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Contents

Reducing ability of infusions from waste of spicy-aromatic raw materials in the technology of alcoholic beverages

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Abstract

Introduction. The aim of the research is to study the reducing ability of aqueous-alcoholic infusions from waste of aromatic raw materials in the technology of alcoholic beverages.

Materials and methods. The regenerative ability of infusions from waste of aromatic raw materials: *Perilla frutescens*; *Elsholtzia stauntonii Benth*; *Artemisia abrotanum*; *Monarda didyma*; *Agastache foeniculum*; *Satureja hortensis*; *Ruta graveolens*; *Nepeta transcaucasica Grossch* was determined by the method of redoxmetry and *pH*-metry; sensory indicators – according to the expert method.

Results and discussion. Waste plant spice-aromatic raw materials, which are formed after maceration, during further preparation, can be reused in the technology of alcoholic beverages.

In relation to the control (7.80 *pH* units) infusions have a *pH* value of 6.73 units *pH* (*Agastache foeniculum*) up to 7.35 units *pH* (*Satureja hortensis*), which is 13.72% and 5.77 %, respectively, less than control. The value of the minimum theoretical redox potential for aqueous-alcoholic infusions Eh_{min} from 219.0 mV (*Satureja hortensis*) to 256.2 mV (*Agastache foeniculum*), which is 14.06% and 33.44% more than in the control (Eh_{min} 192 mV). The value of the actually measured redox potential for aqueous-alcoholic infusions Eh_{act} from 94.0 mV (*Monarda didyma*) to 141.0 mV (*Ruta graveolens*), which is more than 2.17% and 53.26 %, respectively, for the control (Eh_{act} 92 mV).

Aqueous-alcoholic infusions from wastes of spicy-aromatic raw materials have a reduction capacity (reduction energy – *RE*) from 101.4 mV (*Ruta graveolens*) to 153.2 mV (*Monarda didyma*), which is greater than the control (aqueous-alcoholic mixture) *RE* 100 mV by 1.40% and 53.20% respectively.

Aqueous-alcoholic infusions from waste of spicy-aromatic raw materials have the value of *S.e.* from 9.47 to 9.68 points in relation to control *S.e.* 9.21 points. The highest value of *S.e.* 9.68 points are characteristic of the aqueous-alcoholic infusion of *Agastache foeniculum*: color – light amber (1.98 points); taste – bright ethereal, herbal, fragrant (3.98 points); aroma – bitter-sour, tart (3.72 points).

Conclusion. The use of waste from the aromatic raw materials of *Monarda didyma* in aqueous alcoholic tinctures leads to an increase in the reducing characteristics of *RE* infusions by 53.20 %, and positive sensory indicators of *S.e.* – 9.51 points on a 10-point scale.

Introduction

Waste reduction is a key challenge for the sustainable development of the food industry (Barik, 2019; Tekler et al., 2019; Martin-Rios et al., 2018) [1-3], so reducing it is a pressing issue for most businesses in the industry (Hall, Howe, 2012; Fujii, Kondo, 2018) [4, 5]. Waste recycling and utilization is a strategic goal for each company (Fujii, Kondo, 2018; Galanakis, 2020; Garcia-Garcia, 2019) [5-7], which involves the involvement of innovative technologies based on the evaluation of decisions in reducing the cost of finished products, minimizing raw material losses, increasing the yield of finished products (Tekler et al., 2019) [2]. The practical implementation of innovative measures allows to establish relationships between processes and technologies of food industry processing and provides an opportunity to form the main provisions in the field of waste management (Mo et al., 2018) [8].

Today, for the production of alcoholic beverages, a certain amount of plant raw materials is used, which forms waste. Currently, the use of vegetable raw materials in the technology of alcoholic beverages is very relevant (Andreou et al, 2018; Chandrasekara, Shahidi, 2018; Iannitti, Palmieri, 2009; Kawa-Rygielska et al, 2019) [9-12]. Of particular interest in the production of alcoholic beverages is a spicy-aromatic raw material that exhibits antioxidant and tonic properties (Vergun et al, 2019) [13]. At present, the antioxidant characteristics of all prescription components, food additives, biologically active substances and their combinations have not been sufficiently studied (Buglass et al, 2012; Grunert et al, 2018; Gulua et al, 2018) [14-16].

In the process of extracting or infusing spicy-aromatic raw materials with an aqueous-alcoholic mixture, waste remains, which can be further processed and reused. Spice-aromatic plants can be considered a promising raw material for the production of alcoholic beverages: *Perilla frutescens, Elsholtzia stauntonii Benth, Artemisia abrotanum, Monarda didyma, Agastache foeniculum, Satureja hortensis, Ruta graveolens, Nepeta transcaucasica Grossch*, due to their positive characteristics.

Perilla frutescens. *Perilla frutescens* is rich in natural compounds that could be developed as nutraceuticals (Ahmed, Tavaszi-Sarosi, 2019; Lee et al., 2017; Igarashi, Miyazaki, 2013) [17-19] and/or phytomedicine (Ahmed, Tavaszi-Sarosi, 2019) [17]. More 100 compounds have been reported for *Perilla frutescens* and most of them are contributed to its medical benefits (Ahmed, Tavaszi-Sarosi, 2019; Lee et al., 2017; Yu et al., 2017; Lee et al., 1997; Liu et al., 2000) [17, 18, 20-22] such as anti-allergic, anti-inflammatory, anti-oxidant (Ahmed, Tavaszi-Sarosi, 2019; Lee et al., 2017; Yu et al., 2017) [17, 18, 20], anticancer, anti-microbial, anti-depressive and anti-cough effects (Yu et al., 2017; Lee et al., 1997; Liu et al., 2000) [20-22]. The health beneficial capacities of *Perilla frutescens* are related to its metabolite contents (phenolic acids, monoterpenes, flavonoids, and triterpenoids (Banno et al., 2004; Lee et al., 2013; Asif, 2012; You et al., 2014), [23-26]. *Perilla frutescens* characterized with the predominance of perillaldehyde, perilla ketone, β-dehydro-elsholtzia ketone, limonene, shisofuran, farnesene (Z, E, α), β-caryophyllene, trans-shisool (Ahmed, Tavaszi-Sarosi, 2019) [17].

Elsholtzia stauntonii Benth. Plants of the genus *Elsholtzia stauntonii Benth* have a long history of medicinal use in folk. The phytochemical investigations revealed the presence of flavonoids, phenylpropanoids, terpenoids, and other compounds. Abundant volatile components are also identified (Guo et al., 2012) [27]. As folk medicine, the plants in the genus have been used for the treatment of colds, headaches, pharyngitis, fever, diarrhea, digestion disorder, rheumatic arthritis, nephritises, and nyctalopia in China (Guo et al., 2012; Wu et al., 1977) [27, 28].

Artemisia abrotanum. *Artemisia abrotanum* is a rich source of active biological compounds that include terpenoids, sesquiterpenoids, flavonoids, and coumarins (Afshar et al., 2017; Bora, Sharma, 2011; Tan et al., 1998; Taleghani et al., 2020) [29-32]. *Artemisia abrotanum*, a common plant used in the culinary and cosmetics industries, has been reported to accumulate high levels of triquinane silphiperfol-5-en-3-one A (Muangphrom et al., 2019) [33]. *Artemisia abrotanum* and its active phytochemicals have been introduced as having antimalarial, antioxidant, cytotoxic, antispasmodic, anthelmintic, neuroprotective, anti-inflammatory, and antimicrobial agents (Taleghani et al., 2020; Amirmohammadi et al., 2014) [32, 34].

Monarda didyma. Twenty-nine constituents found in the green tissue samples of *Monarda didyma* turn out to be mainly terpenoids with linalool, p-cymene, thymol and thymol methyl ether as main compounds (Wryblewska et al., 2019) [35]. The different chemical composition was represented by the flowers essential oil which possesses p-cymene and terpinolene (above 80%) as main compounds (Wryblewska et al., 2019) [35]. *Monarda didyma* oil revealed the strong antimicrobial activity and completely inhibited the growth of Candida albicans yeast as well as Bacillus cereus and Pseudomonas fluorescens bacteria in a concentration of 0.01% (Wryblewska et al., 2019) [35]. Monarda plants contained of biologically active thymoquinone (Sovova et al., 2015) [36].

