 \times 10^2 / 1.0 \times 10^3$	not detected/ $1.0 \times 10^1 / 1.0 \times 10^2$	not detected/ $2.0 \times 10^2 / 3.0 \times 10^3$	not detected/ $1.0 \times 10^1 / 1.0 \times 10^2$
Yeast, CFU/g: in freshly-made samples/after 75 days of storage/after 90 days of storage	not more than 50	not detected / 5.0 / 8.0	not detected / 2.0 / 4.0	not detected / 6.0 / 9.0	not detected / 2.0 / 4.0
Coliform bacteria: in freshly-made samples/after 75 days of storage/after 90 days of storage	Not allowed in 0.1 g	not detected	not detected	not detected	not detected
Pathogenic microorganisms, including Salmonella bacteria: in freshly-made samples/after 75 days of storage/after 90 days of storage	Not allowed in 25.0 g	not detected	not detected	not detected	not detected
Mould fungi, CFU/g: in freshly-made samples/after 75 days of storage/after 90 days of storage	not more than 50	not detected / 4.0 / 6.0	not detected / 2.0 / 4.0	not detected / 6.0 / 9.0	not detected / 2.0 / 4.0

*At $\varphi=75\pm 2\%$, adding 0.15% of the FAM reduces the microbial contamination of the surface of the marmalade sweets under study: QMAFAnM by 10 times, yeast and mould fungi by 5 times, compared with the reference samples.

From the data in Table 5, one can see that throughout the specified storage period (90 days), the microbiological characteristics of all the test samples of moulded marmalade jellies comply with the regulatory documents, which proves the product's high sanitary and microbiological qualities. Besides, the FAM added inhibits contamination of the surface of the marmalade samples:

– when the test samples of marmalade sweets are stored for 75 days at the air humidity $90\pm 2\%$, the following parameters decrease in Samples 3 and 7, compared with the reference: QMAFAnM by 10 times and 20 times respectively, yeast by 2.5 times and 3 times respectively, mould fungi by 2 times and 3 times respectively;

– when the test samples of marmalade sweets are stored for 90 days at the air humidity $90\pm 2\%$, the following parameters decrease in Samples 3 and 7, compared with the reference: QMAFAnM by 10 times and 30 times respectively, yeast by 2 times and 2.5 times respectively, mould fungi by 1.5 times and 2.5 times respectively.

This is due to the bacteriostatic action of *Magnetofood* [29]. It is also worth mentioning that the reference sample of agar-based marmalade sweets is contaminated to a lesser extent than that of pectin-based sweets, because macroalgae, which are the main source of agar, have more pronounced bactericidal properties.

Conclusion

The results of studying the effect of the food additive *Magnetofood* on the quality characteristics of moulded marmalade jelly sweets have shown that adding it in the amount 0.10-0.20% of the recipe mixture weight has a positive effect on the sensory,

physicochemical, and microbiological characteristics of agar-based and pectin-based moulded marmalade jellies, as compared with the reference. The FAM improves the product's shape, surface, and consistency (by 0.1–0.2 points in agar-based, and by 0.1–0.3 points in pectin-based sweets), increases the moisture content (by 1.15–1.16 times in agar-based, and by 1.13–1.14 times in pectin-based samples) due to the moisture-binding and moisture retention capacity of the FAM's chemically active nanoparticles, reduces the total acidity (by 1.05–1.08 times in agar-based, and by 1.06–1.09 times in pectin-based sweets) due to the FAM's amphoteric properties and its interaction with the acidic substances of marmalade jelly masses.

It has been established that the most advantageous content of *Magnetofood* is 0.15% of the recipe mixture weight, with either gelling agent used (agar, pectin).

It has been found that when storing moulded marmalade jellies, the optimum air humidity is $\varphi=75\pm 2\%$, the optimum temperature $18\pm 2^\circ\text{C}$, and the recommended storage duration is 90 days.

Microscopic studies of the test samples of agar-based and pectin-based moulded marmalade jellies have shown that throughout the specified storage period (90 days), at the relative humidity $\varphi=90\pm 2\%$ and $\varphi=75\pm 2\%$, the microbiological characteristics of all the samples comply with the regulatory documents. This indicates the product's high sanitary and microbiological qualities. It has been proved that introduction of 0.15% of the FAM inhibits microbial contamination of the surface of the test samples of agar-based and pectin-based marmalade jellies.

These findings allow recommending the food additive *Magnetofood* as a stabiliser, structure-forming agent, and improver of gelatinous food systems.

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ВИКОРИСТАННЯ ХАРЧОВОЇ ДОБАВКИ «МАГНЕТОФУД» В ТЕХНОЛОГІЇ МАРМЕЛАДУ ЖЕЛЕЙНОГО ФОРМОВОГО

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Анотація. Розширення й удосконалення виробництва желейно-мармеладних виробів вимагає пошуку спрощеної ресурсо- та енергозберігаючої технології, підвищення стабільності колоїдної дисперсної системи і поліпшення якості готової продукції. Перспективні технологічні застосування мають харчові добавки наномітрового діапазону, завдяки унікальним фізико-хімічним показникам та широкому спектру функціонально-технологічних властивостей. У роботі запропоновано вирішення проблеми стабілізації гелеподібної структури желейних мармеладних виробів і формування їхньої якості шляхом використання харчової добавки «Магнетофуд» (на основі оксидів дво- і тривалентного феруму: FeO-Fe₂O₃). «Магнетофуд» – ультратонкий порошок з розміром частинок ~80 нм, який має високий функціонально-технологічний потенціал: велика питома поверхня, поверхнево активні, комплексотворювальні, сорбційні, стабілізуювальні властивості. Це дозволяє рекомендувати «Магнетофуд» як харчову добавку комплексної дії для підвищення якості та подовження терміну зберігання желейно-мармеладних виробів, зокрема формового желейного мармеладу. Встановлено, що додавання харчової добавки «Магнетофуд» у вигляді водної суспензії на етапі «набрякання-розчинення» гелеутворювача покращує форму, поверхню і консистенцію; збільшує вміст води в 1,15–

1,16 рази в зразках на агарі та в 1,13–1,14 рази в зразках на пектині; зменшує загальну кислотність в 1,05–1,08 рази в зразках на агарі та в 1,06–1,09 рази в зразках на пектині; пригнічує мікробну контамінацію поверхні мармеладних зразків. Крім того, встановлено раціональний вміст харчової добавки “Магнетофуд” – 0,15% від маси рецептурної суміші та оптимальні умови температурно-вологісного режиму під час зберігання формового желейного мармеладу протягом 90 діб: відносна вологість повітря $\varphi=(75\pm 2)\%$, температура $(18\pm 2)^\circ\text{C}$.

Ключові слова: харчова добавка “Магнетофуд”, формовий желейний мармелад, показники якості.

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