Formation of the functional and technological properties of the beef minced meat by using the food additive on the nanopowder basis of double oxide of two- and trivalent iron

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Abstract

Introduction. It is investigated the influence of the food additive on the nanopowder basis of double oxide of two- and trivalent iron for the quality and the technological properties of beef minced meat.

Materials and methods. The beef minced meat in which the nanopowder of double oxide of two- and trivalent iron was added in the amount of 0,05–0,15 %. The water – holding capacity and fat-retaining capacity was determined by using a butyrometer and a refractometer; stability of forage emulsions by centrifugation method; the degree of penetration and the marginal shear stress on a tapered plastomer: the stickiness – by the size of the effort of the separating of two surfaces connected by minced meat.

Results and discussion. Due to the large specific volume, protein affinity, bacteriostaticity, high chemical potential and thermal stability of the nanopowder of double oxide of two – and trivalent iron has sorption, complexing, emulsifying, water-holding and fat-retaining capacities. This contributes to the formation of the new functional and technological indicators of minced meat systems and improve the consumer characteristics of the finished products obtained from them.

The introduction of a food additive which is based on a nanopowder of double oxide of two- and trivalent iron in the beef minced meat in an amount of 0,05–0,15% to the meat mass contributes to the improvement of sensory (by 1,0–1,2 points on a 9-point scale) and the functional and technological indicators in comparison with the control: the water-holding capacity increases by 1,1–2,0%; the fat-retaining – by 1,2–2,6 %; the emulsifying capacity – by 1,3–2,0%; stability or stability of minced emulsions – by 1,4–2,1%; it also helps to reduce the level of total microbial contamination from $6{,}2\times10^5$ CFU/g in the control to $(5{,}1–5{,}8)\times10^5$ CFU/g in samples enriched with Fe_3O_4, that is, by 6,5–19,6%. The losses during the heat treatment of the experimental samples of chilled minced meat with the addition of 0,05–0,15% Fe_3O_4 are reduced by 14,4–18,4%.

The rational amount of a food additive on the basis of nanopowder of double oxide of two- and trivalent iron – 0,1% to the mass of meat raw materials is shown.

Conclusion. The food additive on the basis of nanopowder of double oxide of two- and trivalent iron improves the quality and the technological characteristics of the minced meat systems.

Introduction

At present time the increase in the meat quality with the low moisture in particular with PSE i DFD problems dictates the need to improve the existing technologies of meat products which permit the practical and effectively use of the meat formula with the indicated disadvantages. Therefore, the meat industry uses a variety of food additives-improvers: biologically active additives (BAA), enriched with essential micro-elements and probiotic (BAA) [1, 2]; protein formulation [3, 4]; water-retaining agents E450, E452 [3, 5]; acidity regulators: E451, acetic acid, lactic acid, E262 [3, 6]; spices, spice extracts, dextrose, thickeners E412, E410, E415 [5, 6]; amplifiers of taste and aroma E621 [6]; antioxidants – citric, tartaric and ascorbic acid, E316 [6, 7]; natural food colors, in particular, red rice [6]; flavors, in particular, IN [5, 7]; colorants, in particular, $NaNO_3$ [7].

One of the most common additives is glutamic acid E620 and its salts (E621, E622, etc.) without which almost any enterprise in the meat processing industry cann`t do today. These substances are able to enhance the products taste made from meat especially when using the low-grade stock causing a "sense of satisfaction". This property is called the "glutamine effect" [7]. However, food additives of this group do not bear any technological load which is why they are not necessary either [7].

Another group of food additives that are widely used in the meat industry there are the additives to improve the functional and technological indicators of the meat products, in particular, the increase in the water binding capacity (WBC) of the meat and meat products (sodium and potassium alginates [6, 8]; agar, carrageenan [8, 9]; gums: carob, guar, xanthan, konduk [6, 8, 10, 11]; insoluble dietary fibers of the different origin: wheat, soy, oat, pea, apple, citrus [12–14]; citrates [7, 15], food phosphates: pyro, tri- and polyphosphates [7, 8], cellulose, methylcellulose, to arboximethylcellulose [6–8, 13, 14]. However, they impair the quality and reduce the microbiological safety (as a result of high moisture content) and the economic performance of the product (due to the yield increasing and reducing of the finished products cost). Exceeding the recommended amount of phosphates [7, 8] and citrates [7, 13] leads to a loss of the products aroma taste and a pearl luster appears on the cut. The disadvantage of the insoluble dietary fibers [7, 13–14] is the instability of both high and low temperatures in the acidic media and the salts presence. The lack of insoluble dietary fiber [12–14] – lack of antioxidant and antimicrobial action. The need for accurate the alginates dosing [6, 8] makes it difficult to use them in the meat industry.

To improve the emulsifying capacity it is used the food emulsifiers based on fatty acids:fatty acids salts, mono- and diglycerides of fatty acids cetylated fatty acid [6, 7, 17]. However, they do not have an antioxidant effect.

In the meat processing plants for the improving of the nutrition value and the_water-retention capacities it is used the various functional ingredients derived from the industrial by-products (skin, hooves, feathers, offal, etc.). They are used in the form of enriching powdered protein supplements [6, 19].

However these additives are characterized by a narrow focus and do not have a complex effect [19]. In the meat industry for improving of the nutrition value and quality of finished products it is used the natural phytosolids and probiotics [2, 20]. Their disadvantage is the functional properties loss during heat treatment. Nowadays to improve the quality and shelf life of the meat products the dietary supplements with antioxidant and antimicrobial effects of natural origin are used: essential oils, oils and fats [21, 22]. The disadvantages of these additives include the low water-retention capacity and the insufficient yield of finished products [21, 22].

