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FUNCTIONAL AND TECHNOLOGICAL PROPERTIES OF THE FOOD ADDITIVE *MAGNETOFOOD* IN THE PRODUCTION OF MARSHMALLOWS

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Introduction. Formulation of the problem

Whipped confections have a heterogeneous disperse structure (a polyphase one), that is why it is so important to solve the problem of its stabilisation. Besides, with the fierce competition on the domestic market nowadays, whipped confectionery manufacturers are looking for how to make their products more competitive. The ways to do this include improving the functional and technological characteristics of raw ingredients, making the consumer properties of final products higher, the cost of production lower, and the shelf life longer [1,2].

To stabilise the polyphase structure of whipped products, be able to process raw materials with different properties, and obtain storeable quality products, it is promising to use various food-improving

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Abstract. Production of whipped confectionery (marshmallows, pressed fruit paste, sweets with light-textured centres) is a complex process difficult to control. To expand and modernise their production, it is necessary to find simpler technologies, both resource- and energy-saving, to increase the stability of the heterogeneous dispersed system, and to improve the quality of finished products. In this respect, applying food additives of the nanometer range in technology looks very promising due to their unique physicochemical parameters and their many functional and technological properties. In the paper, it is suggested to solve the problem of stabilising the polyphase structure of whipped confectionery 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 a particle size of ~80 nm. It has a high functional and technological potential: large specific surface and a set of useful properties (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 sugar confections like fruit paste and fruit jelly products, in particular, white and pink marshmallows. 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 shape and consistency, reduces the density of the foam structure by 1.12–1.15 times, reduces the amount of gelling agent by 10–12% for agar and by 7–9% for pectin, increases the mechanical strength of marshmallows by 11.5–12.6% for agar and by 8.2–9.1% for pectin. Besides, the foaming ability of egg white increases by 1.14–1.4 times (with constant foam stability (99±1)% due to the stabilising effect of *Magnetofood* nanoparticles), and the thixotropic property of the gel structure becomes 1.4–1.5 times as much.

Key words: food additive *Magnetofood*, white and pink marshmallow, foam formation, quality characteristics.

additives, in particular, nanometre-sized agents (due to their steady physicochemical parameters and comprehensive effect) [1-3].

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 gel-like and foam-like masses and of final products. Besides, scientists are looking for ways to replace, partly or fully, gelling and foam-forming agents, in particular, agar, pectin, and egg white [4-12].

Development of innovatory technologies of whipped confectionery has been considered by such leading confectionery experts as V. Pertseva [5], K. Iorgachova [7], A. Dorokhovich [8,13], Yu. Kambulova [9,10], I. Sokolovska [14], Yang Y. [15], Zhang X. [16], D. Gawkowska [17], Liang G. [18], and others.

To improve the foam formation and structural and mechanical properties of whipped masses, non-traditional raw materials are used: eggshells [19], processed raw materials of milk production [Patent RU No. 2146473. Marshmallow production method], powdered skim milk and sodium caseinate [17], food production waste (canning, winemaking, and sugar-beet processing industries) and agricultural waste (from seed farms, cotton farming and melon cultivation) [20,21], alternative raw materials, like chitosan, vegetables, fruit, and other plants [22,23], in particular, dates [24], feijoa, kiwi, and Jerusalem artichoke purées [25-27], a blend of gelatine and materials obtained from apples and pumpkins [Patent RU No. 2391855. Method of production whipped composite sweets], a combination of dried ovalbumin and dried wheat gluten [Patent RU No. 2432771. Marshmallow production method], biomodified barley [Patent RU No. 2366257. Marshmallow production method], soya protein isolates [28-30, Patent RU No. 2279229. Marshmallow], sunflower isolates [31,32], linseed extract (its positive effect is explained by the formation of stable protein-polysaccharide complexes comprising egg proteins and linseed mucilage) [33], stevia extract, floral honey, and bran [Patent UA No. 61725. Method of manufacture of marshmallow *Nasoloda*], oat and barley extracts [34], extracts and powders obtained from aromatic herbs and powdered vegetables, fruit, and berries (these improve the consistency and consumer properties of final products, but their foam structure is not stable enough) [34,35], Lamidan (containing sodium alginate) and Cicorlact (containing chicory extract) [Patent UA No. 73692. Marshmallow production method], the dioactive substance Elamin [Patent UA No. 43644. Marshmallow production method], isomaltulose [36], sorbitol [37], such hydrocolloids as carrageenan with its sodium, potassium, and ammonium salts (including furcellaran), xanthan, tara, guar, and locust bean gums (they increase the water holding capacity and improve the resilience and elasticity of new products stored for a long time) [38-41].

Today, to make egg white foams more stable, to stabilise the air-water contact area, and to regulate the rheological properties of jellies and the structural and mechanical characteristics of foam structures, 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 [42,43], combinations of pectin with hydrocolloids (Herbagel SW-010, Ricogel 8100), pectin LM – κ -

carrageenan [39,43,44], a combination of agar with the animal protein concentrate ScanPro [45], β -lactoglobulin – gum arabic, β -lactoglobulin – pullulan, whey protein isolate – gum arabic, ovalbumin – pectin, etc. [46-50]. Interphase films formed by these compositions are stronger than an ordinary protein stabiliser.