Agastache foeniculum. *Agastache foeniculum* is a perennial aromatic plant with antimicrobial and antifungal properties and useful for gastrointestinal problems. Components were identified, representing 95.4% of the oils including methyl chavicol, limonene, spathulenol and caryophyllene oxide (Hashemi et al., 2017) [37]. The extracts of flowers and leaves of *Agastache foeniculum* exhibited a high content of flavonoids, antioxidants and phenolic compounds (Shtereva et al., 2016) [38]. Analysis confirmed the presence of phenylpropanoids i.e., rosmarinic acid, tilianin, and acacetin (Park et al., 2014) [39].

Satureja hortensis. *Satureja hortensis* has been also used as folk remedies to treat various ailments such as cramps, muscle pains, nausea, indigestion, diarrhea, and infectious diseases. It has showed antispasmodic, anti-diarrhoeal, antioxidant, sedative as well as antimicrobial properties (Deans, Svoboda, 1989; Hajhashemi et al., 2000; Leung, Foster, 1996; Madsen et al., 1996) [40-43]. *Satureja hortensis* may be a valuable source of dietary and pharmacologically important phenolic compounds, especially rosmarinic acid, in pharmaceutical and functional food formulations in order to maintain normal health conditions or as a remedy in various diseases caused by oxidative damage (Boroja et al., 2018) [44].

Ruta graveolens. *Ruta graveolens* possess a wide range of pharmacological activities (Colucci-D'Amato, Cimaglia, 2020) [45] including antioxidant, insect repellent, larvicidal, antimicrobial, antiandrogenic, antidepressant, antihyperglycemic, antihyperlipedimic, anti-inflammatory, antitumour and cytotoxic activity on human cancer cell lines (Ahmed et al., 2010; Khouri et al., 2005; Tabanca et al., 2012; Ratheesh et al., 2013; Attia et al., 2018) [46-50], antiseptic, stimulant, abortifacient, antirheumatic, anthelmintic, antispasmodic, antiepileptic (Ahmed et al., 2010; Attia et al., 2018; Stashenko et al., 2000) [46, 50, 51]. The phytochemical studies have attributed these biological activities to the presence of some metabolites such as alkaloids, coumarins, flavonoids, ketones and terpenoids (Ratheesh et al., 2013; Attia et al., 2018; Stashenko et al., 2000) [49-51]. Among all the components of the plant extract, rutin – which is highly, if not the most, abundant – positively interacts with the neurophysiology (Colucci-D'Amato, Cimaglia, 2020) [45].

Nepeta transcaucasica Grossch. *Nepeta transcaucasica Grossch* are widely used in traditional medicine as antimicrobial, antioxidant, antiinflammatory, sedative, relaxant, cholesterol lowering, antiasthmatic, carminative, diuretic, diaphoretic, febrifuge, vermifuge,

herbicidal, insecticidal and insect repellent, all of them directly related to the specific chemical composition (Salehi et al., 2018) [52]. The active constituents from Nepeta genus may provide the opportunity for the production of antidepressive, antidiabetes, analgestic, anti-inflammatory, lipid-lowering and cardioprotective drugs (Salehi et al., 2018) [52].

These circumstances determine the relevance of this work, which is to develop aqueous-alcoholic infusions of vegetable raw materials in the technology of alcoholic beverages.

The aim of the research is to study the reducing ability of aqueous-alcoholic infusions from waste of aromatic raw materials in the technology of alcoholic beverages.

When achieving this goal, it is necessary to solve the following *problems*:

- To substantiate the prospect of using aqueous-alcoholic infusions from waste of aromatic raw materials in the production of alcoholic beverages;
- To establish the value of the restorative capacity of aqueous-alcoholic infusions from waste of aromatic raw materials;
- Identify the most promising sources of natural antioxidants for use in alcoholic beverage technology.

Materials and methods

Materials

The study used plant raw materials that are allowed to be used in the production of alcoholic beverages. In the *M.M. Gryshko National Botanic Garden of NAS of Ukraine* was created new cultures of spicy-aromatic plants, which became the subject of these studies (Rakhmetov, 2011) [53].

In the Figure 1 shows a photo of aqueous-alcoholic infusions from waste of aromatic raw materials. For preparation of aqueous-alcoholic infusions used the following basic raw materials: ethanol rectified, water, cardboard filtering.

The aqueous-alcoholic infusions should meet the requirements on sensory evaluation: appearance – transparent without sediment and foreign impurities fluid, acceptable opalescence that disappears after filtration; color, taste, aroma – the inherent vegetable raw materials from which they are made, without the foreign taste and odor.

The aqueous-alcoholic infusions must meet the requirements by physicochemical parameters: ethyl alcohol by volume – 20.0–90.0 %; mass fraction of essential oil – 0.0–15.0 %; mass concentration of the total extract – 0.1–20.0g/100 cm^3.

Aqueous-alcoholic infusion – semi-finished product, which is prepared by extraction of raw materials in aqueous-alcoholic solution with a strength of 40 %. The static method of extraction is called maceration. The tested aromatic raw material (dry) was infused in a aqueous-alcoholic mixture in this work.

Figure 1. Photo of Samples of crushed plant raw materials:
a – *Perilla frutescens*; b – *Elsholtzia stauntonii Benth*; c – *Artemisia abrotanum*; d – *Monarda didyma*; e – *Agastache foeniculum*; f – *Satureja hortensis*; g – *Ruta graveolens*; h – *Nepeta transcaucasica Grossch.*

Description of research procedure

The first stage – the preparation of infusions. Plant raw materials were minced into a size of 3x3 mm, suspensions of 4 g were placed into the glass bottles, were filled by 100 ml of alcohol solvent with volume fraction of rectified ethyl alcohol 40 %. The resulting infusions were cooled to 20 °C for 7 days, stirring periodically.

Next, the infusions were filtered and studies were performed to determine the indicators of active acidity, which was measured on a *pH* meter in the mode of *pH* measurement with a combined glass electrode. The *redox potential* was measured in the potential measurement mode with a combined redoxmetric platinum electrode.

Methods of sensory evaluation and antioxidant capacity

The expert method of determination of values of indexes of quality is based on the account of opinions of group highly skilled specialists-experts. (The expert of − it a specialist on the certain type of object which owns the increased sensitiveness to properties of this object) (Kuzmin et al, 2016; Kuzmin et al, 2017; Kuzmin et al, 2020) [54–56].

To evaluate the antioxidant properties of the obtained aqueous-alcoholic infusions, the *method* (Priluckij, 1997) [57], based on the difference of *redox potential* in inactivated inorganic solutions and biochemical complex. The main criteria of this method were its clarity, simplicity, specificity, reproducibility of results and efficiency. A number of researchers also emphasize that method allows to determine the total antioxidant activity of liquid products, including in total in a complex mixture, and multifunctional antioxidants (Kuzmin et al., 2016; Frolova et al., 2019; Kuzmin, 2017) [54, 58, 59].

Formula (1) holds for inactivated inorganic solutions in equilibrium. This formula links the active acidity of the *pH* and the *redox potential* (Priluckij, 1997) [57]:

$$Eh_{min}=660–60\cdot pH, \text{ mV} \quad (1)$$

where Eh_{min} – minimal theoretically expected value of the redox potential;
pH – active acidity of the test solution.

Acquired *redox potential* values were compared with actual measurements of Eh_{act} solution. The change of the *redox potential* toward the recovery energy (*RE*) was determined by the formula:

$$RE = Eh_{min}–Eh_{act}, \text{ mV} \quad (2)$$

where *RE* – shift of redox potential to the side of recovered meanings (resilence);
Eh_{act} – actual measured redox potential.

