Comprehensive analysis of food production efficiency using nanoparticles of nutritional supplements on the basis of oxides of two and three valence iron "Magnetofood"

Olena Kruhlova[1], Tetiana Yevlash[1], Victoria Evlash[1], Iryna Tsykhanovska[2], Volodymyr Potapov[1]

1 – Kharkiv State University of Food Technology and Trade, Kharkiv, Ukraine
2 – Ukrainian Engineering and Pedagogical Academy, Kharkiv, Ukraine

Keywords:

Innovation
Nanoparticles
Magnetofood
Food
Quality
Efficiency

Article history:

Received 26.09.2018
Received in revised form 29.11.2018
Accepted 31.05.2019

Corresponding author:

Iryna Tsykhanovska
E-mail: cikhanovskaja@gmail.com

DOI: 10.24263/2304-974X-2019-8-2-17

Abstract

Introduction. The complex analysis of the estimation of the efficiency of the new food product using the nanoparticles of the food additive "Magnetofood" on the basis of two and three valence iron oxides is presented.

Materials and methods. Food products made with the use of nanoparticles of two and three valence iron oxides "Magnetofod" (Fe_3O_4) were investigated using standard and commonly used methods of experimental studies (organoleptic indicators for a 5-point scale; moisture and fat removal capacity using a butyrometer and a refractometer; output the finished product for the difference of masses), expert analysis.

Results and discussion. The conducted researches indicate that the introduction of scientifically grounded food products with nanoparticles will allow to produce competitive products. The nutritional supplement "Magnetofood" has a significant functional and technological potential (sorption, antioxidant, bacteriostatic, emulsifying, stabilizing, foaming and gelling, water and fat-binding, water and fat-retaining properties), which causes the introduction of nanoparticles of supplements to recipes of bakery, flour confectionery, meat, pasty-marmalade products and cheesecakes and whipped desserts. It contributes to resource conservation during the production of food products, the formation of high consumer properties and increase the product yield and economic efficiency of its production. Food products made with the use of food nano additives "Magnetofood", has high organoleptic, functional and technological properties, extended shelf-life. According to the results of the comparative analysis of quality and price characteristics of food products with "Magnetofood" nanoparticles, it was concluded that new products has the more value for B2B consumers compared with analogues.

Conclusions. A high level of scientific, scientific, technical, social and economic efficiency of food products with the addition of a nutritional supplement "Magnetofood" based on oxides of two and three valence iron is proved.

Introduction

The experience of world leaders in the food industry [1] shows the urgency of introducing innovations into the practice of economic activity as one of the factors contributing to the competitiveness of the enterprise and its further development. The analysis of the trends in the food industry shows the active use of nanotechnologies in this area, the application of which in the production of food products is recognized as one of the most promising areas for the introduction of the results of nanosciences [2-6], in particular, changes in the qualitative and functional and technological characteristics of food products [7, 8]. According to [9], the global nanotechnology market will reach $ USA 125 billion by 2024. In the structure of demand for nanoproducts [3], the segments of the consumer market account for 5.0% of the food market. Researchers on nanotechnology commercialization point out that food industry enterprises are most prepared for the perception and implementation of nanotechnologies [2].

Innovative activity of food industry enterprises determines the relevance of research on methodological principles for evaluating the efficiency of innovative food technologies with nanoparticles. The results of this assessment contribute to the innovative activity of food industry enterprises and increase the validity of managerial decisions on the introduction of innovative products into production.

The analysis of literary data testifies to different positions of researchers regarding the criteria, indicators and methods of evaluation of innovation products in general and in the case of introduction of nanotechnologies in particular. Depending on the purpose of the evaluation, the criteria for the new product include the strategic feasibility, technical feasibility, consumer perceptions, market opportunities and financial performance [10], the uniqueness of the product, its market potential, and technical feasibility [11]; use indicators of safety [12], quality [13], prices of products [13, 14]. Conclusions regarding the effectiveness of the implementation of innovative developments are based on the principles of quality estimation, discounting of cash flows, expert assessments [13-16].

Since innovative food products using the Magnetofood nutritional supplement have a multidimensional nature, and their results are the subject of interest of a significant number of subjects (producers, consumers, investors, research institutions, etc.). To conclude on the feasibility of introducing these products into the practice it is advisable to use a set of criteria and indicators that reflect the interests of key players in the implementation of the innovation process.

The aim of the research is a comprehensive analysis of the effectiveness of innovative food products using a nutritional supplement "Magnetofood" based on two and three valence iron oxides by studying functional and technological properties, quality indices and output of finished products, scientific, scientific and technical efficiency and its implementation efficiency, value for the consumer.

To achieve this goal, the following tasks need to be addressed:

– to investigate functional and technological properties, product yield and organoleptic indices of food products using a rational quantity (0,15% by weight of raw materials) of a food additive "Magnetofood";
– to conduct a comprehensive analysis of the effectiveness of the introduction of innovative food products using a nutritional supplement "Magnetofood" based on two and three valence iron oxides.

Materials and methods

Materials

In the course of the research, food products with the addition of a nutritional supplement "Magnetofood" based on two and three valence iron oxides were used: bread and flour confectionery, minced meat product, sour-milk products, pasty and marmalade products, whipped fruit and desserts.

Methods

Food products using a nutritional supplement "Magnetofood" based on two and three valence iron oxides have been investigated using standard and commonly used methods of experimental studies, expert analysis.

The method of complex evaluation of the effectiveness of the introduction of food products with nanoparticles involves the following stages.