There have been numerous studies of how modifying additives effect on the structural and mechanical properties of marshmallow masses. It has been investigated how sodium carboxymethyl cellulose (Na-CMC) and iron chloride increase the gelling power of sulphate polysaccharides [22,42], 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, red algae (as a result, their content is lower by 35–40%) [41,51, 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 marshmallow mass stronger up to 40–60% and reduces the expenditure of the structure-forming agent (agar, agaroid, furcellaran) [42,52].

Researchers pay a lot of attention to improving the functional and technological properties (FTP) of foaming agents, in particular, egg white. Thus, such substances can be added to it as sucrose, lactose, dextrose, and maltose, as well as xanthan, glycerol, sorbitol, or other chemical substances. They increase the viscosity and foam stability of egg white, but lower its foaming power (FP) [53,54]. The works [54,55] prove that metal cations have an effect on the FTP of egg white due to ovotransferrin's interaction with many polyvalent cations, such as aluminium, copper, iron, zinc. With them, it forms complexes with enhanced thermostability. It results in egg white's better FP and higher stability of foam structures. It is established that adding salts of phosphate and citric acids increases the temperature of ovotransferrin denaturation, thus improving the FP of egg white [56].

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 to form supermagnetic nanoparticles with antibacterial and antimycotic action to be used as a bactericide [57], and how nanoparticles of metals and their oxides can be modified with plant and animal proteins: ovalbumin, albumin of serum protein, gelatine, whey protein, gliadin, proteins of legumes and soya, elastin, zein, milk protein [58]. A wide range of functional and technological features allows wide application of nanoparticles in technology, food industry, pharmacy, etc. [59].

However, the effect of nanoadditives (in particular, the food additive *Magnetofood* [Patent UA No. 126502]) on foam formation and gelation when making white and pink marshmallows and on the quality characteristics of the final product needs more research since there is not enough data.

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 polyphase structure, including marshmallows. The food additive *Magnetofood* (FAM) corrects the surface activity of structure-forming agents and influences the effective viscosity of dispersed systems, which is a foam-forming factor. That is, the FAM can correct the structural and mechanical properties of jelly masses and foam structures and has an effect on the structure-forming agent (egg white, gelatine, pectin, agar, etc.) by interacting with it chemically and electrostatically and thus intensifying its action. *Magnetofood* nanoparticles help the formation of supramolecular structures: monolayers, micelles that stabilise polyphase systems and form a certain consistency of gels and foams [11,12,60-63].

Thus, the food additive *Magnetofood* used in marshmallow technologies as a structurant and stabiliser will, in our opinion, allow improving the structural and mechanical properties of marshmallow products. It will increase the dispersion of a foam structure, make it elastic and quickly restituting its shape after being pressed slightly, reduce syneresis in products during storage, extend their shelf life.

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 white and pink marshmallow made with agar and pectin.

The purpose of the research is studying the functional and technological properties of the food additive *Magnetofood* used to manufacture white and pink marshmallows with agar and pectin.

To achieve the purpose, the following **objectives** were set:

- to research the effect of the FAM on the rheological properties of the test samples of aqueous solutions of such structure-forming agents as pectin and agar (their effective viscosity and thixotropic recovery);
- to research the effect of the FAM on foam formation in egg white model systems (foaming power, foam stability, effective viscosity);
- to study the effect of the FAM on the sensory characteristics (flavour, smell, colour, consistency, shape, structure, surface) of the test samples of marshmallows with agar and pectin;
- to study the effect of the FAM on the physicochemical, technological (moisture content, total acidity, density, foam dispersion, duration of whipping), and structural and mechanical (effective viscosity, strength) properties of the test samples of marshmallows with agar and pectin.

Research materials and methods

The food additive *Magnetofood* (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. By its chemical composition, the FAM is a double iron oxide ($\text{FeO}\cdot\text{Fe}_2\text{O}_3$ або Fe_3O_4) obtained by chemical co-precipitation of salts of ferrous and ferric iron from aqueous solutions in an alkaline medium [Patent UA No. 126507.53. Method of producing the food additive *Magnetofood*].

The model systems: gelling agent (pectin or agar)+*Magnetofood*; foam-former (egg white)+*Magnetofood*; suspensions of *Magnetofood* nanoparticles (MNP) in a 3% aqueous solution of high-esterified (HE) pectin, agar, and in a 3 (10)% aqueous solution of egg white. The FAM suspension in the 3% (or 10%) egg white solutions was obtained by adding an estimated amount of the FAM to a 3% (or 10%) egg white solution at 18–20°C, stirring it continuously at $n=2.0\text{--}2.2\text{s}^{-1}$ for (3–5)×60 s, and then resting it for (5–7)×60s [11]. The FAM suspension in 3% agar and HE pectin solutions was obtained by adding a weighed portion of the FAM to a 3% polysaccharide solution at 55–60°C, stirring it continuously at $n=2.0\text{--}2.2\text{s}^{-1}$ for (5–7)×60 s, and then cooling the mixture down to 18–20°C stirring it continuously at $n=2.0\text{--}2.2\text{s}^{-1}$ [60].