Results and discussions

Sensory evaluation

The results of sensory evaluation (Kuzmin et al, 2017) [55] of the obtained infusions on the extractant are presented in the Table 1-2 and Figures 2–3.

Table 1

Sensory evaluation (*S.e.*) of aqueous-alcoholic infusions

Plant raw materials	Color	Aroma	Test
1. Perilla frutescens	Light amber	Floral	Sour-bitter, tart, unpleasant
2. Elsholtzia stauntonii Benth	Light brown	Grassy, floral	Sour-bitter
3. Artemisia abrotanum	Thatched	Grassy	Bitter, with a long, bitter aftertaste
4. Monarda didyma	Thatched	Fragrant, floral	Sour-bitter, unpleasant, with a bitter aftertaste
5. Agastache foeniculum	Light amber	Bright ethereal, herbal, fragrant	Bitter, tart
6. Satureja hortensis	Light brown	Spicy, fragrant, herbal	Moderately hot, irritable, with a sweet taste
7. Ruta graveolens	Thatched	Fragrant, grassy, floral	Bitter, tart
8. Nepeta transcaucasica Grossch	Light brown	Mint	Soft, pleasant, sweet
9. Extractant – aqueous-alcoholic mixture	*Transparent*	*Alcoholly*	*Abrupt*

Table 2

Sensory evaluation (*S.e.*) of aqueous-alcoholic infusions

Plant raw materials	Color, points	Aroma, points	Flavor, points	S.e., points	+/-, points	+/-, %
1. Perilla frutescens	1.95	3.65	3.87	9.47	0.26	2.82
2. Elsholtzia stauntonii Benth	1.89	3.80	3.93	9.62	0.41	4.45
3. Artemisia abrotanum	1.91	3.69	3.90	9.50	0.29	3.15
4. Monarda didyma	1.88	3.71	3.92	9.51	0.30	3.26
5. Agastache foeniculum	1.98	3.72	3.98	9.68	0.47	5.10
6. Satureja hortensis	1.85	3.86	3.93	9.64	0.43	4.67
7. Ruta graveolens	1.91	3.70	3.95	9.56	0.35	3.80
8. Nepeta transcaucasica Grossch	1.73	3.96	3.95	9.64	0.43	4.67
9. Extractant – aqueous-alcoholic mixture	*1.84*	*3.57*	*3.80*	*9.21*		
min	1.73	3.65	3.87	9.47	0.26	2.82
max	1.98	3.96	3.98	9.68	0.47	5.10

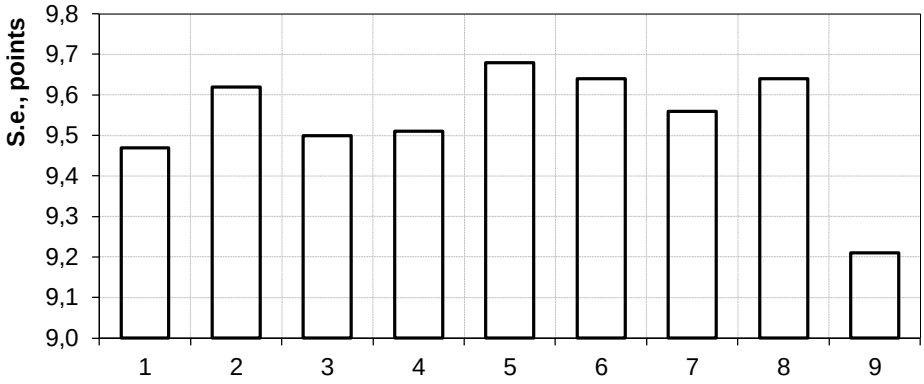

Figure 2. Sensory evaluation *(S. e.)* indicators of aqueous-alcoholic infusions on the extractant:
1 – Perilla frutescens; 2 – Elsholtzia stauntonii Benth; 3 – Artemisia abrotanum; 4 – Monarda didyma; 5 – Agastache foeniculum; 6 – Satureja hortensis; 7 – Ruta graveolens; 8 – Nepeta transcaucasica Grossch; 9 – aqueous-alcoholic mixture

Antioxidant capacity

Physicochemical studies, namely determination of the *pH* level and redox potential, were performed according to the method (Priluckij, 1997) [57] and calculations given above (Kuzmin et al, 2016) [54]. As a result of extraction received infusions (Andreou et al, 2018; Chandrasekara, Shahidi, 2018; Iannitti, Palmieri, 2009; Kawa-Rygielska et al, 2019) [9–12], physicochemical indicators of which are presented in the Table 3.

Figures 4–7 show graphically the change in the physicochemical indicators of the quality of aqueous-alcoholic infusions of spicy-aromatic raw materials on the extractant.

Table 3

Quality indicators of aqueous-alcoholic infusions on extractant

Plant raw materials	***t*, ºC**	***pH***	Eh_{min}**, mV**	Eh_{act}**, mV**	*RE*, **mV**
1. Perilla frutescens	18	7.11	233.4	124.0	109.4
2. Elsholtzia stauntonii Benth	19	7.04	237.6	117.0	120.6
3. Artemisia abrotanum	18	7.28	223.2	103.0	120.2
4. Monarda didyma	18	6.88	247.2	94.0	153.2
5. Agastache foeniculum	18	6.73	256.2	120.0	136.2
6. Satureja hortensis	18	7.35	219.0	108.0	111.0
7. Ruta graveolens	18	6.96	242.4	141.0	101.4
8. Nepeta transcaucasica Grossch	18	7.11	233.4	105.0	128.4
9. Aqueous-alcoholic mixture	*18*	*7.80*	*192.0*	*92.0*	*100.0*
min	**18**	**6.73**	**219.0**	**94.0**	**101.4**
max	**19**	**7.35**	**256.2**	**141.0**	**153.2**

where: *t* – temperature of infusion; *pH* – active acidity of the test solution; Eh_{min} – minimal theoretically expected meaning of *redox potential*; Eh_{act} – actual measured *redox potential*; *RE* – recovery energy