1. To form a group of experts.

To determine the effectiveness of the introduction of innovative food products with nanoparticles, form a group of experts, which include experts in the field of food technology. The number of experts (m) is determined by the formula:

$$m = \frac{t_a^2}{\varepsilon^2}, \quad (1)$$

where m – number of experts, persons;

t_α – the tabular value in accordance with the accepted confidence probability α;

α – confidence probability, %;

ε – maximum permissible error.

To determine the competence of experts, were used the methods of questionnaire survey and self-assessment.

2. To carry out an expert evaluation of innovative food products with nanoparticles on the criterion of scientific effectiveness.

To do this, were formed a questionnaire to include questions about the scientific level, novelty, depth of scientific developments and knowledge of products. Characteristics and scale for expert evaluation of the scientific effectiveness of innovative food technologies are given in Table 1.

Table 1

Characteristics and scale of evaluation of innovative food products with nanoparticles on the criterion of scientific efficiency

Indicator	Linguistic assessment		
	high level	average level	low level
	Scale for evaluation		
	3 points	2 points	1 point
Scientific level	A new direction of scientific knowledge and research has been created	Existing techniques have been improved	The existing theoretical positions are confirmed
Novelty	Fundamentally new results	Methods, ways to create new products	Solutions based on simple generalizations
The depth of scientific development	The hypotheses are theoretically substantiated and tested on a large amount of experimental data	Hypotheses are theoretically grounded and tested on a small amount of experimental data	Hypotheses are theoretically grounded
Knowledge of products	The coefficient of knowledge intensity exceeds the average value of enterprises of a certain type of economic activity	The coefficient of knowledge intensity corresponds to the average value of enterprises of a certain type of economic activity	The coefficient of knowledge intensity of products is smaller, the average value of enterprises of a certain type of economic activity

Developed on the basis of [12-14].

Calculate the coefficient of scientific efficiency (K_s) v:

$$Ks = \frac{\sum_{j=1}^{k}\sum_{i=1}^{n} B_{si}}{\sum_{j=1}^{k}\sum_{i=1}^{n} B_{si\max}}, \quad (2)$$

where K_s – coefficient of scientific efficiency;

B_{si} – actual value of the *i*-th indicator of scientific effectiveness, score;

$B_{si\max}$ – the maximum value of the *i*-th indicator of scientific effectiveness, the score;

n – the number of scientific performance indicators, units;

k – number of experts, persons. B_{si}

To assess innovative food products on the criterion of scientific efficiency to adhere to these conditions (Table 2).

Table 2

Estimation of innovative food products with nanoparticles on the criterion of scientific effectiveness

Value of the factor	Conclusion
$0 \leq K_s < 0{,}33$	Low level of scientific effectiveness of innovative food products with nanoparticles
$0{,}34 \leq K_s < 0{,}66$	The average level of scientific effectiveness of innovative food products with nanoparticles
$0{,}67 \leq K_s \leq 1{,}0$	High level of scientific effectiveness of innovative food products with nanoparticles

3. To carry out an expert evaluation of innovative food products with nanoparticles on the criteria of scientific and technical efficiency.

For this purpose, to formulate a questionnaire to include questions about the prospects of use, scale of implementation, period and degree of implementation of technologies of innovative food products with nanoparticles. Characteristics and scale for expert evaluation of scientific and technical efficiency of innovative food technologies are given in Table 3.

Table 3

Characteristics and scale of evaluation of innovative food products with nanoparticles on the criterion of scientific and technical efficiency

Indicator	Linguistic assessment		
	High level	High level	High level
	Scale for evaluation		
	3 points	2 points	1 point
Perspectives of use	Results can be found in many scientific fields	Results can be used to develop a particular scientific direction	Results can be used in applied research
Scale of implementation	National, world economy	Regional market	Local market, individual enterprises
Implementation period	Up to 3 years old	From 3 to 5 years	More than 5 years
Degree of implementation	The results are published in the form of scientific reports, formalized in the form of normative and technical documentation, introduced into practical activities	The results are formalized in the form of normative and technical documentation	The results are published in the form of scientific reports

Developed on the basis of [12-14].

Calculate the coefficient of scientific and technical efficiency (K_{st}) by the formula:

$$Kst = \frac{\sum_{j=1}^{k}\sum_{p=1}^{m} B_{stp}}{\sum_{j=1}^{k}\sum_{p=1}^{m} B_{stp\max}}, \quad (3)$$

where K_{st} – coefficient of scientific and technical efficiency;

B_{stp} – actual value of *p*-th indicator of scientific and technical efficiency, score;

$B_{stp\max}$ – maximum value of *p*-th indicator of scientific and technical efficiency, score;

m – number of indicators of scientific and technical efficiency, units;

k – number of experts, persons.

To assess innovative food products by the criterion of scientific and technical efficiency, to adhere to these conditions (Table 4).

Table 4

Estimation of innovative food products with the acquisition of criteria of scientific and technical efficiency

Value of the factor	Conclusion
$0 \le K_{st} < 0{,}33$	Low level of scientific effectiveness of innovative food products with nanoparticles
$0{,}34 \le K_{st} < 0{,}66$	The average level of scientific effectiveness of innovative food products with nanoparticles
$0{,}67 \le K_{st} \le 1{,}0$	High level of scientific effectiveness of innovative food products with nanoparticles

4. To carry out an experimental study of the quality of food products with nanoparticles of the additive "Magnetofood".

To do this, determine the organoleptic and functional-technological indicators by type of food products.