Recently, silver, titanium dioxide and silicon dioxide nanopowders have been used as the polyfunctional food additives [23]. However the use of these additives in food products is very limited, since their functional, technological, microbiological, and physical-chemical parameters have not been studied sufficiently [23]

Thus, the well-known food additives-improvers, as a rule, separately allow to improve the certain functional and technological characteristics, the product quality; slow down the processes of oxidative, microbial damage; lengthen storage time. However, they do not have a complex action.

Therefore, it is relevant in the meat-processing industry to search for and research the food polyplastic additives of the complex action.

For the formation of the necessary functional and technological properties of the meat products can be offered a dietary supplement based on iron oxides “Magnetofood” [Patent UA No. 126502 Food additive “Magnetofood”, 2018, Bul. No. 12, 4 p., Ukrainian Engineering Pedagogical Academy, Kharkov, Ukraine], which is a scientific development of the authors of this research paper. “Magnetofood” is a highly dispersed nanopowder with a particle size of 70 – 80 nm and with a large specific surface and chemical potential [24 – 28]. According to the chemical formulation “Magnetofood” is a double iron oxide ($FeO \cdot Fe_2O_3$ або Fe_3O_4) which was obtained by the using the improved technology that allows to obtain nanoparticles of a given size; adjustment the physical-chemical and functional-technological properties; reduce the process complexity and the cost of the final product [24, 29 – 31]. Due to Fe (II), “Magnetofood” shows the reducing properties and can be used as an antioxidant additive which prevents the fats oxidation and fat-containing products and thereby improves their quality and the period of use [32, 33]. Considered the biological compatibility of the supplement “Magnetofood” with the living organisms and its positive effect on the human body [24, 34] it is possible to use the food additive based on Fe_3O_4 nanopowder (“Magnetofood”) as an additional source of the easily digestible iron [24, 35].

Nanoobjects which include a nanopowder based on Fe_3O_4 iron oxides (“Magnetofood”) have a huge potential and carry a lot of the important fundamental discoveries,the new functional-technological properties and promising technological applications [36, 37].

The nanoparticles interaction of a food additive based on Fe_3O_4 nanopowder (“Magnetofood”) with biopolymers (proteins, proteins, carbohydrates, lipids) it is a complex of the complex chemical reactions. The process of nucleation is nucleation of a new stable phase with an initial metastable phase passes through. The supramolecular organization of “Magnetofood” nanoparticles and the organic matrix structure play an important role. The result is the formation of spatial nanostructures that significantly affect on the functional and technological properties of raw materials and semi-finished products. In food systems such additives in particular, a food additive, based on Fe_3O_4 nanopowder (“Magnetofood”) can show restorative, antioxidant, bacteriostatic, sorption, complexing, emulsifying, water-binding, water-retaining, greasy properties [24, 38–42].

The researchers of VM Pasechny, TA Shugurova, NN Tolkunova and others have devoted their research to the modern directions of the technologies perfection for the meat split-off semifinished products. In numerous scientific publications the innovative approach prospects to the development or the technology improvement of the meat-split semi-finished products are considered both in the aspect of the formation of the formulation with the use of additive- improvers and the technological process improvement [43–47].

Hence, the advanced way of the issue solution of the improving technological, sensory qualities and ensuring their stability and safety, extending the meat products shelf life, in particular, split semis can be used the new food ingredients which designed to perform, as a rule, the several functions at the same time: the structure formers, stabilizers, emulsifiers, antioxidants; to possess bacteriostatic, water-retention and fat-containing capacities [45-47].

Therefore, the research related to the technology improvement of the high-quality meat products with a long shelf life with the food additives of complex action is relevant and well-timed.

Also the unknown effect of the food additive based on Fe_3O_4 nanopowder ("Magnetofood") on the sensory characteristics, the structural and mechanical and functional-technological properties of the meat-split semi-finished products, in particular, the beef mincemeat in the beef steaks technology.

As this research is the integral part of the authors' scientific and practical work for the beef steaks technology improving of a food additive using based on Fe_3O_4 nanopowder (“Magnetofood”), the aim of this work is to research the functional and technological properties of the beef minces by using of the food additives of Fe_3O_4 nanopowder (“Magnetofood”) and determine the rational mass fraction of its addition.

To achieve the aim the following tasks were set:

– to investigate the effect of “Magnetofood” food additive on the heat treatment losses and sensory characteristics of prototypes of chilled beef mince after storage for 24 hours at 5 °C ±1 °C;
– to investigate the influence of “Magnetofood” food additive on the functional and technological properties of prototypes of fresh made and chilled beef mince after storage for 24 hours at 5 °C ±1 °C;
– to investigate the influence of “Magnetofood” food additive on the microbiological indicators of the test samples of fresh made and chilled beef mince after storage for 24 hours at 5 °C ±1 °C;
– to investigate the influence of “Magnetofood” food additive on the structural and mechanical properties of the experimental samples of fresh made beef mince;
– to establish a rational mass fraction of “Magnetofood” food additive in the experimental samples of the beef mince.

Materials and methods

Materials

Object of research: the effect of the food additive based on Fe_3O_4 nanopowder (“Magnetofood”) on the heat treatment losses; the functional and technological (emulsifying, water-binding, water-retention and fat-containing capacities, the stability of beef mince emulsion) and the structural-mechanical (ultimate shear stress, stickiness), and the properties; the sensory and microbiological (the level of total microbial contamination – NMAFAnM, the number of bacteria of the coliform bacterium group – BCBG, bacteria of the genus Salmonella and L. Monocytogenes) the indicators of beef minced meat.