Systems modelling the compositions of whipped masses: egg white (10% solution)+*Magnetofood*, egg white (10% solution) + agar or HE pectin (3% aqueous solution) + *Magnetofood* [11]; marshmallow masses with MNP; model samples of white and pink marshmallow with agar and pectin prepared according to basic formulations No. 95 and 126, respectively (see Table 1 and [164]). The FAM was introduced into the formulations as an aqueous suspension, with the gel-forming agent swelling and dissolving in the amount 30 g per 1000 g of the recipe mixture, which is equal to 0.15% of the FAM of the total recipe mixture weight [11,63].

The sensory and physicochemical evaluation of the quality was carried out according to DSTU GOST (State Standard) 6441-2003. The sensory parameters (flavour, smell, colour, consistency, structure, shape, surface) were evaluated by the 1 to 5 scale. The physicochemical, technological parameters (total acidity, density, duration of whipping) and rheological properties were studied by standard, commonly used methods [11,63]. The dispersion (distribution of air bubbles by their diameters) was studied by photomicrography through a monocular microscope Biolam LOMO at 400 magnification by means of a digital camera. The data were processed with the software PhotoM 1.21 [11,63,65]. The strength of the whipped mass was studied at the yield value of shear stress using a penetrometer AP-4/1. The rheological properties were determined with *Rheotest-2* [11]. The foaming power of the test samples of egg white and whipped masses was determined by Lurye's method [65]. Changes in the foam stability were

established by lowering of the foam column with time [3].

Table 1 – Recipes of white and pink marshmallows with agar and pectin made by the traditional technology (control), and of marshmallows with the food additive *Magnetofood* (FAM) (experiment)

Raw material	Raw material expenditure per 1000 g of the final product, g			
	Test samples of white and pink marshmallow			
	With agar		With pectin	
	Sample 1 – control	Sample 2 – experiment with 0.15% of the FAM	Sample 3 – control	Sample 4 – experiment with 0.15% of the FAM
Granulated sugar	673.0	673.0	671.0	671.0
Powdered sugar	29.9	29.9	29.9	29.9
Treacle	139.4	139.4	142.9	142.9
Apple purée	390.0	390.0	298.0	298.0
Egg white	65.0	65.0	65.0	65.0
Agar	8.6	8.6	–	–
Apple pectin	–	–	13.4	13.4
Lactic acid	6.7	6.7	8.4	8.4
Sodium lactate	–	–	6.8	6.8
Various essences	2.0	2.0	2.0	2.0
Red colourant	0.6	0.6	0.6	0.6
Aqueous suspension of the FAM	–	30.0	–	30.0
Final product yield	1000.0	1000.0	1000.0	1000.0

Results of the research and their discussion

Fig. 1 shows the effective viscosity (η) of the aqueous solutions of the test samples “gelling agent + *Magnetofood*” with different amounts of the FAM (per cent of total weight). It can be seen that with the FAM added, the viscosity of all the samples analysed increased in the whole shear stress range $\dot{\gamma}=(1.5-40)\text{s}^{-1}$. For agar, it increased by 1.22-1.27 times, compared to the control, and for pectin, by 1.24-1.29 times. This is explained by the chemical potential of structure-forming cations Fe^{2+} and Fe^{3+} on the surface of *Magnetofood* nanoparticles (MNP), and by the coordination and electrostatic interaction of NPM with polysaccharide macromolecules. As a result, a three-dimensional network is formed. It is build by hydrocolloid molecules structured by *Magnetofood* nanoparticles [11,63].

The rational proportion of the FAM is 0.15%. A further increase in its content has practically no effect on changes in the viscosity of gelling agent solutions.

The thixotropic recovery coefficient of the primary structure of the sample aqueous solutions of gelling agents has been analysed (Fig. 2). The thixotropy coefficient $K_{(\text{thix})}$ has been shown to increase by 1.4–1.5 times with the FAM added to the system (compared to the control). Thus, the thixotropic properties of FAM-containing gel systems have been established. In particular, adding the FAM to aqueous solutions of gelling agents slows down destruction processes by 1.15–1.22 times and accelerates by 8.8–9.2% the recovery of the gel structure after the physical impact. Thus, the structure’s thixotropic ability increases as much as 1.4–1.5 times.