Calculate a comprehensive index of food quality by the formula:

$$Kqr = \frac{\sum_{j=1}^{k}\sum_{x=1}^{z} B_{xr}}{\sum_{j=1}^{k}\sum_{x=1}^{z} B_{xr\max}}, \quad (4)$$

where Kqr – coefficient of quality *r*-th products;

B_{xr} – actual value of the quality of *r*-th products in the x-th indicator, score;

$B_{xr\max}$ – the maximum value of the quality of *r*-th products in the *x*-th indicator, the score;

z – number of quality indicators, units;

k – number of experts, persons.

To identify the quality of innovative food products with nanoparticles, to adhere to these conditions (Table 5).

Table 5

Estimation of innovative food products with nanoparticles on the criterion of quality

Value of the factor	Conclusion
$0 < Kqr \leq 0{,}33$	The quality of innovative food products with nanoparticles is low
$0{,}34 < Kqr \leq 0{,}66$	The quality of innovative food products with nanoparticles is average
$0{,}67 < Kqr \leq 1{,}0$	The quality of innovative food products with nanoparticles is high

5. To carry out an expert evaluation of innovative food products with nanoparticles on the criterion of value for the consumer.

To do this, calculate the food value ratio by matching the quality and price availability factors.

The coefficient of price availability of innovative food products with nanoparticles is based on the formula:

$$Kpr = \frac{P_r}{P_{cr}}, \tag{5}$$

where Kpr – coefficient of price availability of *r*-th products;

P_r – the price of *r*-th products, monetary units;

P_{cr} – the price of a product-analogue of *r*-th products, monetary units.

The coefficient of value of innovative food products with nanoparticles for the consumer to calculate by the formula:

$$Kv = \frac{Kqr}{Kpr}. \tag{6}$$

To identify the value of innovative food products with nanoparticles for the consumer, to adhere to these conditions (Table 6).

Table 6

Estimation of innovative food products with nanoparticles on the criterion of value for the consumer

Value of the factor	Conclusion
$Kv > 1{,}0$	The high value of innovative food products with nanoparticles for the consumer; the benefits received by the consumer exceed the cost of purchasing the product
$Kv = 1{,}0$	Low value of innovative food products with nanoparticles for the consumer; the benefits received by the consumer correspond to the cost of purchasing the product
$Kv < 1{,}0$	The low value of innovative food products with nanoparticles for the consumer; the benefits that the consumer receives is less than the cost of purchasing the product

6. To carry out an expert evaluation of innovative food products with nanoparticles on the criterion of economic efficiency.

To do this, determine the growth of profitability of production per unit of output by the formula:

$$\Delta R_r = \left(\frac{P_{r1} - C_{r0}}{C_{r1}} \right) \times 100 - R_{r0}, \quad (7)$$

where ΔR – an increase in the profitability of *r*-food products in the event of the introduction of innovative technologies, %;

P_{r1} – the price of sales of *r*-innovation food products, monetary units;

C_{r0} – cost price of *r*-food products according to traditional technology, monetary units;

C_{r1} – the cost price of r-food products in the case of the introduction of innovative technologies, monetary units;

P_{r0} – the profitability of the r food in accordance with traditional technology, %.

7. Conclude on the effectiveness of the introduction of innovative food products with nanoparticles.

Results and discussion

In accordance with the methodology of the integrated analysis of the effectiveness of the introduction of innovative food products, as outlined above, the evaluation of innovative food products using the nanoparticles of a food additive "Magnetofood" based on two and three valence iron oxides was carried out, the results of which concluded that a high level of efficiency of the indicated innovation development.

The results of scientific work have significant potential not only in the food industry, but also in the field of production of cosmetic and pharmaceutical products, food products of medical and preventive action, indicating the prospects of using the scientific results obtained in many scientific fields and types of economic activity.

Innovative is not only the indicated theoretical and experimental scientific results, but also brought to the practical introduction into the economic activity of food industry enterprises new types of products that have a high level of knowledge intensity (Figure 1).

According to calculations, the coefficients of scientific and scientific and technical efficiency of food products made with the use of a nutritional supplement "Magnetofood" based on two and three valence iron oxides were 0.83 and 0.84 points, respectively, indicating a high level of scientific and scientific-technical efficiency developed innovative food products (Table 7).