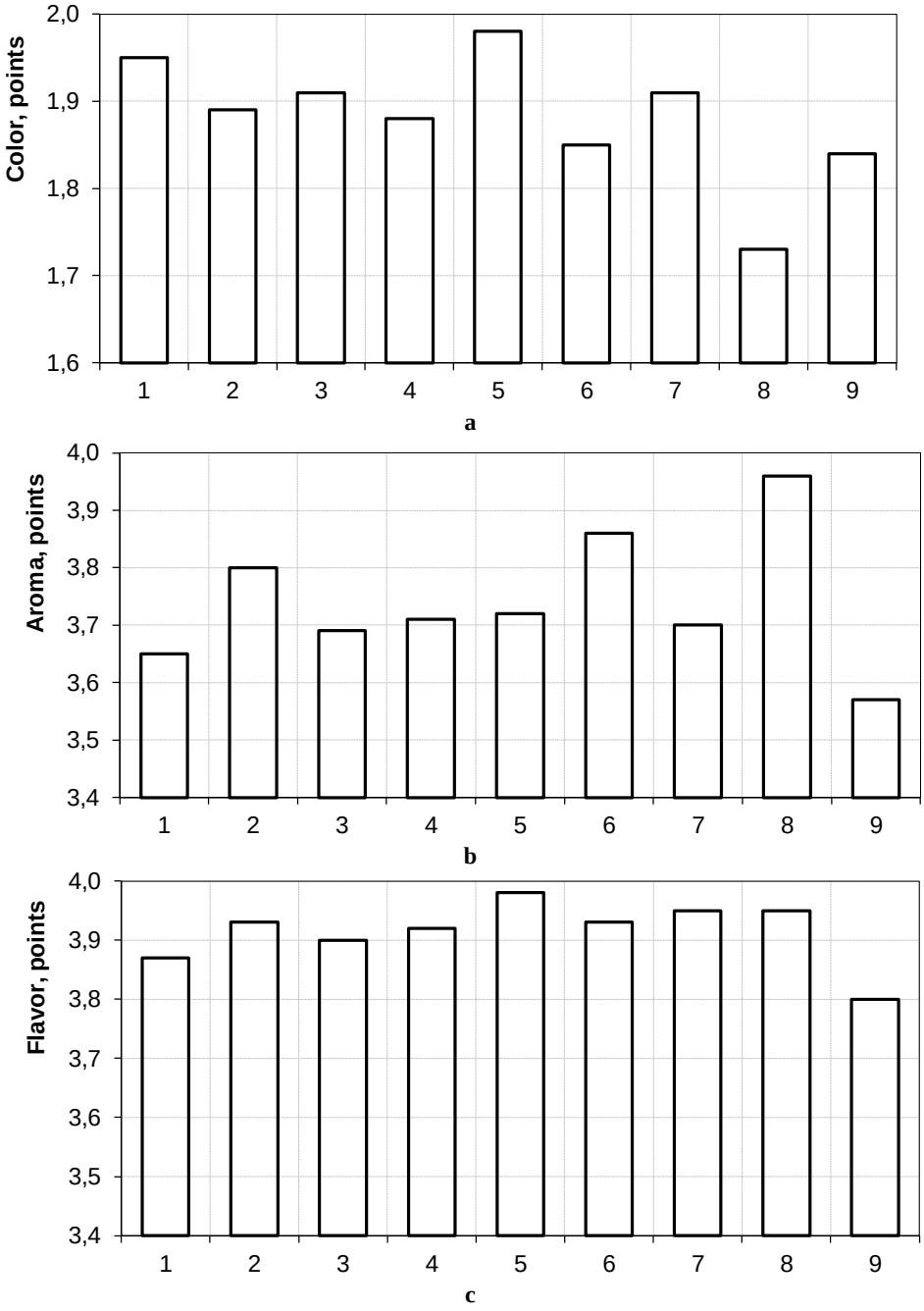

Figure 3. Sensory evaluation indicators of aqueous-alcoholic infusions on extractant:
a – color; b – aroma; c – flavor;
1 – Perilla frutescens; 2 – Elsholtzia stauntonii Benth; 3 – Artemisia abrotanum;
4 – Monarda didyma; 5 – Agastache foeniculum; 6 – Satureja hortensis; 7 – Ruta graveolens;

Figure 4. Hydrogen index (*pH*) of infusions of the investigated raw material:
1 – Perilla frutescens; 2 – Elsholtzia stauntonii Benth; 3 – Artemisia abrotanum; 4 – Monarda didyma; 5 – Agastache foeniculum; 6 – Satureja hortensis; 7 – Ruta graveolens; 8 – Nepeta transcaucasica Grossch; 9 – aqueous-alcoholic mixture

The minimum theoretical value of redox potential (Eh_{min}) for plant aqueous-alcoholic infusions (Priluckij, 1997) [57] was obtained, which has a value from 219.0 mV (*Satureja hortensis*) to 256.2 mV (*Agastache foeniculum*), which is 14.06% and 33.44% more than in the control (Eh_{min} 192 mV).

The value of the actually measured redox potential for aqueous-alcoholic infusions Eh_{act} from 94.0 mV (*Monarda didyma*) to 141.0 mV (*Ruta graveolens*), which is more than 2.17% and 53.26 %, respectively, for the control (Eh_{act} 92 mV).

In relation to the control (7.80 *pH* units) infusions have a *pH* value of 6.73 units *pH* (*Agastache foeniculum*) up to 7.35 units *pH* (*Satureja hortensis*), which is 13.72% and 5.77 %, respectively, less than control.

Aqueous-alcoholic infusions from wastes of spicy-aromatic raw materials have a reduction capacity (reduction energy) *RE* from 101.4 mV (*Ruta graveolens*) to 153.2 mV (*Monarda didyma*), which is greater than the control (aqueous-alcoholic mixture) *RE* 100 mV by 1.40% and 53.20% respectively. Aqueous-alcoholic infusions from waste of spicy-aromatic raw materials have the value of *S.e.* from 9.47 to 9.68 points in relation to control *S.e.* 9.21 points. The highest value of *S.e.* 9.68 points are characteristic of the aqueous-alcoholic infusion of *Agastache foeniculum*: color – light amber (1.98 points); taste – bright ethereal, herbal, fragrant (3.98 points); aroma – bitter-sour, tart (3.72 points).

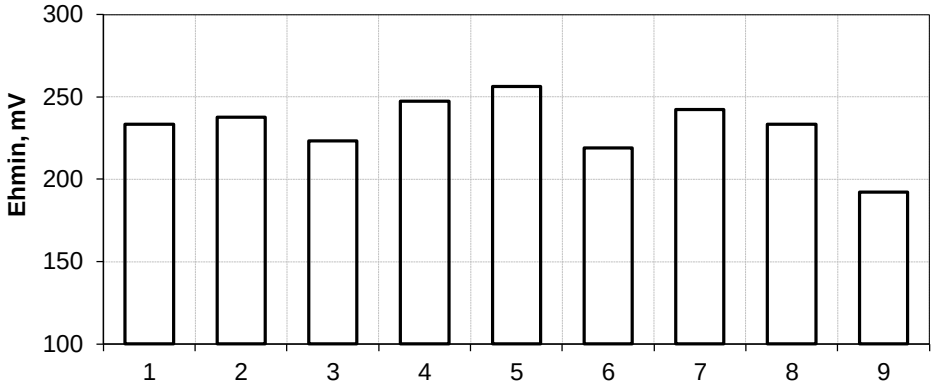

Figure 5. The minimum theoretical value of redox potential (Eh_{min}) of infusions of the investigated raw material

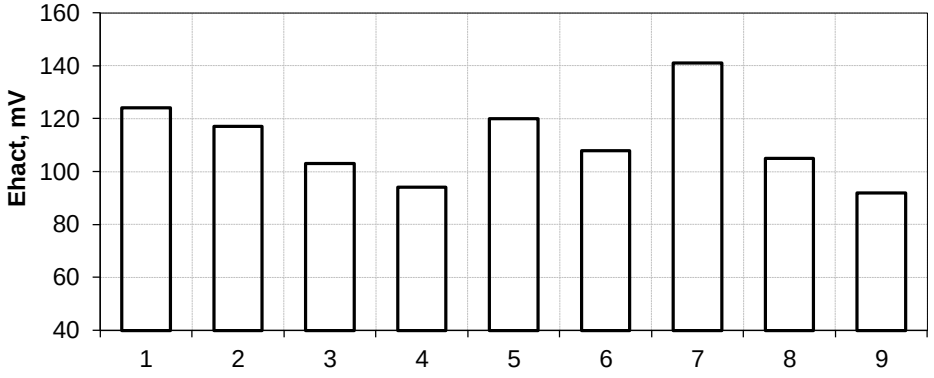

Figure 6. The actual measured redox potential of infusions (Eh_{act}) of infusions of the investigated raw material

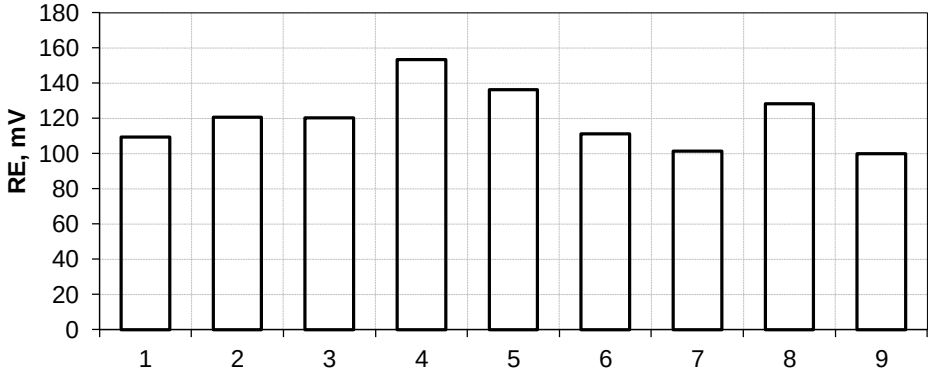

Figure 7. Recovery energy (RE) of infusions of the investigated raw material

For Figures 5–7: 1 – Perilla frutescens; 2 – Elsholtzia stauntonii Benth; 3 – Artemisia abrotanum; 4 – Monarda didyma; 5 – Agastache foeniculum; 6 – Satureja hortensis; 7 – Ruta graveolens; 8 – Nepeta transcaucasica Grossch; 9 – aqueous-alcoholic mixture

Development of recipes of alcoholic beverages

On the basis of the obtained results, it was established that the maximum values of redox potential has a aqueous-alcoholic infusion of *Ruta graveolens.* This aqueous-alcoholic infusion was used in the preparation of cocktail, the recipe of presented in Table 4.