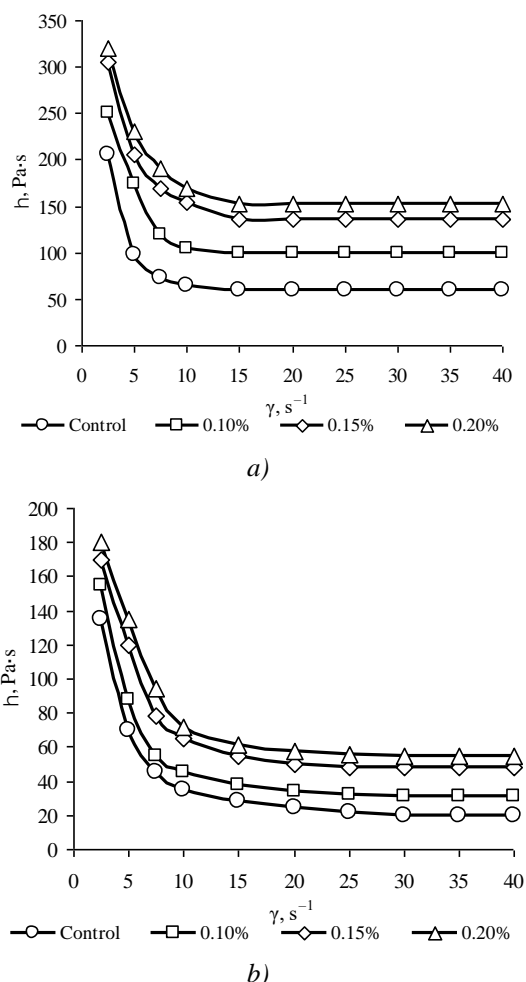


Fig. 1. Dependence of the effective viscosity of gel systems on the concentrations of the FAM:

a – with agar; b – with pectin

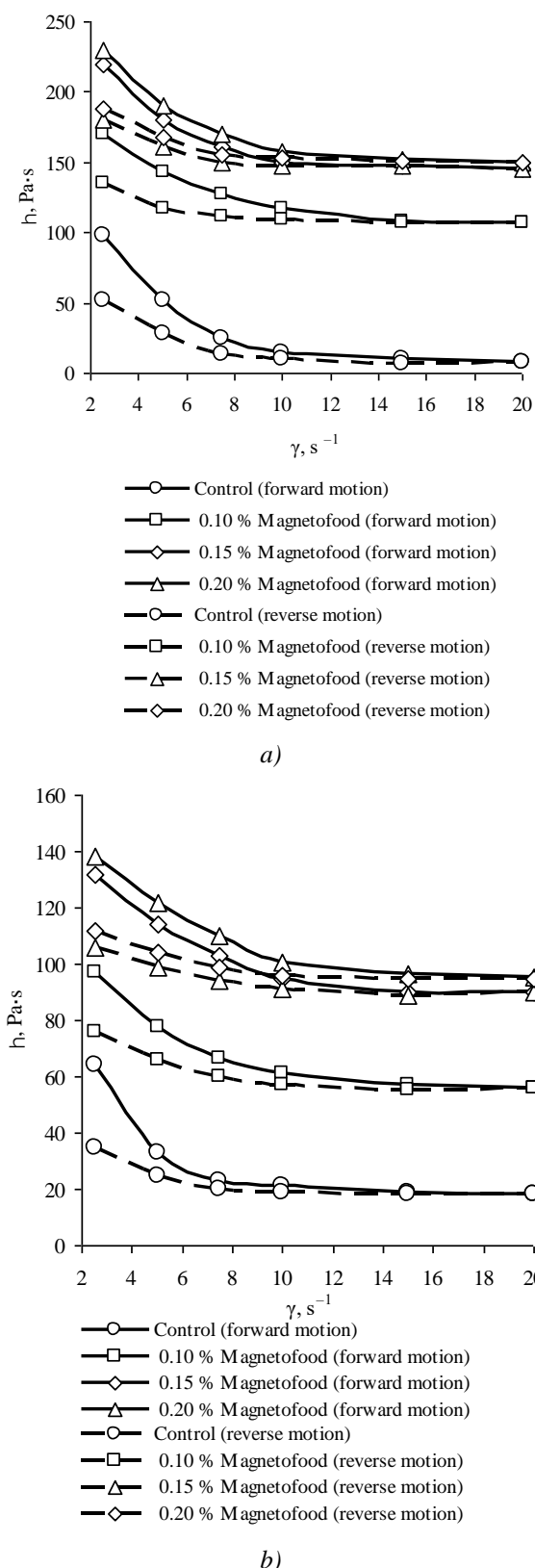


Fig. 2. Dependence of thixotropic recovery of gel systems on the concentrations of FAM:
a – with agar; *b* – with pectin

This is due to the FAM’s surface-active properties and to its ability to form and stabilise a certain

consistency of a dispersed system, thus preventing its disintegration [60,62]. So, studying the rheological properties of aqueous solutions “gelling agent+Magnetofood” with different gelling agents has confirmed the hypothesis that Magnetofood nanoparticles correct these properties of gel systems.

The surface activity and the cluster-philic property of the FAM can reveal itself in its effect on foam formation. So it is reasonable to study the foaming power (FP) (Fig. 3a) by Lurye’s method [65] and the foam stability by lowering of the foam column with time. The model system for the study is “egg white (10% aqueous solution) + Magnetofood” with different FAM amounts (0.10, 0.15, 0.20% of the weight of dried egg white).