Research subjects:

– sample 1 control is beef mince. For its preparation the meat was taken: prime beef or the first quality. After cleansing and degreasing, the beef was ground on a meat grinder with a diameter of the openings of the output grating of 3 – 4 mm. Then the sample was thoroughly mixed with salt and spices and held for 10 minutes;
– sample 2 is beef mince which was prepared as in sample 1. Only a mixture of the spices, salt and nutrient additive based on Fe_3O_4 nanopowders (“Magnetofood”) was

added to the crushed beef (the amount of the additive was 0,05% relative to the meat raw mass). Then the sample was thoroughly mixed and held for 10 minutes;
- sample 3 is beef mince which was prepared like sample 1. Only a mixture of spices, salt and food additive based on Fe_3O_4 nanopowder ("Magnetofood") was added to the crushed beef (the amount of additive was 0,10% relative to the meat raw mass). Then the sample was thoroughly mixed and kept for 10 minutes.
- sample 4 is beef mince which was prepared like sample 1. Only a mixture of spices, salt and food additive based on Fe_3O_4 nanopowder ("Magnetofood") was added to the crushed beef (the amount of additive was 0,15% relative to the meat raw mass). Then the sample was thoroughly mixed and kept for 10 minutes.

All samples were stored in a vacuum package at a temperature of (5±1) °C for 24 hours, the heat losses were investigated; their emulsifying, water-binding, water-retention and fat-containing capacities; emulsion stability; the rheological characteristics (shear stress, stickiness) are the microbiological (the level of total microbial contamination is NMAFAnM, the number of bacteria of the coliform bacterium group – BCBG, bacteria of the genus Salmonella and L. Monocytogenes) and the sensoryal indicators (appearance, sectional view, consistency, odor and taste).

Food additive based on iron oxides ("Magnetofood") [Patent UA No. 126502 Food additive "Magnetofood", 2018, Bul. No. 12, 4 p., Ukrainian Engineering Pedagogical Academy, Kharkov, Ukraine], which is a scientific development of the authors of this research paper. "Magnetofood" is a highly dispersed nanopowder of brown or black color with a particle size 78 nm. According to the chemical composition of "Magnetofood" is a double ferrous oxide ($FeO \cdot Fe_2O_3$ or Fe_3O_4) obtained by the method of the chemical co-precipitation from aqueous solutions of salts of two- and trivalent ferrum in the alkaline medium.

Methods

In the researches the mince recipe for beef steak was chosen as the basic formula [48].

In the process of performing experimental work the research methods were used which are given in [40, 49, 51].

The heat treatment of the experimental samples of the minced meat was carried out by the frying method in the main way at a frying surface temperature of 150-160°C till the temperature of culinary readiness in the center of the product is reached (85 ± 1) °C.

Losses determination during the heat treatment and sensory parameters of the experimental samples of beef mince

In the inal meat solid products it was researched the finished product yield (FPY) and heat treatment losses (HTL) which was determined as the difference in the case of the initial semi-finished product and the finished product in accordance with the methods [49, 51].

Sensory estimation of the minced meat quality and products made from them was carried out on a 9-point scale in accordance with [40, 49, 50]. To estimate of the minced meat quality from beef and made of meat split products according to sensory indicators, the study samples were taken from the different places of the stuffing mass depending on the volume and from 3 to 7. The appearance of minced meat semi-finished products was determined visually raw and fried. The quality of beef (grinding degree, equability mixing, texture) was determined visually. The smell and taste of minced meat and split meat semi-finished products, as well as fried products made from them, were determined organoleptically at the cut. Moreover, the appearance and smell of the fried products was determined sensory in the hot condition (the product temperature is not lower than 65 °C) and the taste after cooling the product to a temperature of 25–30 °C.

The degree of grinding and equability mixing of the minced meat and also the correctness of split products heat treatment made from them were determined visually in the hot products (the product temperature is not lower than 65 °C), for which each product was cut into four parts (along and across through the middle).

Determination of functional and technological properties of the beef mince prototypes

The water–holding capacity (WHC) was determined by using a butyrometer according to the method [49]. The sample of minced meat portion weighing 4–5 g was thoroughly crushed. The glass rod was uniformly applied to the inner surface of the milk butyrometer which was punched with a stopper and placed narrowly into the water bath at a boiling temperature for 15 min. After that the moisture mass was determined according to the amount of division on the scale of the butyrometer. Water-holding capacity (WHC) of the minced meat (%) was determined by the formula (1):

$$WHC = W - WHLC \quad (1)$$

water-highlighting capacity (WHlC) of the minced meat (%) (2):

$$WHlC = a \cdot m \cdot n^{-1} \cdot 100, \quad (2)$$

W – is the total mass fraction of moisture in the weight,%;
a – is the price of dividing the butyrometer; a = 0,01 cm^{-1};
n – is the number of divisions on the zymometer scale;
m – is the sample weight, g

Fat-retaining capacity (FRC) was determined by using a butyrometer and refractometer according to the method [49]. The MPC was preliminarily calculated and the minced meat weight was found that remained in the oil with an accuracy of ± 0,0001 g. The sample was placed in a tube and dried to a post mass at 150 °C for 1,5 hours. After drying, the sample weighing (2,0000 ± 0,0002) g is placed in a porcelain mortar, 2,5 g (1,6 cm^3) of fine calcined sand and 6 g (4,3 cm^3) α - monobromo-naphthalene are added. The contents of the mortar were carefully ground for 4 minutes and filtered through the folded paper filter.