Table 4

Composition of the cocktail

№ of point	Content, %						Conclusions
	Red wine	**Cognac**	**Vodka**	**Sugar**	**Nutmeg, cloves, cinnamon, allspice**	**Aqueous-alcoholic infusion of Monarda didyma**	
1	67	12	7	8	0.2	5.8	The composition of the recipe provides an alcoholic cocktail with satisfactory physicochemical and organoleptic characteristics, but not sufficiently enriched with biologically active substances
2	66	9	5	9	0.4	10.6	The composition of the recipe provides an alcoholic cocktail with good physicochemical and organoleptic characteristics, and is also sufficiently enriched with biologically active substances
3	64	6	4	10	0.6	15.4	
4	63	3	2	11	0.8	20.2	
5	62	0	0	12	1.0	25.0	The composition of the recipe provides an alcoholic cocktail with good physicochemical characteristics and biologically active substances, but deteriorated organoleptic characteristics

The data obtained are correlated with the basic scientific concepts which are displayed in the works (Buglass et al, 2012; Grunert et al, 2018; Gulua et al, 2018) [14–16], regarding the processes of extracting of plant materials.

Improvement of the technology of alcoholic beverages (Andreou et al, 2018; Chandrasekara, Shahidi, 2018; Iannitti, Palmieri, 2009; Kawa-Rygielska et al, 2019; Vergun et al, 2019) [9–13] is due to the addition of spicy-aromatic aqueous-alcoholic infusions. It allows to increase the antioxidant properties of the product (Vergun et al, 2019) [13], will help to increase the immunity of the human body, improve the metabolism, positively affect the cardiovascular system, in addition it increases the consumer properties and will allow to reduce the cost of the finished product.

The relevance of the use of *Monarda didyma* in the technology of alcoholic beverages and their waste is confirmed by the studies of other scientists (Wryblewska et al., 2019; Sovova et al., 2015) [35, 36] and our research (Kuzmin et al, 2020) [56].

Conclusions

1. It is established that one of the promising ways of forming consumer properties and expanding the range of alcoholic products is the use of aqueous-alcoholic infusions from waste of aromatic raw material, which include biologically active substances. Such substances improve the sensory evaluation of beverages, contribute to the promotion of human health (antioxidant effects, enhancing redox reactions).
2. Experimental studies show that all aqueous-alcoholic infusions from waste of aromatic raw materials contain antioxidant systems. It was found that the recovery value of all the tested aqueous-alcoholic infusions is positive and ranges from 101.4 to 153.2 mV.
3. Improvement of the technology of alcoholic cocktails by adding spicy-aromatic aqueous-alcoholic infusions allows to increase the redox properties of the product, increases consumer properties and reduces the cost of the finished product.

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Determination of aroma and volatile flavor compounds and sensory properties of set-type yoghurts enriched with immature wheat grain

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Abstract

Introduction. The aim of this study was to investigate how enriching yoghurt with immature wheat grain (IWG) influence on aroma and volatile compounds and sensory properties of yoghurts.

Materials and methods. IWG was harvested in two different stages called the milky and dough stage before fully maturation phase. Yoghurt samples were enriched with milky stage grain flour (MSF) and dough stage grain flour (DSF) at different levels (0, 1, 2, and 3%) to benefit from their prebiotic and functional properties. The flavor and volatile compound contents of the yoghurt samples were identified by using the solid-phase microextraction (SPME) technique on the 1st, 14th and 28th days of the storage period.

Results and discussion. The amount of acetaldehyde, the characteristic flavoring agent of yoghurt, was at a higher concentration in the yoghurt enriched with MSF. Also, acetaldehyde decreased from 14.87 to 7.54 ppm in the samples as the storage period progressed. An increase in the amount of ethyl alcohol was observed in the control and other enriched yoghurt samples in accordance with the decrease in the amount of acetaldehyde with storage. Besides, volatile acids that contributed to taste and aroma such as butyric acid, octanoic acid, acetic acid and hexanoic acid were identified in the enriched yoghurt samples. Isobutyl 2-methylvalerate, which caused cereal-like taste and smell, was determined in yoghurt samples enriched with MSF and DSF. This ester increased depending on the enrichment ratios and it led to intense cereal-like taste in yoghurts with enrichment ratio of 3%. As the ratio of addition to yoghurt samples enriched with IWG flour increased, the cereal flavor became predominant and this reduced consumer appreciation.

Conclusions. Using IWG flour in yoghurt production effected on aroma and volatile flavor compounds of yoghurt samples. In this context, flavoring agents can be used to mask the cereal flavor and taste that becomes dominant by increasing concentration of MSF and DSF in yoghurts.

Introduction

Yoghurt has long been among the most recognized and consumed products of fermented milk products. It is produced by lactic acid fermentation using *Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus*. More than 90 different aroma and volatile flavor compounds have been identified in yoghurt and the formation of these aromatic compounds is impressed by the milk composition, yoghurt processing condition, yoghurt starter cultures, and incubation conditions [1].

As well as lactic acid with an acidic and refreshing taste, various carbonyl compounds such as acetone, diacetyl, and acetaldehyde are the main compounds that give the yoghurt its typical taste and aroma. Among these compounds, acetaldehyde is considered as the most important characteristic flavor compound of yoghurt [2, 3]. Several compounds including non-volatile acids (lactic, pyruvic, oxalic or succinic acids) consisting of lactose, caseins, amino acids, lipids, citric acid, and free fatty acids, volatile acids (butyric, acetic, formic or propionic acid), carbonyl compounds (acetaldehyde, acetone, diacetyl or acetoin) and amino acids also form flavor compounds in yoghurt [4]. Since yoghurt bacteria lack the alcohol dehydrogenase enzyme required for the conversion of acetaldehyde to ethanol, acetaldehyde compounds are present in yoghurt in high concentrations (in the range of 5-21 mg/l) compared to other compounds [5].

In 2020 years, there has been an increase in demand for functional foods in conjunction with low-calorie, low-fat and low-cholesterol foods. An important development regarding this issue has been in foods enriched with dietary fiber [6]. In this context, IWG containing high dietary fiber (especially fructooligosaccharides), protein, and antioxidant components was used in recent studies as a prebiotic, improving textural properties and nutritional value of food product [7, 8]. IWG was harvested at 2–3 weeks after anthesis, this physiological stage called the ‘milky phase’. In the milky phase, wheat grain has maximum fructooligosaccharides content and antioxidant compounds, thereafter their concentration rapidly reduces per grain [7, 9].

The flavor and aroma of yoghurt play an important role in the consumption of it. Therefore some researchers investigated the effect of various additives used fortification of yoghurt to improve textural, nutritional, and sensorial attributes on aroma compounds of yoghurts [10, 11]. These authors stated that of all the additives studied, starch, pectin, and some sweeteners presented a significant effect on the aroma compounds of yoghurt.

In this study, the aroma and volatile compound contents of the yoghurt samples enriched with MSF and DSF were determined and their effects on their sensory properties were investigated. For this purpose, the solid-phase microextraction technique (SPME) was used to define the aroma and volatile profiles of the yoghurt samples enriched IWG by using gas chromatography-mass spectrometry (GC-MS).