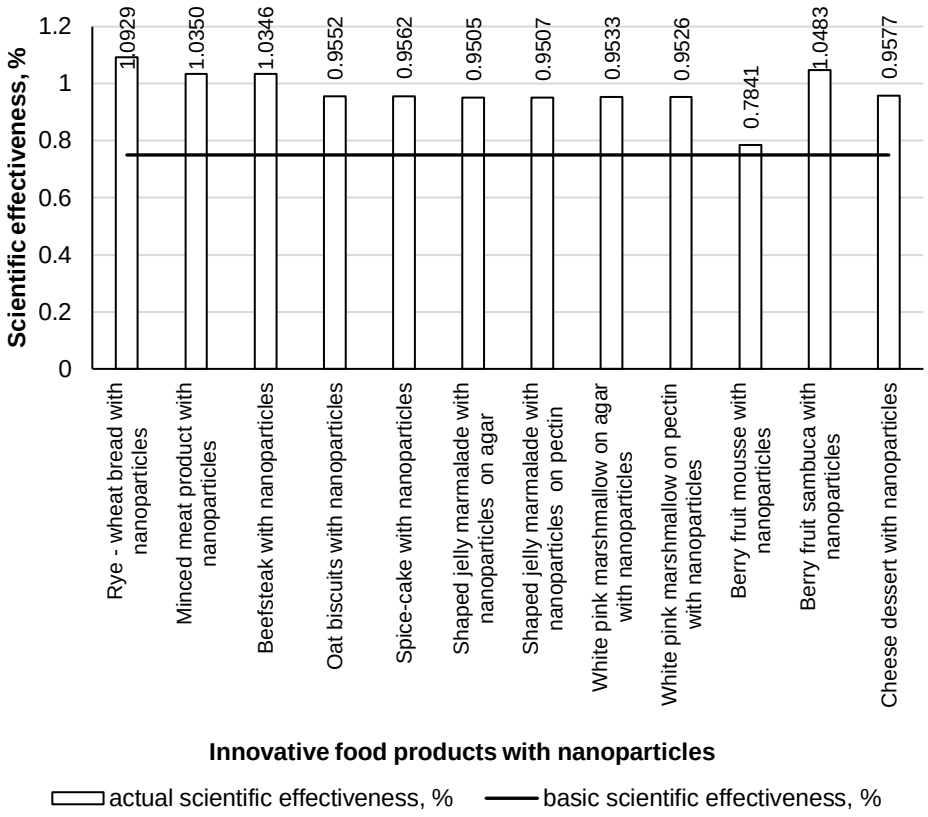

Figure 1. Indicators of scientific effectiveness of products based on the results of the introduction of innovative food products with the addition of 0.15% of a nutritional supplement "Magnetofood" based on two and three valence iron oxides, %

The most highly appreciated by experts were scientific efficiency and the prospect of using the results. The maximum values in these areas reached 0.88 and 0.90 points, respectively.

Based on the innovative idea of food products using nanoparticles, innovative products characterized by high organoleptic characteristics (Figures 2-13) and new functional and technological properties – sorption, emulsifying, structuring, foaming and gelling, stabilizing, water and fat-binding, water and fat-retaining properties (Table 8 and Figures 2–13). Experimental way is the rational mass fraction of nutritional supplement "Magnetofood" on the basis of two and three valence iron oxides in the formulation of food products, which is 0.15% of the mass of raw materials [19, 20].

Table 7

Results of expert evaluation of innovative food products using a dietary supplement "Magnetofood" based on two and three valence iron oxides on the criteria of scientific and scientific – technical efficiency

Indicator	Value, score		Coefficient
	maximum	actual	
Scientific performance			
Scientific level	3,0	2,4	0,81
Novelty	3,0	2,4	0,79
The depth and extent of the dissemination of ideas	3,0	2,5	0,83
Scientific efficiency of products	3,0	2,6	0,88
Together	12,0	9,9	0,83
On the average	3,0	2,5	0,83
Scientific and technical performance			
Perspectives of use	3,0	2,7	0,90
Scale of implementation	3,0	2,5	0,83
Implementation period	3,0	2,4	0,81
Degree of implementation	3,0	2,5	0,83
Together	12,0	10,1	0,84
On the average	3,0	2,5	0,84

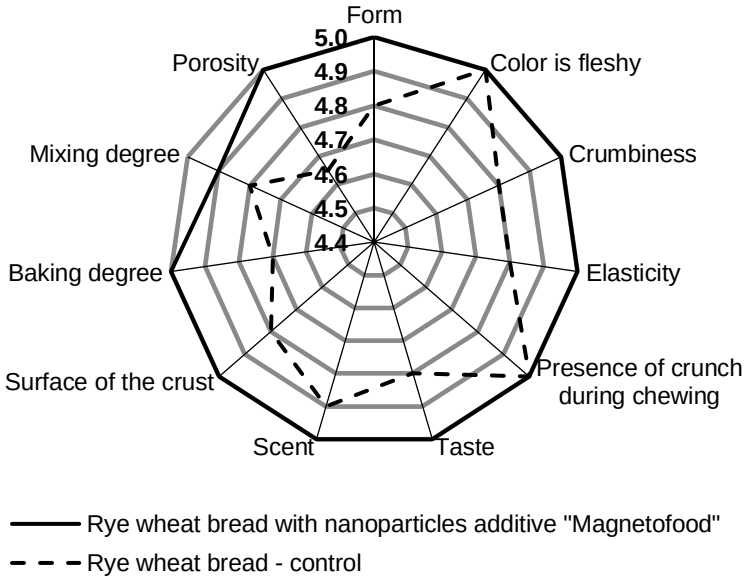

Figure 2. Levels of quality of organoleptic properties of rye-wheat bread with nanoparticles added to "Magnetofood" in comparison with control rye-wheat bread

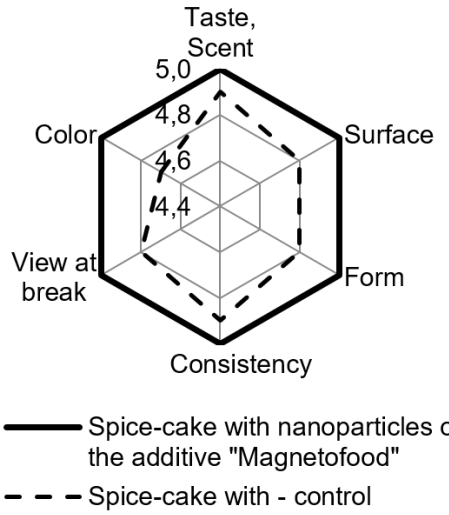

Figure 3. Levels of quality of organoleptic properties of spice-cake cooked with nanoparticles of the additive "Magnetofood" in comparison with control – spice-cake