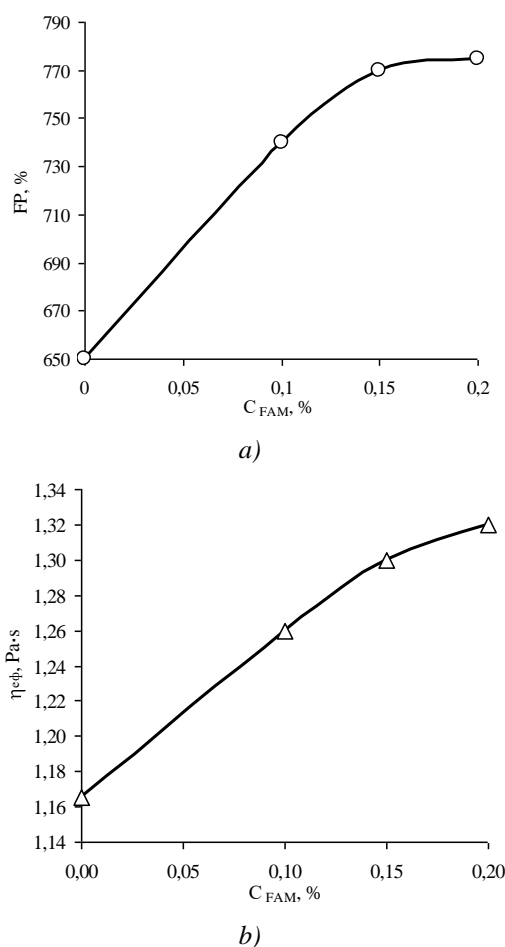


Fig. 3. Dependence of the foaming power (a) and effective viscosity (b) on the FAM concentration in foam systems (with the shear rate $\gamma=4.4\text{s}^{-1}$)

Fig. 3 makes it evident that adding the FAM to egg white increases the FP of the samples analysed by 1.14–1.19 times, compared to the control. This is due to egg white’s lower superficial tension and faster coagulation of protein molecules (acted upon by MNP), which leads to a higher volume concentration of air in the egg white solution and to smaller air bubbles. It has been established that in all the test samples “egg white (10% aqueous

solution) + *Magnetofood*,” the foam stability is $(99\pm 1)\%$. This is because MNP act as stabilisers: the nanoparticles with the chemically active surface present on the phase contact area in the adsorption layer increase the cohesion of protein molecules. As a result, the liquid loses its mobility, its flowing in the film slows down, and this prevents the coalescence of foam bubbles [11]. Besides, the liquid becomes more viscous in the foam films, which slows down their destruction and fixes the foam stability at the level $(99\pm 1)\%$ [11]. It has been found that the effective viscosity of the egg white solution increases by 1.10–1.15 times (Fig. 3b) with the FAM added in the amounts 0.05, 0.15, and 0.2% of the weight of dry egg white. The increase is due to the electrostatic and coordination interaction of MNP with egg white macromolecules and to branching of their main chains.

It has been shown that adding the FAM in the amount 0.05–0.2% of the weight of dry egg white increases the FP in the samples of foam systems “egg white (10% aqueous solution) + gelling agent + *Magnetofood*” (the foam stability of these samples is $(99\pm 1)\%$). This is not only due to correcting the surface activity, but also to the influence of MNP on the effective viscosity of protein systems with agar and pectin (Fig. 4).

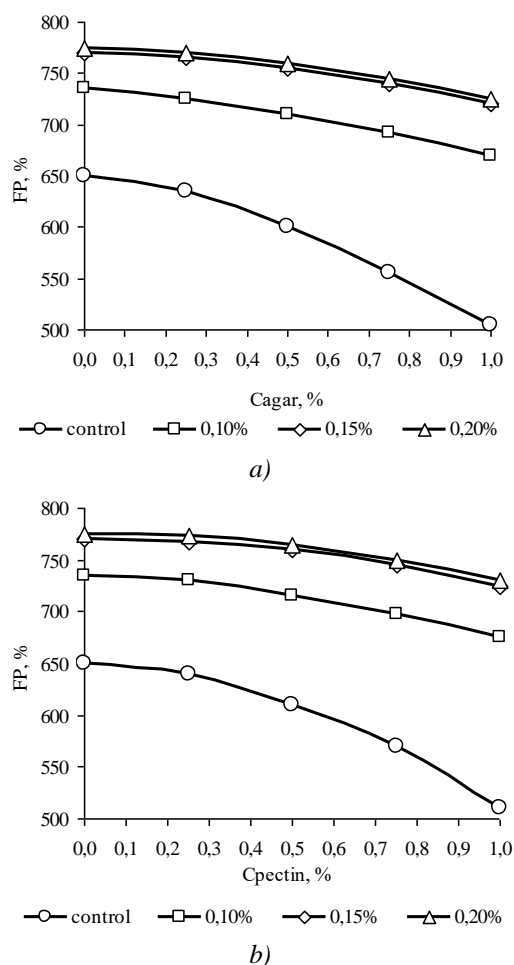


Fig. 4. Dependence of the foaming power of foam systems on the concentrations of the gelling agent and the FAM: *a* – with agar; *b* – with pectin

So, due to the cluster-philic property and interaction of polar MNP with protein and polysaccharide macromolecules, an extra three-dimensional network is formed, which stabilises the dispersed system [11,60,61].

This research into the foaming behaviour (in particular, FP, FS) of the model systems “egg white + *Magnetofood*” and “egg white + gelling agent + *Magnetofood*” proves that the FAM can stabilise foam systems and correct foam formation in the technology of foam-structured foods.

The results of the sensory evaluation of the white and pink marshmallow samples are given in Fig. 5. According to them, the recommended FAM content is 0.15% of the recipe mixture weight.