Materials and methods

Materials

Whole-fat raw milk (12.44±0.08% total dry matter, 3.85±0.08% protein, 0.76±0.11% ash, 4.00±0.14% fat, pH: 6.74±0.01) used in yoghurt production was taken from the dairy farm of the Faculty of Agriculture at Selcuk University. Total non-fat milk solids of the milk were standardized to 12% with medium-heated skim milk powder (ENKA Dairy Product, Turkey). Yoghurt starter cultures (*Streptococcus thermophilus* and *Lactobacillus delbrueckii*

subsp. *bulgaricus*) and κ-carrageenan were obtained from Chr. Hansen-Peyma (Istanbul, Turkey) and Sigma-Aldrich Chemical Company (St. Louis, MO, USA), respectively.

IWG was obtained from the 'Soylu Durum Wheat' which harvested from the Sarıcalar Research and Application Farm of the Faculty of Agriculture at Selcuk University in two different maturing stages called milky (65% moisture in grain) and dough stage (50% moisture in grain).

Production of whole wheat flour from immature wheat grain

After the harvest, wheat grains were separated from their stems and husks. The cleaned wheat was milled in a laboratory type hammer mill equipped with a 1 mm opening screen (Falling Number-3100 Laboratory Mill, Perten Instruments AB, Huddinge, Sweden) to produce IWG flour.

Production of yoghurt samples

After non-fat solids of raw milk were standardized to 12% (w⁄w) with the medium-heated skim milk powder, it was portioned in equal amounts and put into containers. Standardized milk was enriched with the MSF and DSF at levels of 0 (control), 1, 2, or 3% (w⁄v). 0.03% κ-carrageenan was added to prevent sedimentation of the MSF and DSF into the yoghurt samples and mixed with Ultra-Turrax blender until it became homogeneous. The obtained mixture, which was subjected to heat treatment at 90 ˚C for 10 minutes by stirring, was cooled to approximately 45±1˚C. After cooling, the mixture was inoculated with 3% (v/v) yoghurt starter cultures and incubated until pH 4.6 at 43±1 ˚C. At the end of incubation, yoghurt samples were cooled to +4 ˚C and stored for 28 days under refrigerator conditions.

Method

Determination of flavor and volatile compounds

The aroma and volatile compounds in the samples were identified according to the method of Lee, Diono [12] by using gas chromatography and mass spectrometry (GC-MS, model GC 7890 A, Agillent, USA). For this purpose, 3 g sample was put into 20 ml vials and 3 ml NaCl solution (10%, w/v) and 10 µl of internal standard (IS, 81 ppb; 2 methyl-3 heptanone and 2-methyl pentanoic acid in methanol) were added on it. Samples were mixed at 50 ˚C for 30 min in a heat stirrer. The extraction of volatile compounds was carried out with SPME, a solvent-free extraction technique. It was exposed to headspace conditions at 50 ˚C for 30 minutes for the absorption of the aroma compounds of 75 µm carboxen / polydimethyl siloxane fiber (CAR / PDMS, Supelco, PA, USA). At the end of this period, it was injected into the GC-MS. After the injection, the fiber was kept in the detector for 3 mins, at 250 ˚C. The analysis was carried out in splitless mode. The aroma materials were separated using DB-Wax column (30 m x 0.25 mm x 0.25 µm). Helium with a flow rate of 3 ml/min was used as the carrier gas. The oven temperature program was started with a 10 min wait at 50 ˚C. The oven temperature was gradually raised to 110 ˚C with an increase of 5 ˚C per minute. Then, it was raised to 250 ˚C with an increase of 10 ˚C per minute and waited for 10 minutes. Volatile compounds were identified by using the Wiley and NIST flavor libraries in GS/MS. Relative quantities of volatile compounds were calculated by proportioning the peak areas of the internal standard and the peak areas of the volatile compounds.

Sensory analysis

Yoghurt samples enriched with MSF and DSF were stored at +4 ˚C for 28 days and sensory analyzes were performed on the 7th and 21st days of storage. The panelist group of 9 people, who carried out the sensory evaluations, consists of academicians between the ages of 30-50 who are working at the Food Engineering Department of Selcuk University. The sensory properties of yoghurt samples were evaluated in terms of appearance, texture, mouth feel, smell, and taste by using a scale of 1 to 5 (1: extremely dislike; 5: extremely like) [13].

Statistical analysis

Sensory evaluation results were evaluated statistically (ANOVA) in terms of mean and variance analysis and comparisons were made according to the Tukey test at the level of $p<0.05$ using the MiniTab 7.1 statistics program [14].

Results and discussion

The aroma and volatile compound content

The relative amounts of the aroma and volatile compounds of immature wheat flour used to enrich yoghurt are given in Table 1. Flavors and volatile compounds in 7 different groups such as carboxylic acids (4), ketones (8), esters (9), aldehydes (8), hydrocarbons (2), alcohols (9) and, terpenes (2) were identified in the flour obtained from the wheat harvested in milky stage and dough stage.

16 different flavors and volatile compounds were identified in yoghurt samples enriched with MSF and DSF. These compounds belong to different chemical groups such as carboxylic acids (4), aldehydes (1), esters (1), alcohols (3), hydrocarbon (1), and ketones (6).

Carboxylic acids

4 different volatile acids including butyric acid (butanoic acid) octanoic acid (caprylic acid), acetic acid, and hexanoic acid (capric acid) were identified in the yoghurt samples enriched with MSF and DSF (Table 2).

The concentrations of butyric acid, octanoic acid (caprylic acid), acetic acid and hexanoic acid (capric acid) in the samples ranged between 9.95-24.23 ppm, 20.18-68.76 ppm, 15.53-34.96 ppm and 23.53-79.25 ppm, respectively. The amounts of these short-chain fatty acids increased during the storage period. This could be explained by the high metabolic activity of *L. delbrueckii* ssp. *bulgaricus* during the storage period, which may lead to increased amounts of these compounds. Terpou, Bekatorou [15] indicated similar results for probiotic yoghurts enriched with wheat bran, that's the amount of short-chain fatty acids increased as the storage period progressed.

In general, it was observed that butyric acid concentrations in yoghurt samples enriched with MSF and DSF increased depending on the enrichment ratio and storage period. However, in some studies, it was stated that enrichment in prebiotic and fiber added yoghurts did not affect butyric acid production [16, 17]. Additionally, free butyric acid, which is found in fermented milk products more than milk, causes rancid taste as well as cheese taste and aroma [18].

When the concentration of acetic acid of the yoghurt samples was analyzed, it could be stated that they did not show a regular increase or decrease depending on the enrichment material, the enrichment ratio, and the storage period.

Table 1

Identification of aroma and volatile compounds (ppm) of MSF and DSF

Compound name	MSF[1]	DSF[2]	Compound name	MSF[1]	DSF[2]
Carboxylic acids			***Aldehydes***		
Hexanoic acid	1.91	3.69	trans-2-Heptenal	0.41	1.00
Isovaleric acid	3.32	ND	Nonanal	0.43	10.41
Octanoic acid	0.21	ND	Octanal	ND	3.85
2- Methylheptanoic acid	1.13	ND	n-decanal	ND	1.91
Ketones			Benzaldehyde	ND	3.53
3,5-octadiene-2-one	ND	3.73	trans-2-Nonenal	ND	0.57
3-octanone	ND	0.32	2-Butyl-2-octenal	ND	0.88
2-undecanone	ND	0.29	Furfural	ND	0.38
2-octanone	ND	1.00	***Hydrocarbons***		
2-nonanone	3.16	23.66	Styrene	5.56	4.40
6-Methyl-5-hepten-2-one	7.83	0.95	n-Dodecane	ND	1.09
4-(3'-Thienyl)-1,5-dihydro-2H-pyrrol-5-one	7.20	ND	***Alcohols***		
Esters			Nonanol	2.18	0.38
Hexyl hexanoate	ND	0.47	1-Tetradecanol	1.06	0.06
Methyl heptacosanoate	ND	1.24	2-Heptanol	2.11	0.68
Butyl hexanoate	ND	0.65	1-Hexanol	0.35	3.89
Methyl myristate	0.39	ND	Benzyl alcohol	3.37	2.24
Methyl nonanoate	4.43	3.02	Phenethyl alcohol	0.39	
2-Propenoic acid, 3-ethoxy-, ethyl ester	1.93	2.83	3-Pentanol	ND	2.38
Methyl hexanoate	9.61	3.83	1-octen-3-ol	ND	2.99
Propanoic acid, 2-methyl-, 2,2-dimethyl-1-(2-hydroxy-1-methylethyl) propyl ester	1.16	ND	3,5-Octadien-2-ol	ND	1.78
Ethyl acetate	0.59	ND	***Terpenes***		
			Limonene	1.54	2.43
			Eucalyptol	1.50	ND