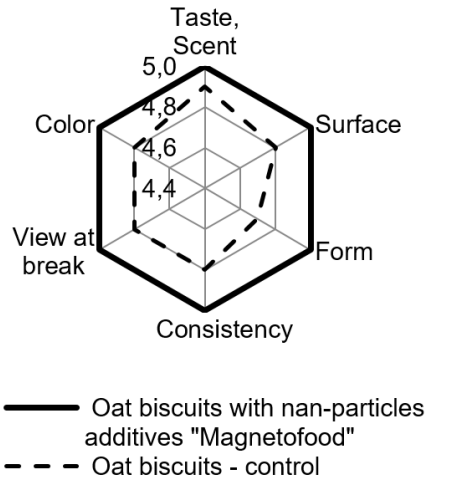

Figure 4. Levels of quality of organoleptic properties of oat biscuits with nanoparticles of the additive "Magnetofood" in comparison with the control – oat biscuits, made according to the traditional technology

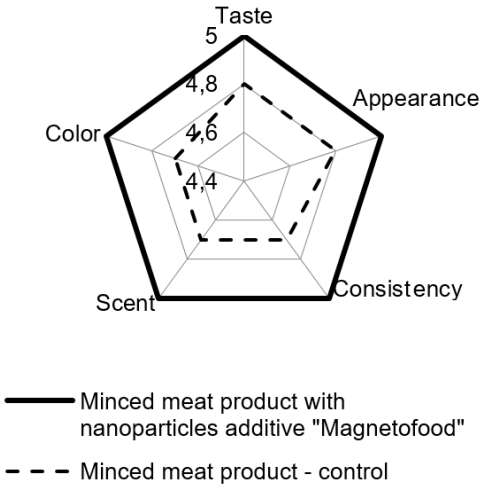

Figure 5. Levels of quality of organoleptic properties of minced meat products cut with nano-particles of additive "Magnetofood" in comparison with control – minced meat products manufactured using traditional technology

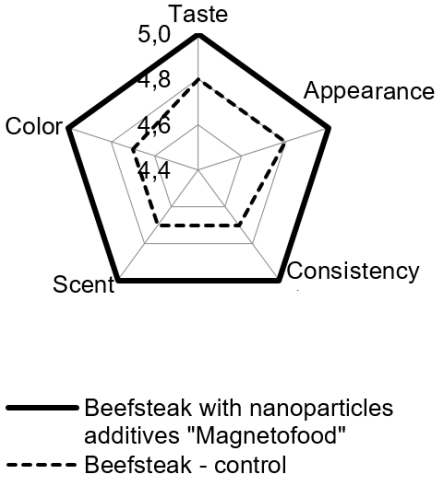

Figure 6. Levels of quality of organoleptic properties of beefsteaks with nanoparticles of supplements "Magnetofood" in comparison with control – beefsteaks made according to traditional technology

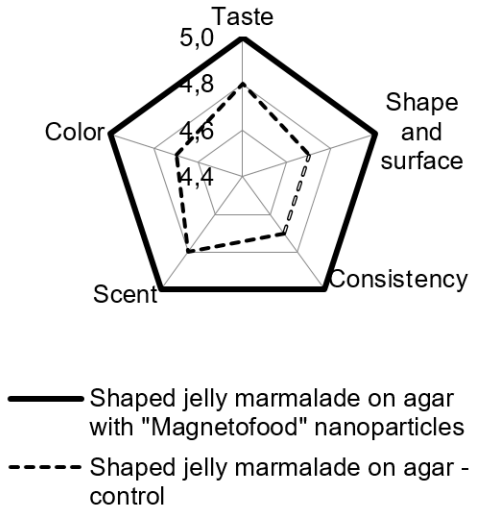

Figure 7. Levels of quality of organoleptic properties of shaped jelly marmalade with nanoparticles on agar with nanoparticles of the additive "Magnetofood" in comparison with control – shaped jelly marmalade on agar, made according to traditional technology

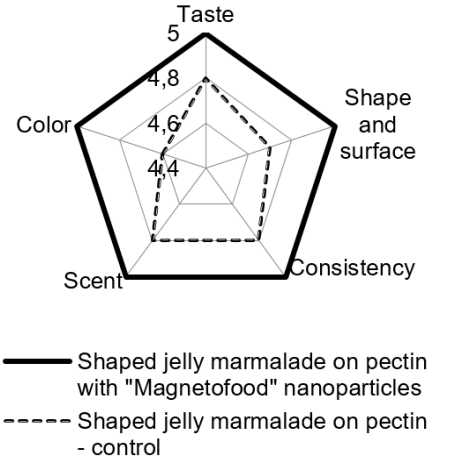

Figure 8. Levels of quality of the organoleptic properties of the shaped jelly marmalade with nanoparticles on pectin with nanoparticles of the additive "Magnetofood" in comparison with the control – shaped jelly marmalade on pectin, made according to the traditional technology