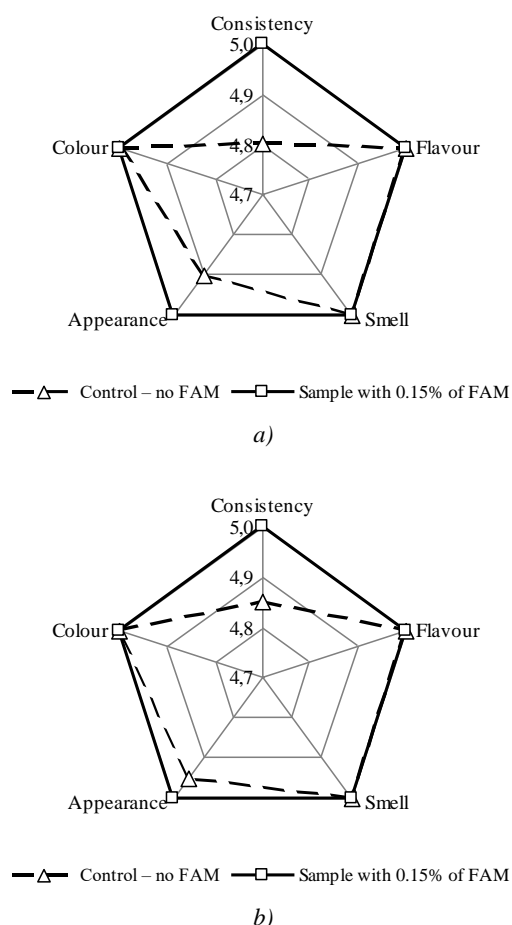


Fig. 5. Sensory characteristics of the test samples of white and pink marshmallow compared to the control: *a* – with agar; *b* – with pectin

Table 2 presents the main physicochemical and technological parameters of the white and pink marshmallow samples with different gelling agents. It is clear that adding the FAM reduces the density by 1.12–1.15 times and shortens the whipping duration by $(1.5–2.5)\times 60$ s, because MNP interact with egg white molecules, and this promotes branching of the main chains of its macromolecules in a dispersion medium and slows down the outflow of the liquid and thinning of the walls of air bubbles.

Table 2 – Physicochemical and technological parameters of the test samples of white and pink marshmallow

Parameter	Test samples of white and pink marshmallow			
	With agar		With pectin	
	Sample 1 – control	Sample 2 – with 0.15% of the FAM	Sample 3 – control	Sample 4 – with 0.15% of the FAM
Moisture content, %	17.0±0.8	17.4±0.8	17.0±0.8	17.5±0.8
Total acidity, degrees	0.7±0.03	0.6±0.02	5.90±0.3	5.30±0.2
Density, kg/m ³ (the minimum value)	545±12	485±8	550±12	480±8
Duration of whipping, τ-60s	16.0	14.0	10.0	8.0
Strength, kPa	9.0±0.5	10.8±0.6	6.5±0.3	7.4±0.4

Table 3 – Dependence of the volume of the test samples of marshmallow masses on the storage duration

Storage period, day	Volume of the test samples of marshmallow masses, cm ³			
	With agar		With pectin	
	Sample 1 – control	Sample 2 – with 0.15% of the FAM	Sample 3 – control	Sample 4 – with 0.15% of the FAM
0	100±5	100±5	100±5	100±5
20	81.7±4	98.2±5	80.4±4	97.2±5
40	76.4±3	93.6±5	75.2±3	92.8±5
60	68.2±2	86.8±4	67.0±3	85.6±5

Besides, the FAM strengthens a foam structure by 1.1–1.2 times due to the cluster-philic property of Magnetofood nanoparticles. This makes the gelling agent more viscous in Gibbs – Plateau channels, and thus slows down syneresis and stabilises the gel framework of a foam structure.

Table 3 presents how the volume of the test samples of marshmallow masses depends on the duration of storage (throughout the recommended period of 60 days).

From Table 3, one can see that with the FAM added, the structure of the samples under study is stabilised due to better foam formation and fixation of air bubbles in the system under the action of MNP. This is confirmed by the distribution of the air bubbles according to their diameter (Fig. 6). So, the FAM increases the dispersivity of air bubbles and their narrower distribution according to their diameter, compared to the control.

Destruction of foam is caused by air diffusion, by flowing of the liquid down the bubble walls (by the viscosity of the liquid), and by enlargement of bubbles due to their coalescence. The peak, quite a narrow one, for the test samples containing 0.15% of the FAM indicates that the marshmallow mass is evenly whipped. Moreover, the higher viscosity of these samples and their lower surface tension make their foam more stable. This means that adding the FAM in the amount 0.15% of the recipe mixture weight, in the form of suspension based on an aqueous pectin or agar solution, stabilises the foam structure of marshmallow masses, in particular, within the storage period provided for by regulations.