1MSF: whole meal obtained from wheat harvested at milky development stage; DSF: whole meal obtained from wheat harvested at milky development stage; ND: not detected

Table 2

Concentration of carboxylic acids and esters (ppm) of enriched yoghurt samples with MSF and DSF during storage period

	Period of storage (days)	Control	1% MSF	2% MSF	3% MSF	1% DSF	2% DSF	3% DSF
Carboxylic acids								
Butyric acid (Butanoic acid)	1	17.48 ±1.82	ND	15.59 ±1.38	21.19 ±1.29	9.95 ±0.49	12.45 ±1.30	ND
	14	20.76 ±0.96	11.79 ±2.00	17.60 ±0.44	ND	ND	16.98 ±1.91	24.23 ±0.56
	28	ND	18.17 ±0.94	19.92 ±1.13	ND	19.59 ±1.53	19.23 ±1.21	ND
Octanoic acid	1	49.82 ±3.94	39.89 ±5.62	ND	43.33 ±4.56	ND	20.18 ±0.47	ND
	14	46.11 ±5.11	38.56 ±3.09	ND	56.30 ±2.17	46.98 ±4.47	43.35 ±6.12	47.17 ±3.74
	28	56.66 ±7.97	53.37 ±5.96	52.49 ±6.83	68.76 ±6.02	54.26 ±2.90	51.72 ±5.84	48.78 ±1.95
Acetic acid	1	28.85 ±9.35	25.31 ±3.80	23.59 ±1.80	28.62 ±5.73	16.48 ±3.78	15.53 ±6.33	18.95 ±3.93
	14	24.95 ±0.62	19.89 ±0.38	33.86 ±1.80	32.58 ±8.19	25.09 ±6.26	28.67 ±7.06	34.96 ±6.46
	28	27.75 ±3.30	40.58 ±9.53	29.28 ±3.66	31.76 ±6.10	28.54 ±0.14	27.70 ±5.31	22.57 ±1.87
Hexanoic acid	1	ND	ND	23.53 ±1.17	31.26 ±2.77	25.60 ±0.23	64.03 ±1.66	56.38 ±8.45
	14	45.19 ±1.82	53.59 ±3.00	ND	57.02 ±2.81	52.25 ±1.11	59.02 ±6.68	79.25 ±8.62
	28	55.00 ±2.83	56.91 ±1.62	47.22 ±3.93	ND	67.32 ±3.39	64.65 ±3.98	56.32 ±3.17
Esters								
Isobutyl 2-methylvalerate	1	ND	ND	ND	ND	ND	13.63 ±0.51	20.31 ±0.55
	14	ND	22.24 ±0.66	ND	12.42 ±0.42	14.89 ±0.77	20.96 ±0.42	ND
	28	ND	17.78 ±0.63	ND	ND	ND	30.38 ±0.72	ND

[1]MSF: whole meal obtained from wheat harvested at milky development stage; [2]DSF: whole meal obtained from wheat harvested at milky development stage; ND: not detected

Esters

During the 28 days of storage, one ester, an isobutyl 2-methylvalerate in amounts ranging from 12.42 ppm to 30.38 ppm, was identified in the yoghurt samples. The isobutyl 2-methylvalerate was not found in the control yoghurts without enrichment MSF and DSF, but only in the yoghurts containing MSF and DSF. Thus, it could be stated that this ester causes the cereal-like taste and aroma in the enriched yoghurt samples. Similarly, Terpou, Bekatorou [15] identified high amounts of five different esters in yoghurts fortified with wheat bran and reported that these esters gave cereal flavor to yoghurts. In addition to these, in another study, Terpou, Gialleli [18] reported that esters such as ethyl butanoate, ethyl hexanoate, ethyl octanoate, and ethyl decanoate were important esters identified in all sour milk was produced by using wheat bran supported probiotic biocatalysts. Esters generally are responsible for the fruit odor in food products. In addition, esters are known to reduce the effects of unpleasant odor from phenolic compounds and short-chain fatty acids [19].

Aldehydes

The concentrations of acetaldehyde, which is the characteristic flavoring agent of yoghurt, varied between 14.87 ppm and 1.27 ppm during the storage period in yoghurt samples (Table 3). As seen in Table 3, the acetaldehyde level of yoghurts enriched with MSF was higher than those enriched with DSF. This could be explained by the fact that MSF including high fructooligosaccharides further supports the activity of yoghurt bacteria. While the amount of fructooligosaccharide that is prebiotic in the wheat grain during maturing of wheat increases rapidly until the 10th day after flowering, it decreases rapidly in the latter days of the next maturing stages [20, 21]. In this context, the MSF additive harvested on the 20th day after flowering supported the development of yoghurt bacteria more than the DSF additive harvested on the 30th day after flowering. In 1% MSF, 2% MSF, and 3% MSF samples, the acetaldehyde was determined as 9.66, 6.28, and 5.27 ppm, respectively, on the first day of the storage period. As seen from the results, the amount of acetaldehyde decreased in yoghurt samples as the enrichment ratio increased. The cereal-like taste and aroma became dominant in the samples as the concentrations of MSF and DSF added to enrich the yoghurt samples increased. Besides, some aroma compounds such as esters identified in enriched yoghurts can mask acetaldehyde, which is the characteristic aroma of yoghurt.

The concentration of acetaldehyde was determined as 14.78, 12.18, and 7.54 ppm in control yoghurt on the 1st, 14th, and 28th days of storage, respectively. The acetaldehyde levels showed a decrease in all samples depending on the progressive storage time (Table 3). This decrease in the concentration of acetaldehyde could be explained by the reduction of acetaldehyde to ethyl alcohol [22]. In addition, it could be said that the decrease in acetaldehyde level in yoghurts during storage might be due to evaporation of acetaldehyde from samples and/or hydrolysis by microbial enzymes to form different substances. Acetaldehyde can easily oxidize to acetate and accordingly, its level decreases. Since the said condition occurs at high acidity values, it is stated that the loss of acetaldehyde occurring in the later stages of storage is caused by the enzyme alcohol dehydrogenase originated from *S. thermophilus*. [4, 23, 24]. Our result is similar to the studies performed with plain yoghurt samples [25, 26] or the yoghurt samples enriched with different additives [27, 28].