The investigated solution (3–4 drops) was evenly applied to the lower prism of the refractometer with a glass rod. The prism was closed by fastening the screw. The beam of light was directed with the help of a mirror on the prism of the refractometer, setting the sight tube so that the borders of the intersecting fields (aliada) were clearly visible. Aliada moved until the boundary between the illuminated and the dark fields did not coincide with the intersection point of their limits, counting the index of refraction. At the same time the refractive index of α-monobromonaphthalene was determined. Fat-retaining capacity of forcemeat (FRC) (%) was determined by the formula (3):

$$FRC = g_1 \cdot g_2^{-1} \cdot 100, \quad (3)$$

where g_1 – is the fat mass fraction in the weight after the heat treatment, %;
g_2 – is the same one before the heat treatment, %.

The emulsifying capacity (EC) and **the stability** or **the emulsion stability (ES)** were determined according to the procedure [49, 50]. A portion of ground beef by the weighing

7 g is suspended in 100 cm^3 of the water in a homogenizer at a frequency of 66,6 s^{-1} for 60 s. 100 cm^3 of the sunflower oil are added and the mixture is emulsified in a homogenizer at a speed of 1500 s^{-1} for 5 minutes. Then the emulsion is poured into 4 calibrated centrifugal tubes with a volume of 50 cm^3 and centrifuged at 500 s^{-1} for 10 minutes. It is determined the volume of the emulsified oil. The emulsifying ability (EC) (%) was determined by the formula (4):

$$EC = V_1/V \cdot 100 \quad (4)$$

where V_1 – is the volume of the emulsified oil, cm^3;

V – is the total volume of oil, cm^3.

The emulsion stability (ES) was determined by the heating at a temperature of 80 °C for 30 minutes. and the cooling water for 15 minutes. Then emulsion was filled with 4 calibrated centrifuged tubes in a volume of 50 cm^3 and centrifuged for 500 s^{-1} for 5 minutes. It is determined the volume of the emulsified layer. The emulsion stability (ES) (%) was determined by the formula (5):

$$ES = V_1/V_2 \cdot 100 \quad (5)$$

where V_2 – is the total volume of the emulsion, cm^3

R.M. Salavatulina determined the **WHC**, **FRC** and the stability of the stuffing emulsions (SE) in one weight [49, 51].

The minced meat samples by the weighing 180–200 g, were placed in the hermetically sealed cans № 3, weighed and subjected to the heat treatment with the modes corresponding to the production (cooking at temperatures of 78–80 °C for 1 hour, cooled in the running water to a temperature of 12–15 °C).

The cans were opened the broth and the fat released were transferred into pre-weighted cans. After removing the broth and fat, minced meat was blotted with filter paper and weighed. Buks with broth were placed in a drying cabinet and dried to constant weight at a temperature of 103–105 °C. The mass fraction of moisture released during the heat treatment of minced meat and the water-holding capacity of minced meat were determined. From the cups with the rest of the broth and fat, the fat was extracted in 10–15 cm^3 of solvents, (a mixture of chloroform and ethanol in a 1: 2 ratio). The fat extraction was carried out for 3 to 4 minutes from three to four replicates. Having established the mass fraction of the fat remaining after the heat treatment of minced meat it was calculated the grease capacity. The stability of the stuffing emulsion (% by weight of meat) was determined by the formula (6).

$$SE = (m - m_{b1}/m) \cdot 100, \text{ or } SE = m_b/m \cdot 100, \quad (6)$$

where $m = m_{tk} - m_t$;

$m_{b1} = m - m_b$;

m – mass of minced meat, g;

m_{b1} – mass of broth with highlighted fats, g;

m_b – mass of the bunch of the minced meat after the heat treatment, g;

m_{tk} – mass of tight cans with fork stuffed, g;

m_t – the weight of cans, g

WHC of the minced meat (% to the weight of minced meat) was determined by the formula (7):

$$WHC = ((W - m_{b1} \cdot m_b) / m_{b2} \cdot m) \cdot 100, \quad (7)$$

where W – the mass fraction of moisture in the minced meat, %;

m_b – the mass in the investigated broth, g;

m_{b2} – the mass of the broth investigated with fat, g.

FRC of the minced meat (% to the weight of minced meat) was determined by the formula (8):

$$FRC = F_f - m_{б1} \cdot m_{fb} / m_{б2} \cdot m, \quad (8)$$

where F_f – the fat mass fraction in the minced meat, %;

m_{fb} – the fat body mass in the investigated broth, g.

Determination of microbiological parameters and structural and mechanical properties of test samples of beef minced meat

The list of the microbiological indicators used to control the quality of minced meat was established following the requirements: the number of mesophilic aerobic and facultative anaerobic microorganisms (NMAFAnM, KUO/g); the presence of bacteria in the group of coliform bacterium (BGCB (coliform), in 0,001 g); detection of the golden staphylococci, protein and other pathogenic microorganisms (pathogenic microorganisms including bacteria of the genus Salmonella, in 25 g) [40, 44, 45].

With the structural-mechanical (rheological) properties of the minced meat the degree of penetration (h) and ultimate shear stress (θ_0) on a conical plastomer were determined using a conical identifier [49].

The experimental sample of the beef minced cooking is made of the appropriate consistency and placed in the device cuvette. Align the surface of the experimental sample with the metal ruler so that the minced meat in the cuvette is level with its edges. A cuvette with a prototype set on the table of the instrument and raised up to the touch of the surface with the edge of the cone. Press the start button, turn on the stopwatch and holding the bar at a slight pace lower the cone. As the immersion cone like minced meat fixes the depth of immersion of the corrugated cone through the indicator every minute. Dipping ends in 3–5 minutes as at the end of this time the cone drops to a slight depth which can be practically neglected. The immersion drainage from 180 to 300 s corresponds to the largest period of relaxation of meaty minced meat from the beef used for research.