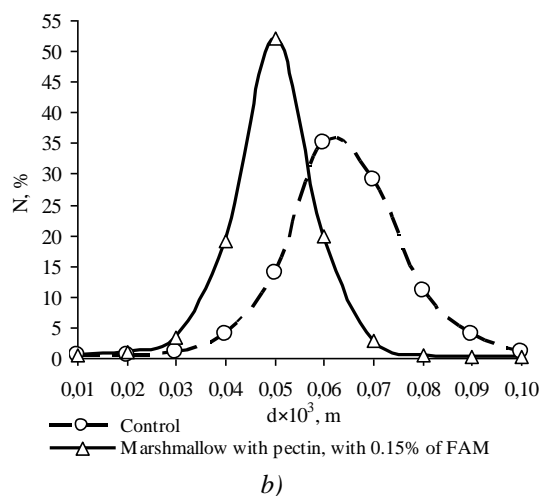
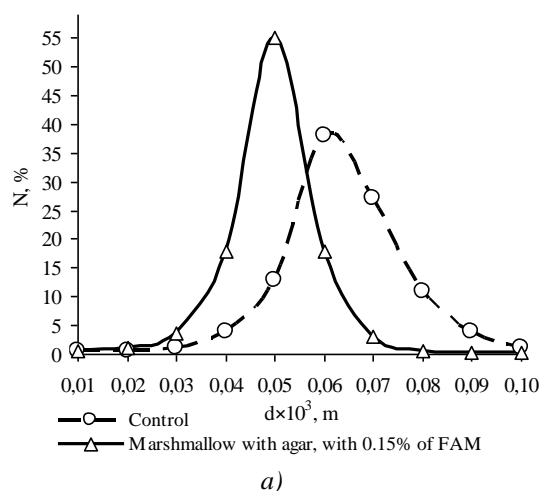
**Fig. 6. Distribution of air bubbles by their diameter in the samples of whipped masses: a – with agar; b – with pectin**

Fig. 7 shows the strength (τ , kPa) of the test samples of marshmallow masses in the course of resting ($\tau \times 60$ s). It can be seen that adding the FAM accelerates gell formation by $(2.0-2.5) \times 60$ s with agar and by $(2.0-2.5) \times 60$ s with pectin, and increases the maximum shear stress by 11.9–12.6% with agar and by 8.2–9.1% with pectin. This is due to the formation of supramolecular associates with the additive's nanoparticles. As a result, the gelation process accelerates, and the whipped mass becomes stronger.

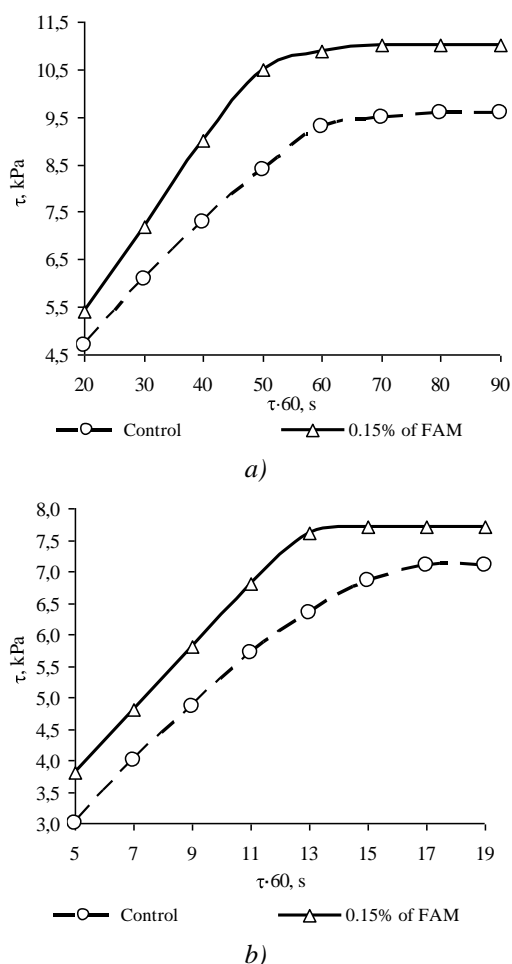


Fig. 7. Dependence of the strength of whipped masses on the duration of resting the test samples:
a – with agar; b – with pectin

An important rheological characteristic of whipped masses is their viscosity. Any change in it causes changes to the coagulation and crystallisation structure of foam, thus influencing the viscosity of the mass. Fig. 8 presents the effective viscosity (η , kPa) of the test samples of marshmallow masses. From it, it is evident that the FAM included in the recipe increases the effective viscosity of marshmallow masses by 1.35–1.55 times, compared to the control. This can be explained by the gelling action of MNP, which leads to coalescence of polysaccharides and greater roughness of their channels. As a result, foam films become more stable, and increased gelling power of pectin and agar allows increasing the viscosity in Gibbs – Plateau

channels, which stabilises the gel framework of the foam structure and slows down syneresis [11].