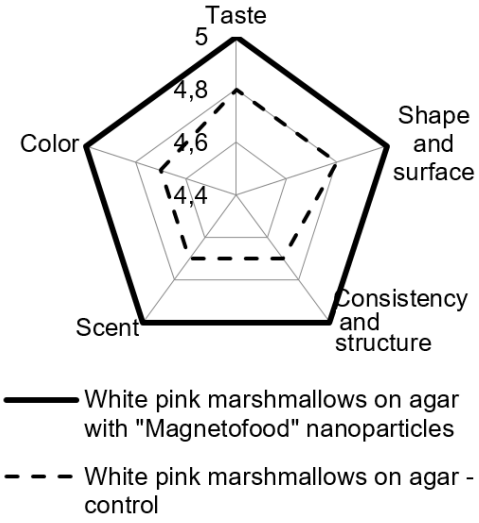

Figure 9. Levels of quality of organoleptic properties of white pink marshmallow on agar with nanoparticles of the additive "Magnetofood" in comparison with control – white and pink marshmallows on agar, made according to the traditional technology

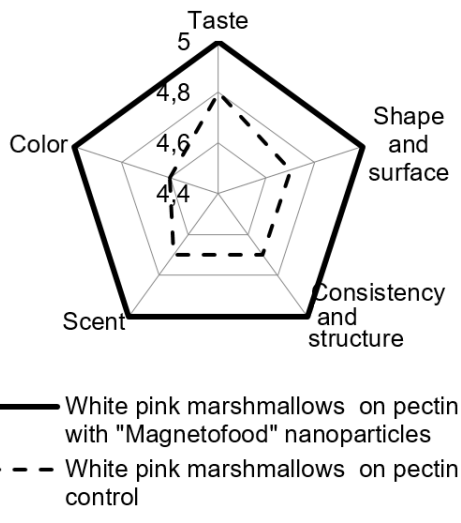

Figure 10. Levels of quality of organoleptic properties of white pink marshmallows on pectin with nano-particles of additive "Magnetofood" in comparison with control – white pink marshmallows on pectin, made according to traditional technology

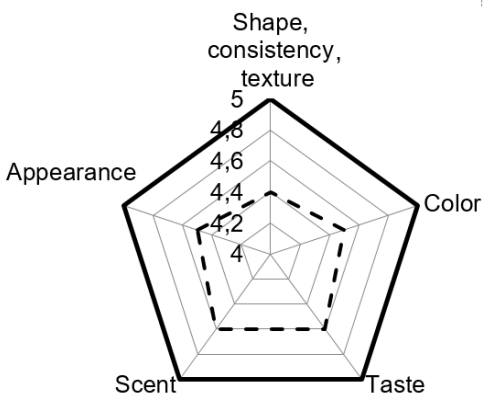

Figure 11. Levels of the quality of the organoleptic properties of the berry fruit mousse with the nanoparticles of the additive "Magnetofood" in comparison with the control – berry fruit mousse produced by traditional technology

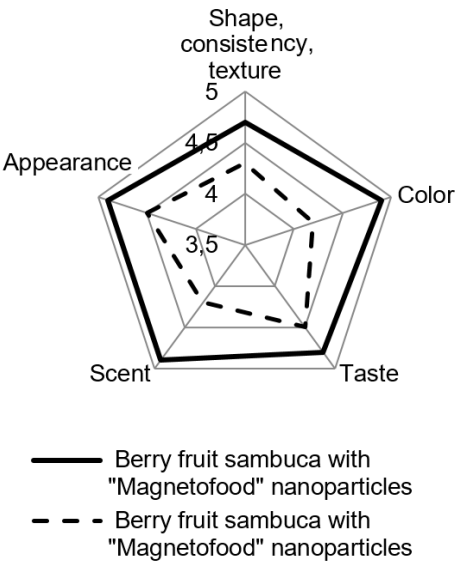

Figure 12. Levels of quality of organoleptic properties of berry fruit sambuca with nanoparticles of the additive "Magnetofood" in comparison with control – berry fruit sambuca made according to traditional technology

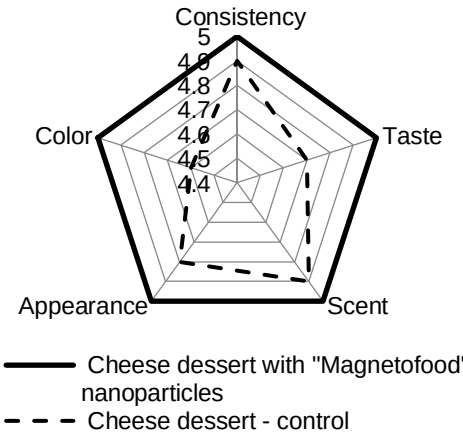

Figure 13. Levels of quality of organoleptic properties of cheese dessert with nanoparticles of supplement "Magnetofood" in comparison with control – cheese dessert made according to traditional technology

From Figure 2–13 it follows that the introduction of nanoparticles of a dietary supplement "Magnetofood" based on the two and three valence iron oxides improves the organoleptic parameters of food products by an average of 0.6–0.8 points in comparison with control samples, made according to the traditional technology. This is due to the correction of functional and technological properties of food systems under the influence of "Magnetofood" nanoparticles, in particular, stabilizing, gelling and foaming ability; the formation of aqua and lipid complexes, the uniform distribution of moisture in the system.

Table 8 shows the influence of "Magnetofood" nanoparticles on the functional and technological properties of food products.