Fix the magnitude of the angle 2α at the vertex of the cone and the cone constant C (m/kg), the total mass of m_{tot} (kg) of the rod, the mass of the cone (m_{ind}) and the mass of the additional load (m_{ad}) by its presence. It is known that the depth of the immersion of a conical ident (h_{ind}) is equal to the degree of penetration (h) and is a function of the total mass, that is, according to the formula (9):

$$h = h_{ind} = f(m_{tot}), \quad (9)$$

where h_{ind} – depth of immersion of a conical ident, mm;

h – degree of penetration of the prototype, mm;

m_{tot} – total weight of the bar of the cone plastomer, kg

Hence, the estimated value of the mass of goods was determined by the formula (10):

$$m_{tot} = m_{ad} + m_{ind}, \quad (10)$$

where m_{tot} – is the total weight of the bar of the tapered plastomer, kg;

m_{ad} – is the mass of additional load, kg

m_{ind} – mass of cone identor, kg.

For each sample, the boundary shear stress θ (Pa) was calculated for a fixed immersion duration (h) by the formula (11):

$$\theta = K \cdot m/h_2 = K \cdot m_{tot} - m_{ind} / h^2, \quad (11)$$

where m_{tot} – is the total weight of the bar of the tapered plastomer, kg;

m – the weight of the experimental sample, kg;

m_{ind} – the mass of conical identer, kg;

C – the constants of the cone of the ident;
h – the depth of immersion of a conical ident, mm.

The arithmetic mean of the marginal shear stress (θ) for each of the variants (θi) of the experimental sample (i) was determined by the formula (12):

$$\theta = \Sigma\, \theta_i / i, \qquad (12)$$

where θ – is the arithmetic mean value of the marginal strain of displacement, Pa;
θ_i – is the strain of the displacement of the experimental sample of minced beef, Pa
i – the number of samples of the beef minced samples.

The liposynthesis (ρ_o) was investigated on Sokolov-Bolshakov device which was based on the determination effort amount required to separate the two surfaces of the bound (bonded) minced meat that is being investigated. Adhesion or adhesion (Pa) was calculated as the specific force of the normal separation of the plate from the prototype minced meat from the beef by the formula (13):

$$\rho_o = F_o / S_o = 9{,}81 \cdot m / F_o \qquad (13)$$

where F_o – is the separation force, N;
S_o – the geometric area of the plate, m^2;
m – the weight of the load, kg.

Results and discussion

Table 1 and Figure 1 show the of the heat treatment losses and sensory evaluation data of the cooled experimental samples of the beef minced meat.

Table 1
The losses results due to the heat treatment and the sensory parameters of the experimental samples of the cooled minced beef (on a 9 – point scale)

Name of the indicator	The experimental samples of the minced beef			
	Sample 1	Sample 2	Sample 3	Sample 4
The heat treatment losses %	20,6	18,0	17,5	17,4
Appearance	8,0±0,2	9,0±0,2	9,0±0,2	9,0±0,2
Appearance in the sections	8,0±0,2	9,0±0,2	9,0±0,2	8,0±0,2
Consistence	7,0±0,2	8,0±0,2	9,0±0,2	9,0±0,2
Scent and taste	8,0±0,2	9,0±0,2	9,0±0,2	9,0±0,2
Averaged scoring value	7,8±0,2	8,8±0,2	9,0±0,2	8,8±0,2

The analysis of the experimental data in the Table 1 shows that when introducing a food additive based on Fe_3O_4 nanopowders (“Magnetofood”) in the experimental samples of the cooled minced beef the losses amount in their heat treatment is reduced with the increase in Fe_3O_4 content by 14,4–18,4%.

The data given in Table 1 and Figure 1 indicate a positive effect of the adding Fe_3O_4 nanopowders to meat stuffing systems. The sensory parameters of the experimental samples of the cooled minced beef enriched with a food additive based on Fe_3O_4 nanopowder (“Magnetofood”) are improved. The average scoring value for the sensory parameters increases by 1,0–1,2 points in comparison with the control.

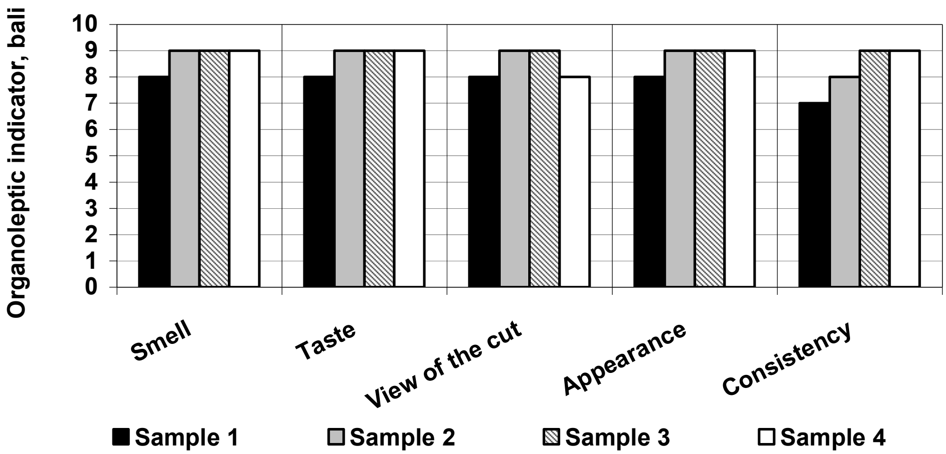

Figure 1. Sensory indicatory quality of the experimental samples of cooled minced beef

The introduction of a nutritional supplement based on Fe_3O_4 nanopowder ("Magnetofood") and its ability to the electrostatic and coordination interaction with proteins of meat forages systems leads to the changes in the moisture content of the experimental samples and the water-retaining capacity of minced meat and consequently changes in the heat treatment losses whose the value decreases with increasing Fe_3O_4 content [29]. The optimum mass fraction of Fe_3O_4 additives which provides the best sensory characteristics of meat sausages and less heat treatment losses is 0,10 %.