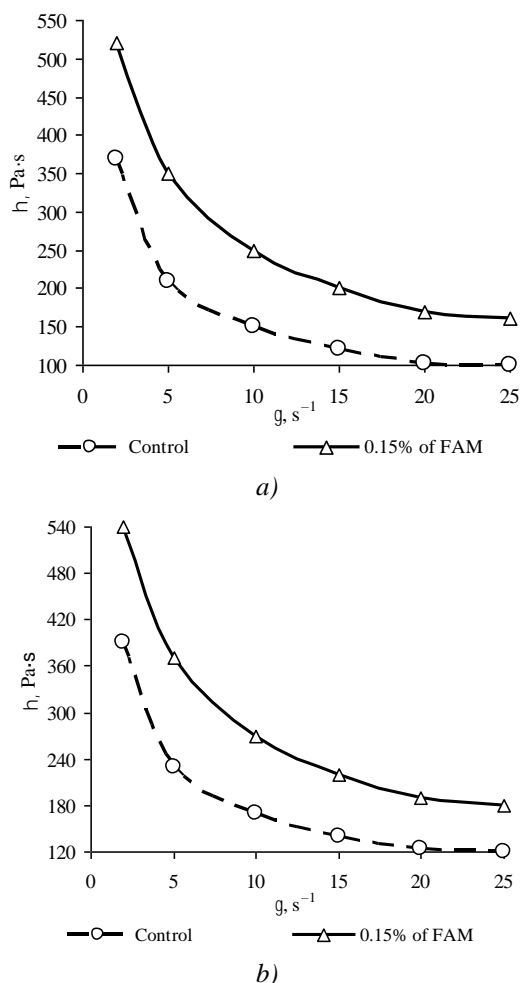


Fig. 8. Dependence of the effective viscosity of the test samples of whipped masses on the shear rate:
a – with agar; b – with pectin

So, the structural and mechanical characteristics of marshmallow masses with different structure-forming agents prove the hypothesis that MNP stabilise their structure and that when the FAM, in the form of aqueous suspension, is added to white and pink marshmallow at the stage of the gelling agent's swelling and dissolution, it allows reducing the amount of the latter by $(11 \pm 1)\%$ for agar and by $(8 \pm 1)\%$ for pectin. Besides, this additive increases the mechanical strength of marshmallow masses by 11.5–12.6% for agar and by 8.2–9.1% for pectin.

Approbation of results

The research results were the topic of laboratory classes for food technology students specialising in foods of plant origin at the Educational and Research Institute of Food Technologies and Business (part of Kharkiv State University of Food Technology and Trade).

Conclusions

The results of studying the effect of the food additive *Magnetofood* on foam formation have shown that adding it in the amount 0.10-0.20%, compared to the control:

- increases the viscosity of aqueous solutions of gelling agents in the whole shear stress range ($\gamma=(1.5-40)\text{s}^{-1}$) by 1.22–1.27 times for agar and by 1.24–1.29 times for pectin;
- slows down the destruction of the gel structure by 1.15-1.22 times, accelerates its recovery after a physical impact by 8.8–9.2%, and increases its thixotropic ability by 1.4–1.5 times;
- increases the foaming power of the egg white test samples by 1.14–1.4 times, with the foam stability

of all the test samples being (99±1)% due to the stabilising action of *Magnetofood* nanoparticles.

It has been established that when the food additive *Magnetofood*, in the form of aqueous suspension, is introduced into white and pink marshmallow at the stage of the gelling agent's swelling and dissolution, it allows improving the shape and texture, on average, by 0.1–0.2 points, reducing the density of the foam structure by 1.12–1.15 times, reducing the amount of the gelling agent by (11±1)% for agar and by (8±1)% for pectin; and increasing the mechanical strength of marshmallow masses by 11.5–12.6% for agar and by 8.2–9.1% for pectin.

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

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ФУНКЦІОНАЛЬНО-ТЕХНОЛОГІЧНІ ВЛАСТИВОСТІ ХАРЧОВОЇ ДОБАВКИ «МАГНЕТОФУД» У ВИРОБНИЦТВІ ЗЕФІРУ

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Анотація. Виробництво збивних кондитерських виробів (зефір, пастила, цукерки зі збивним корпусом) є складним для управління процесом. Розширення й удосконалення їхнього виробництва вимагає пошуку спрощеної ресурсо- та енергозберігаючої технології, підвищення стабільності гетерогенної дисперсної системи і поліпшення якості готової продукції. Перспективними є харчові добавки нанорозміру, завдяки їхнім унікальним фізико-хімічним показникам та широкому спектру функціонально-технологічних властивостей. У роботі запропоновано вирішення проблеми стабілізації поліфазної структури збивних кондитерських 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 ~80нм, який має високий функціонально-технологічний потенціал: велика питома поверхня, поверхнево активні, комплексоутворювальні, сорбційні, стабілізуювальні властивості. Це дозволяє рекомендувати «Магнетофуд» як харчову добавку комплексної дії для підвищення якості та подовження терміну зберігання пастильно-мармеладних виробів, зокрема зефіру біло-рожевого. Встановлено, що додавання «Магнетофуду» у вигляді водної суспензії на етапі «набрякання-розчинення» гелеутворювача покращує форму і консистенцію; зменшує густину пінної структури в 1,12–1,15 рази; скорочує кількість гелеутворювача на 10–12% для агару і на 7–9% для пектину; підвищує механічну міцність зефірних мас на 11,5–12,6% для агару і на 8,2–9,1% для пектину. Крім того, збільшується піноутворювальна здатність яєчного білка в 1,14–1,4 рази (при постійній пінності 99±1)% за рахунок стабілізуювальної дії наночастинок «Магнетофуду» та підвищується здатність гелевої структури до тиксотропії в 1,4–1,5 рази.

Ключові слова: харчова добавка «Магнетофуд», зефір біло-рожевий, піноутворення, показники якості.

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