Table 8

Output products, water-retaining ability (HRA) and fat-retaining ability (FRA) of food products with nanoparticles of food additive "Magnetofood" in comparison with control

Name of food products	Output products, %	Water-retaining ability (HRA), %	Fat-retaining ability (FRA),%
Rye – wheat bread with nanoparticles	87,9±1,0	58,0±1,0	68,4±2,0
Rye – wheat bread	82,7±1,0	50,0±1,0	62,1±2,0
Spice-cake with nanoparticles	88,7±1,0	55,0±1,0	70,4±2,0
Spice-cake «Kharkivski»	84,4±1,0	46,2±1,0	64,1±2,0
Oat biscuits with nanoparticles	86,8±0,9	56,0±1,0	69,4±2,0
Oat biscuits with traditional technology	81,4±0,9	48,0±1,0	63,1±2,0
Minced meat product with nanoparticles	85,4±0,7	82,0±0,9	73,4±1,0
Minced meat product by traditional technology	80,8±0,7	72,3±0,9	66,1±1,0
Beefsteak with nanoparticles	86,4±0,7	81,3±0,9	72,3±1,0
Beefsteaks by traditional technology	81,8±0,7	71,0±0,9	65,2±1,0

It can be seen from Table 8 that the addition of Magnetit of (Fe_3O_4) nanoparticles in the amount of 0.15% to the mass of raw materials contributes to an increase in the yield of finished products by 4.3–5.4% due to the water and fat retaining ability of the nanoparticles "Magnetofud"; HRA – by 8.0–10.3%, FRA – by 6.3–7.3% due to the mechanism of cluster affinity of nanoparticles of the additive [17, 19].

According to the expert assessments, the coefficients reflecting the quality and price availability of innovative food products are within the range of 0.67–1.0 and 0–1.0 respectively, and their ratio (quality to price) is greater than 1.0, indicating that the high value of innovative products for the consumer (Figure 14).

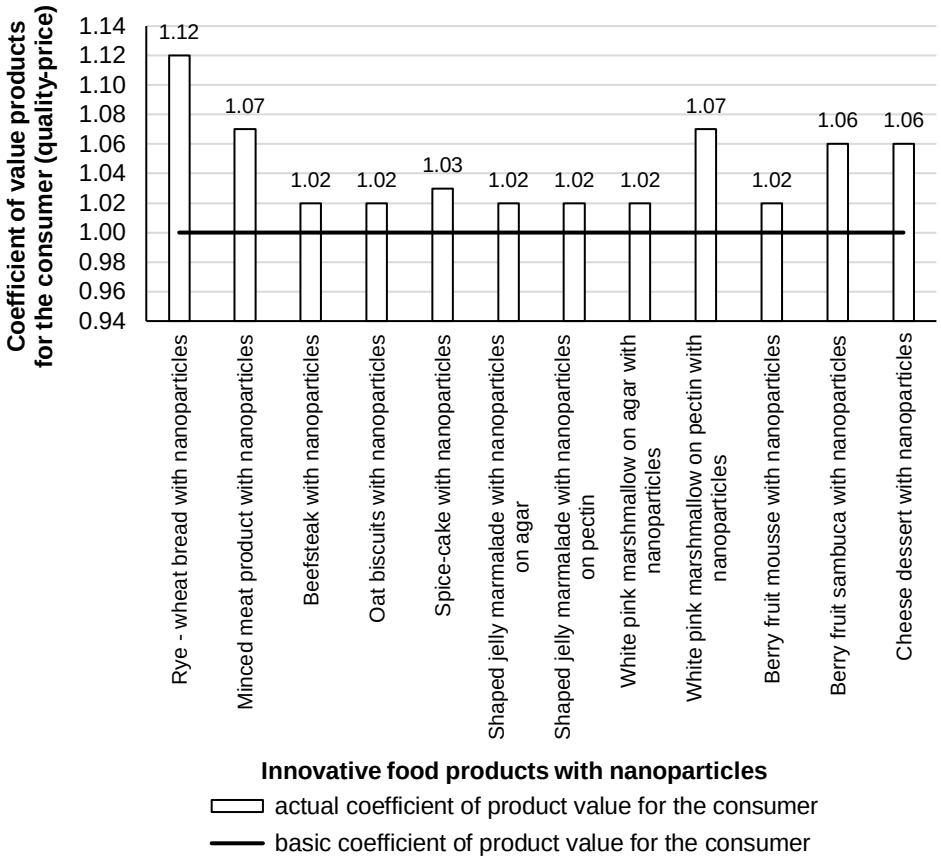

Figure 14. Indicators of the value of food products using the nanoparticles of the nutritional supplement "Magnetofood" for consumers, coefficient

The calculation of the selling prices for the new products developed and their comparison with the prices for products manufactured according to the traditional technology allowed us to conclude that as a result of the use of a nutritional supplement "Magnetofood", which causes an increase in the output of finished products, the cost of raw materials for new products are smaller compared to analogues, which, in other equal conditions, leads to an increase in profits and an increase in the profitability of products.

According to the calculations, the price of the developed innovative products corresponds to the prices for analogue products, which, taking into account higher qualitative characteristics, gives the company the opportunity to increase the profitability of innovative products by 0.2–5.4% and to obtain additional profit.

Conclusions

As a result of the study, the following conclusions were drawn.

1. Complex assessment of the effectiveness of the introduction of innovative food products had been carry out, which involves the implementation of interconnected stages in determining the scientific, scientific and technical efficiency of innovative technologies, the quality and value of innovative products for the consumer, the economic efficiency of the introduction of innovative food products.
2. The improvement of organoleptic parameters of food with the use of a food additive "Magnetofood" on the basis of on two and three valence iron oxides was improved by an average of 0.6–0.8 points in comparison with control samples, made according to the traditional technology. It was established that the addition of Magnetitofud (Fe_3O_4) nanoparticles in the amount of 0.15% to the mass of raw materials contributes to an increase in the yield of finished products by 4.3–5.4% due to the water and fat-binding properties of Magnetofood nanoparticles; HRA – by 8.0–10.3%, FRA – by 6.3–7.3% due to the mechanism of cluster affinity of nanoparticles of the additive.
3. On the basis of the integrated evaluation of innovative food products using a nutritional supplement "Magnetofood" on the basis of on two and three valence iron oxides, the effectiveness of its implementation is established.