The water-holding (WHC) and fat-retaining (FRC) capacity causes the product properties to store in it the prescribed amount of moisture and fat in the cooking process. Therefore, these characteristics are the main functional and technological properties of the meat forages systems. In the heat treatment process of the meat cut trunks and the physical and chemical changes of the ingredient composition occur. The part of moisture and fat are separated in the form of bouillon-fatty flushes which shows the result in the mass loss. As part of the finished product the moisture and fat retained and the amount determines the moisture and fat-retaining capacity of minced meat [28].

Table 2 presents the main functional and technological properties of the experimental samples of beef minced meat: WHC and FRC and the emulsifying capacity (EC), emulsion stability (ES) when adding the additive based on Fe_3O_4 nanopowder ("Magnetofood") compared to control.

In the experimental samples of freshly prepared beef minced there is a gradual increase in WHC, FRC, EC, ES with an increase in Fe_3O_4 mass fraction in comparison with the control sample: WHC is increased by 1,1–2,0%; FRC by 1,2–2,6%; EC by 1,3–2,0%; ES by 1,4–2,1%.

The similar dynamics changes in these indices and in the experimental samples of cooled minced meat in 24 hours of their storage at 6 $^{o}C \pm 1\ ^{o}C$ only in all cases their value is lower by 1,3%–2,0% compared to freshly prepared beef minced meat. The best result is obtained with Fe_3O_4 mass fraction of 0,10%. Further increase of Fe_3O_4 to 0,15% practically does not affect the indicators change.

Table 2

Functional and technological properties of freshly prepared and the cooled beef minced meat after storage with the addition of a nutritional additive based on Fe_3O_4 nanopowder ("Magnetofood") in comparison with the control sample

Name of the indicators		The experimental samples			
		Sample1	Sample2	Sample 3	Sample 4
WHC, %	freshly prepared beef minced meat	76,3±0,9	77,2±0,9	77,6±0,9	77,7±0,9
	in 24 hours of the storage at 6±1 °C	75,3±0,9	76,7±0,9	77,1±0,9	77,2±0,9
FRC,%	freshly prepared beef minced meat	72,1±0,7	73,3±0,8	73,8±0,9	73,9±0,8
	in 24 hours of the storage at 6±1 °C	71,6±0,7	72,7±0,8	72,9±0,9	73,0±0,8
EC,%	freshly prepared beef minced meat	78,2±0,9	79,2±0,9	79,5±0,9	79,8±0,9
	in 24 hours of the storage at 6±1 °C	77,2±0,9	77,9±0,9	78,3±0,9	78,4±0,9
ES,%	freshly prepared beef minced meat	80,2±0,8	81,3±0,8	81,6±0,9	81,7±0,8
	in 24 hours of the storage at 6±1 °C	79,2±0,8	79,9±0,8	80,2±0,9	80,3±0,8

The surface-active, sorption, complexing properties of the ionized nanoparticles of a food additive based on Fe_3O_4 nanopowder ("Magnetofood"), its catalytic activity, heat treatment stability, bio-affinity of the main component of "Magnetofood" – Fe_3O_4 nanoparticles with a lot of proteins determine the emulsifying, wetting, wet and fat-retaining capacity of "Magnetofood" [39]. Therefore, the introduction of the additive "Magnetofood" to meat minced meat increases the level of moisture and fat content and the formation of stable emulsions, in particular, with the lipid and protein components of meat sausage systems.

On the sanitary well-being of meat minced meat enriched with a food additive based on Fe_3O_4 nanopowder ("Magnetofood") were judged by the microbiological parameters in accordance with [40, 44, 45]. The microbiological characteristics of freshly prepared (*) and cooled beef minced meat (**) were researched after storage at a temperature of – 5 °C ± 1 °C for 24 hours. The data obtained are presented in Table 3.

It can be seen from Table 3, the level of general microbial contamination of both freshly prepared minced meat and those stored for 24 hours at a temperature of – 5 °C ± 1 °C did not exceed the permissible levels and was: after the end of the technological process and cooling $5,0 \times 10^4$ CFU/g – in all prototypes; and after 24 hours of storage – $6,2 \times 10^5$ CFU/g in the control and $(5,1–5,8) \times 10^5$ CFU/g in the samples enriched with Fe_3O_4 thate is, on 6,5–19,6% less than in the control sample. In this case in all experimental samples bacteria of the group of intestinal sticks (BGIS) in 0,001 g, bacteria of the genus Salmonella and L. Monocytogenes were not detected in 25 g.

Table 3

Microbiological characteristics of the fresh and cooled beef minced meat with the addition of a food additives on the basis of the Fe_3O_4 nanopowder (“Magnetofood”) compared to the control

The experiment al samples	(NMAFAnM, CFU/g)	BGIS, in 0,001 g	Salmonella, in 25 g	L. Monocyto-genes, in 25 g
*Sample 1	$5,0\times10^4$	missing in 0,001 g	missing in 25 g	missing in 25 g
**Sample 1	$6,2\times10^5$	missing in 0,001 g	missing in 25 g	missing in 25 g
* Sample 2	$5,0\times10^4$	missing in0,001 g	missing in 25 g	missing in 25 g
** Sample 2	$5,8\times10^5$	missing in 0,001 g	missing in 25 g	missing in 25 g
* Sample 3	$5,0\times10^4$	missing in 0,001 g	missing in 25 g	missing in 25 g
** Sample 3	$5,2\times10^5$	missing in 0,001 g	missing in 25 g	missing in 25 g
* Sample 4	$5,0\times10^4$	missing in 0,001 g	missing in 25 g	missing in 25 g
** Sample 4	$5,1\times10^5$	missing in 0,001 g	missing in 25 g	missing in 25 g
Standard	1×10^6	not allowed	not allowed	not allowed

Note. * – *fresh beef minced meat*
** – *cooled beef minced meat*

Reducing of the total microbial contamination in the cooled meat minced meat indicates the bacteriostatic effect on the food additive based on Fe_3O_4 nanopowder (“Magnetofood“). The obtained data also indicates that the meat minced from the beef enriched with “Magnetofood” when stored in a refrigerated state for 24 hours, complied with the requirements of the microbiological standards established for this type of product [40, 44, 45].

The most complete picture of some essential aspects of the quality of meat stuffings is the physical properties that depend on the biological and chemical composition (formulation) and the internal structure (product structure). Minor changes in these defining characteristics should cause the significant changes in the properties values that are registered by devices. At the same time the characteristics of the meat raw materials determine the main indicators of finished products. One of the groups of such indicators include structural – mechanical (rheological) properties.

Table 4 shows the results of determining the depth of immersion and (or the degree of penetration), h and the marginal displacement stress, θ^0.

From the experimental data of Table 4 it follows that with the increase in the angle of the cone, the marginal shear stress (θ^0) decreases for all experimental samples of the minced meat. At the same time θ^0 in the experimental sample of 3 meat minced with a food additive based on Fe_3O_4 nanopowders (“Magnetofood”) in the optimum amount of 0,10 % by the meat weight is less than 26 % on average than in the control sample minced without Fe_3O_4. This indicates a softer and tender consistency of the beef minced with the addition of a nutritional supplement based on Fe_3O_4 nanopowders.

When forming a monolithic structure of the crushed meat the index of stickiness or adhesion (Ro) is the great importance [25, 28]. The research of stickiness for example, the sausage minced allows you to determine the optimal time of rubbing. Similarly in the state of the meat surface it is possible with a certain plausibility to assess its water-holding capacity. Stickiness is associated with other phenomena and products properties: adhesion, cohesion, viscosity and surface friction [48, 51].

Table 4

Structural – mechanical properties of the beef minced meat with the addition of the food additive based on Fe_3O_4 nanopowder ("Magnetofood") compared with the control.

The angle of the cone *α*, deg.		Load *F*, H	Depth of immersion *h*, mm		Average depth diving *h* av. mm		Tensile displacement of the experimental samples of the beef minced meat θ_0, Pa "A"/ "B"				
			Sample 1 or "A"	Sample 3 or "B"	"A"	"B"	$C_{\alpha 1}$	$C_{\alpha 2}$	$C_{\alpha 3}$	$C_{\alpha 4}$	$C_{\alpha 5}$
30°	1	0, 25	4,65	4,25							
	2	0, 25	4,70	4,20	4,70	4,20	12,5 /9,5	12,0 /9,0	11,5 /8,5	11,8 /8,9	12,2 /8,4
	3	0, 25	4,75	4,30							
60°	1	0,15	4,20	3,25							
	2	0,15	4,15	3,20	4,15	3,20	7,5 /6,0	7,0 /5,8	6,5 /5,3	6,8 /5,7	7,4 /5,6
	3	0,15	4,25	3,15							
**	1	0, 50	12,90	9,65							
	2	0, 50	12,85	9,70	12,85	9,70	16,5 /11,0	16,0 /10,5	15,5 /10.0	15,8 /10,4	16,2 /10,3
	3	0, 50	12,80	9,75							

***Note.** ** – thin core; sample 1 or "A" is the control sample of the beef minced (without "Magnetofood"); sample 3 or "B" is the sample of the beef minced with the addition of a rational quantity of "Magnetofood"– 0,10%; C_α is the value of the constant of the cone for the different angles of the cone (30°/60°): ($C_{\alpha 1}$ = 1,110 0,415 – P. A. Rebinder; $C_{\alpha 2}$ = 0,959/0,214 – M. M. Agranat, M. F. Shirokov; $C_{\alpha 3}$ = 0,456/0,164 – V.O. Aret, O.N. Pirogov, $C_{\alpha 4}$ = 0,663/0,213 – A. V. Gorbatov, V. D. Kosoy.; $C_{\alpha 5}$ = 0,976/0,210 – V. D. Karpichev, V.D. Kosoy.

The results of the research of stickiness content of the beef minced meat with the addition of a nutritional additive based on Fe_3O_4 nanopowders ("Magnetofood") as compared to the control are given in Table 5 and Figure 3.

Table 5

The stickiness of the beef mince with the addition of a dietary additive based on Fe_3O_4 nanopowder ("Magnetofood") compared with the control

The experimental samples of the beef mince	Contact pressure, $R_к \times 10^{-4}$, Н/м^2	Stickiness, $R_o \times 10^{-4}$, Pa
Sample1-control	0,80	0,60
Sample 2	0,86	0,75
Sample 3	0,92	0,80
Sample 4	1,29	0,85

The analysis of data in Table 5 and Figure 2 shows that the use of beef minced meat on the basis of Fe_3O_4 nanopowder by helping to increase the stickiness content of meat minced meat at $(0,15–0,25)\times10^{-4}$ Pa. Moreover with the increase in the mass fraction of the additive on the basis of Fe_3O_4 nanopowder ("Magnetofood") the stickiness of the meat mints increases in 1,16–1,42 times compared with the control sample.