References

1. Available at: https://latifundist.com/novosti/26634-top-10-proizvoditelej-produktov-pitaniya-v-mire.
2. Viznachennya prioritetnih napryamkiv komercializaciyi nanotehnologij v Ukrayini, Available at: https://ndc-ipr.org/researches/post/prioritetni-napryamki-nanotehnologiy
3. Fesenko O.M., Kovalchuk PP.V., Nishik R.A. (2017), Problemi ta perspektivi rozvitku nanotehnologij v Ukrayini ta sviti, *Marketing i menedzhment innovacij*, 1, pp. 170-179
4. Dasgupta N., Ranjan PP., Mundekkad D., Ramalingam Ch., Shanker R., Kumar A. (2015), Nanotechnology in agro-food: From field to plate, *Food Receach International*, 69, pp. 381–400, DOI: 10.1016/j.foodres.2015.01.005.
5. Bhupinder Singh Sekhon (2014), Nanotechnology in agri-food: an overview, *Nanotechnology Science and Application*, 7, pp. 31–53, DOI: 10.2147/NSA.S39406.
6. Gruère G.P. (2012), Implications of nanotechnology growth in food and agriculture in OECD countries, *Food Policy*, 37(2), pp. 191–198, DOI: 10.1016/j.foodpol.2012.01.001
7. Chellaram C., Murugaboopathi G., John A.A., Sivakumar R., Ganesan PP., Krithika PP., Priya G. (2014), Significance of Nanotechnology in Food Industry, *APCBEE Procedia*, 8, pp. 109–113, DOI: 10.1016/j.apcbee.2014.03.010
8. Bigliardi B., Galati F. (2013), Innovation trends in the food industry: the case of functional foods, *Trends in Food Science&Technology*, 31(2), pp. 118–129, DOI: 10.1016/j.tifs.2013.03.006
9. (2018), *Global Nanotechnology Market (by Component and Applications), Funding & Investment, Patent Analysis and 27 Companies Profile & Recent Developments – Forecast to 2024*, Available at:

https://www.researchandmarketpp.com/reports/4520812/global-nanotechnology-market-by-component-and

10. Carbonell-Foulquié P., Rodríguez-Escudero A. (2004), Criteria employed for go/no-go decisions when developing successful highly innovative products, *Industrial Marketing Management*, 33(4), pp. 307–316, DOI: 10.1016/S0019-8501(03)00080-4
11. Hart P.P., Hulting E.J., Tzokas N., Commandeur H.R. (2003), Industrial Companies' Evolution Criteria in New Product Development Gates, *Product innovation management*, 20 (1), pp. 22–36
12. Korecka I.L., Zinchenko T.V. (2003), Ocinyuvannya novih harchovih virobiv za dopomogoyu kriteriyu «bagatokutnik yakosti», *Naukovi praci NUHT*, 14, pp. 64–65.
13. *Metodika ocinki efektivnosti naukovo-doslidnih robit*, Available at: http://dspace.oneu.edu.ua.jspui/bitstream/123456789/2202/1/Методика%20оцінки%20ефективності%20науково-дослідних%20робіт.pdf
14. Capuk O.Yu. Sistema kriteriyiv ta pokaznikiv ocinyuvannya efektivnosti vprovadzhennya innovacijnih rozrobok (2013), *Marketing i menedzhment innovacij*, 3, pp. 137–145.
15. (2010) *A comparative methodology for estimating the economic value of innovation in nanotechnologies*, Available at: file:///C:/Users/Elena/Downloads/CB0435_9835_FRP.pdf
16. Lin Y.-H., Tseng M.-L., Cheng Y.-L., Chiu A. PP.F., Geng Y. (2013), Evaluating firm technological innovation capability under uncertainty, *Scientific Research and Essays*, 8(13), pp. 501–514, DOI:10.1016/j.technovation.2007.10.007
17. Tsykhanovska I., Alexandrov A., Evlash V., Lazareva T., Svidlo K., Gontar T., Yurchenko L., Pavlotska L. (2018), Substantiation of the mechanism of interaction between biopolymers of rye-and-wheat flour and the nanoparticles of the «Magnetofood» food additive in order to improve moisture-retaining capacity of dough, *Eastern-European Journal of Enterprise Technologies*, 2/11(92), pp.70–81, DOI: 10.15587/1729-4061.2018.126358.
18. Asmalovskij A., Sadilek T. (2016), Food quality perception in the Czech Republic: trial study results,*Ukrainian Food Journal*, 5(1), pp. 186–194.
19. Tsykhanovska I., Evlash V., Alexandrov A., Gontar T. (2018), Mechanism of fat-binding and fat-contenting of the nanoparticles of a food supplement on the basis of double oxide of two- and trivalent iron, *Ukrainian food journal*, 7(4), pp. 702–715. DOI: 10.24263/2304-974X-2018-7-4-14
20. Tsykhanovska I., Skurikhina L., Evlash V., Pavlotska L. (2018), 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, Ukrainian food journal, 7(3), pp. 379–396, DOI:10.24263/2304-974X2018-7-3-4