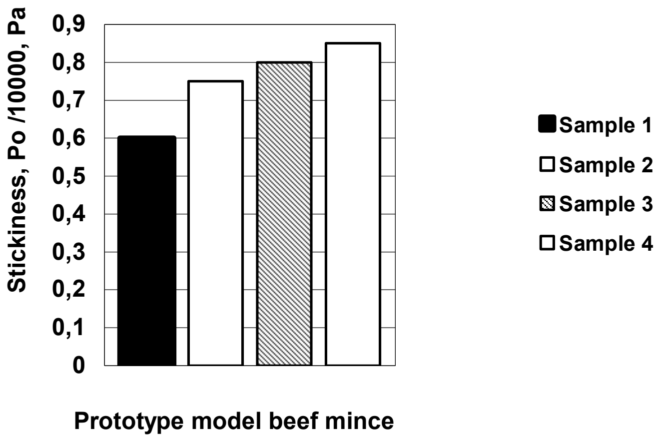

Figure 2. The influence of nutritional additive based on Fe_3O_4 nanopowder (“Magnetofood”) on the stickliness of the experimental samples of the beef minced meat

This is probably due to the intracellular enzymes activation as a result of the interaction of the ionogenic groups of their proteins with polarized Fe_3O_4 nanoparticles and the formation of the “biopolymer matrix of the enzyme – the nanoparticle of the magnetofoot (Fe_3O_4)” [38, 39].

The complex of the structural and mechanical indicators of the crushed raw material is the information that objectively characterizes the consistency features and is in the close correlation with the specific sensory perception of the latter in the process of disintegration and plasticization of the product in the oral cavity.

The results of research of the nutritional supplement influence on the basis of Fe_3O_4 nanopowder (“Magnetofood”) on the ultrasound WHC, FRC, EC, ES and on the stickliness of the beef minced meat indicate that the effective action of Fe_3O_4 additive nanoparticles is based on the technological characteristics of the meat filling systems.

The investigated technological properties of the beef minced meat make it possible to consider the rational mass fraction of a food additive on the basis of Fe_3O_4 nanopowder (“Magnetofood”) of 0,10 % to the meat mass.

Conclusion

The results of the sensory analysis of beef minced meat with the addition of the food additive based on Fe_3O_4 nanopowder (“Magnetofood”) showed the improvement in the sensory characteristics of the experimental samples of the beef minced meat – the average score for sensory indicators increased by 1,0–1,2 points compared to the control.

The losses reduction during the heat treatment of chilled minced meat with addition of 0,05 – 0,15% Fe_3O_4 by 14,4–18,4% was established due to the ability of Fe_3O_4 nanoparticles to the electrostatic and coordination interaction with proteins of the minced meat systems [29, 39, 40]. This leads to a change in the moisture content in the experimental samples of the beef minced meat for the increasing in the water-holding capacity of minced meat and better distribution and content of H_2O and, as a result, a decrease in losses during the heat treatment.

It is proved that the addition of 0,05–0,15% to the food additive on the basis of the Fe_3O_4 nanopowder ("Magnetofood") has a positive effect on the functional and technological properties of minced beef. In particular, in the experimental samples of the fresh minced meat there is a gradual increase in all functional and technological indicators with an increase in the mass fraction of Fe_3O_4 compared to the control: the WHC increases by 1,1% – 2,0%; FRC – 1,2–2,6%; EC – 1,3–2,0%; ES – 1,4–2,1%.

Similar dynamics and in the experimental models of the chilled beef from beef after 24 hours of storage at 5°C ±1 °C only in all cases of their value dropped by 1,3% to 2,0% compared to freshly prepared minced meat.

This is probably due to the surface-active sorption, the complex-forming properties of ionized nanoparticles of the food additive "Magnetofood", as well as its affinity with protein molecules [39, 40]. Therefore, the introduction of the food additive based on Fe_3O_4 nanopowder ("Magnetofood") to the minced meat increases the level of moisture and fat and the formation of the stable minced emulsions, in particular, with the lipid and protein components of minced meat systems.

The microbiological characterization of prototypes of the chilled beef from beef showed that the introduction of food additives on the basis of the Fe_3O_4 nanopowder ("Magnetofood") in the amount of 0,05–0,15% by weight of the meat after 24 hours storage reduces the level of total microbial contamination from $6,2 \times 10^5$ CFU/g in control to $(5,1 – 5,8) \times 10^5$ CFU/g in the samples enriched "Magnetofood", that is, 6,5–19,6%.

The positive influence of the dietary additives on the basis of Fe_3O_4 nanopowder ("Magnetofood") on the structural and mechanical properties of the minced meat from beef:

1) the shear stress reduction limit to 26% compared to the control sample, i.e. the beef minced meat with the introduction of the food additive Fe_3O_4 has a softer and gentler consistency than the control;

2) the stickiness increasing of the minced meat by $(0,15–0,25)\times10^{-4}$ PA. Moreover, with the mass fraction increase of Fe_3O_4 nanopowder ("Magnetofood") stickiness of the minced meat increased 1,16–1,42% compared to control.

This is probably connected with the activation of intracellular enzymes due to their interactions of ionogenic groups of the components of the minced meat with the polarized nanoparticlesof the food additives on the basis of the Fe_3O_4 nanoparticles ("Magnetofood") and the formation of complexes "boolen matrix enzyme – Fe_3O_4 nanoparticles" [38, 39].

The rational mass fraction of food additives on the basis of Fe_3O_4 nanopowders ("Magnetofod") is established, which provides the best complex of technological properties of forage systems and the smallest losses in heat treatment, it is 0,10% to the mass of meat.

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