Table 3

Concentration of aldehydes, alchols and hydrocarbons (ppm) of enriched yoghurt samples with MSF and DSF during storage period

	Period of storage (days)	Control	1% MSF	2% MSF	3% MSF	1% DSF	2% DSF	3% DSF
Aldehydes								
Acetaldehyde	1	14.87 ±1.02	10.35 ±0.84	9.66 ±0.78	6.28 ±1.14	5.27 ±0.71	2.81 ±1.20	1.27 ±0.11
	14	12.18± 0.62	7.66 ±1.15	7.53 ±0.42	4.36 ±0.83	4.10 ±0.54	2.88± 0.97	2.75 ±0.19
	28	7.54 ±0.101	5.78 ±0.28	4.76 ±0.48	4.37 ±0.49	3.82 ±0.41	1.71 ±0.78	1.44 ±0.16
Alcohols								
Ethanol	1	2.12 ±0.19	3.76 ±0.62	5.56± 0.35	2.58± 0.69	4.33± 0.31	6.10± 0.79	1.64 ±0.31
	14	3.73 ±0.59	4.11 ±1.08	6.42 ±0.65	2.24 ±0.52	2.94 ±0.79	7.46 ±1.03	7.77 ±0.63
	28	5.38 ±0.85	6.26 ±1.06	5.81 ±1.29	3.55 ±0.46	3.27 ±0.39	8.03 ±0.77	8.77 ±0.41
1,2-Butanediol	1	ND	ND	ND	6.97± 0.60	ND	ND	ND
	14	ND	ND	ND	ND	ND	ND	ND
	28	4.95 ±0.26	ND	ND	3.96 ±0.43	3.45 ±0.56	2.95 ±0.23	
Furfuryl alcohol	1	ND	15.62 ±0.67	3.80 ±0.37	ND	ND	ND	ND
	14	ND	ND	8.06 ±0.63	3.70 ±0.45	ND	ND	8.67 ±0.47
	28	7.01 ±0.98	7.88 ±0.95	9.86 ±0.57	ND	ND	ND	12.68 ±0.96
Hydrocarbons								
Styrene	1	4.65 ±0.27	ND	ND	2.53 ±0.29	ND	ND	ND
	14	ND	ND	ND	ND	ND	ND	ND
	28	23.31 ±1.03	ND	ND	26.36 ±0.43	ND	ND	ND

[1]MSF: whole meal obtained from wheat harvested at milky development stage; [2]DSF: whole meal obtained from wheat harvested at milky development stage; ND: not detected

Alcohols

As seen in Table 3, three different types of alcohol, including ethyl alcohol, 1,2-butanediol, and furfuryl alcohol were identified in yoghurt samples enriched with MSF and DSF. The amount of ethyl alcohol varied between 1.64 and 8.77 ppm in yoghurt samples.

An increase in the concentration of ethyl alcohol was observed in all samples in accordance with the decrease in the amount of acetaldehyde depending on the storage period. Besides, the content of ethyl alcohol was higher in enriched yoghurt samples compared to control yoghurts (Table 3). This may be explained by the fact that MSF and DSF additives added to yoghurt support the activity of starter culture [29].

Furfuryl alcohol amounts of enriched yoghurt samples ranged from 3.70 ppm to 15.62 ppm. Furfuryl alcohol consists of lactose, which occurs as a result of heat treatment applied to yoghurt milk [30]. Although a regular increase and decrease in concentration of furfuryl alcohol were not detected during the storage period, it was observed that the furfuryl alcohol content of yoghurts enriched with 2% MSF increased as the storage period progressed. This increase in furfuryl alcohol level is thought to be due to the activity of yoghurt starter bacteria that continue during storage were best supported by a 2% MSF additive.

Hydrocarbons

Styrene, one of the aromatic hydrocarbons, was identified in the control and yoghurt samples enriched with 3% MSF on the 1st and 28th days of the storage period, while this hydrocarbon was not found in any yoghurt samples on the 14th day of storage. Styrene, which has a sweet taste and can be easily evaporable is usually found in plants, but also in fruits, vegetables, nuts, milk, and dairy products [31]. Our result is in agreement with the findings of Terpou, Gialleli [18] who identified volatile flavor compounds in sour milk produced by using wheat bran supported probiotic biocatalysts. On the other hand, these researchers stated that while the styrene was detected on the first day of storage, were not detected at 30th day and this situation could be caused by metabolizing other compounds.

Ketones

Six different ketones were identified in the yoghurt samples during the storage. Of these ketones, 2,3-pentanedion and 4-octanone were identified in all yoghurt samples, while 2-butanone, 3-hydroxy, 2-nonenone 3-methyl-2-butanone, and 2-dodecanone were not identified in some yoghurt samples throughout the storage (Table 4). It could be said that the identified ketones were caused by heat treatment applied to yoghurt milk. Because ketones are formed by the thermal breakdown of fat caused by heating the yoghurt milk [32].

Table 4

Concentration of ketones (ppm) of enriched yoghurt samples with MSF and DSF during storage period

	Period of storage (days)	Control	1% MSF	2% MSF	3% MSF	1% DSF	2% DSF	3% DSF
Ketones								
2-Butanone, 3-hydroxy (Acetoin)	1	12.43 ±1.28	10.86 ±0.88	ND	12.14 ±1.43	ND	4.43± 0.36	3.67 ±0.35
	14	7.61 ±0.70	4.03± 1.17	6.79 ±0.52	9.16 ±0.89	10.38 ±1.22	8.68 ±0.45	8.87 ±3.02
	28	8.35 ±2.04	10.94 ±2.78	7.80 ±0.21	9.77 ±0.46	11.71 ±1.27	6.78 ±1.06	ND
2-nonanone	1	6.63 ±1.17	ND	6.14 ±0.36	8.20 ±1.24	ND	8.10 ±0.61	ND
	14	5.92 ±1.22	ND	5.81 ±2.06	5.61 ±1.03	ND	7.27 ±0.59	ND
	28	5.53 ±0.24	7.57 ±0.89	9.35 ±1.06	8.39 ±0.67	7.74 ±0.66	14.78 ±0.95	25.86 ±0.90
4-Octanone	1	5.60 ±0.18	5.57 ±0.21	4.72 ±0.92	5.19 ±0.41	5.43 ±0.19	5.01 ±1.10	5.22 ±0.30
	14	5.89 ±0.78	6.12 ±0.60	4.83 ±0.57	4.96 ±0.28	5.11 ±0.12	4.94 ±1.42	5.90 ±0.44
	28	5.77 ±0.17	5.69 ±0.32	5.96 ±0.00	4.89 ±0.21	5.58± 0.33	4.99± 0.87	5.14 ±0.19
3-methyl-2-butanone	1	ND	ND	ND	3.63 ±0.17	ND	ND	
	14	ND	ND	ND	3.54 ±0.35	ND	ND	3.38 0.34
	28	ND	2.04 ±0.47	ND	4.71 ±0.24	ND	ND	
2,3-Pentanedione (Acetylpropionyl)	1	3.51 ±0.35	11.08 ±0.11	13.41 ±0.48	25.45 ±1.42	3.21 ±0.85	20.04 ±2.70	24.96 ±2.23
	14	3.38 ±0.17	9.77 ±0.98	22.51 ±1.06	33.49 ±0.57	6.67 ±0.34	27.22 ±3.51	37.40 ±2.75
	28	4.37 ±0.30	11.00 ±1.17	15.16 ±1.43	23.04 ±0.43	15.00 ±0.85	17.61 ±1.83	23.95 ±1.72
2-Dodecanone	1	2.39 ±0.19	ND	ND	ND	ND	ND	6.30 ±0.71
	14	4.54 ±0.66	ND	6.80 ±0.27	ND	ND	ND	ND
	28	6.79 ±0.29	ND	ND	10.10 ±1.24	ND	ND	ND

[1]MSF: whole meal obtained from wheat harvested at milky development stage; [2]DSF: whole meal obtained from wheat harvested at milky development stage; ND: not detected

Sensory characteristic

Results of sensory evolution of yoghurt samples enriched with MSF and DSF for the 7th and 21st day of storage are given in Table 5. Yoghurt samples enriched with MSF were scored higher than yoghurt with DSF in the evaluation of appearance, and as the contribution rate increased, the likability of the samples decreased in terms of appearance. This outcome is in agreement with data reported by Tomic, Dojnov [33] who investigated the sensory properties of yoghurts enriched with triticale, wheat, and oat fiber (15 g/kg and 30 g/kg). It was reported that insoluble triticale fiber caused cereal flavor and taste, yellowish-brown color, and a sandy texture in enriched yoghurts. Despite the low-quality ratings given to the yoghurts enriched with 30 g/kg fiber due to their grainy texture and a little bitterness, it was reported that the enriched yoghurts were in the 'very good' quality category.

Table 5

Sensory properties of yoghurt sample on the 7th and 21st days of storage at 4 ˚C

Period of storage (days)	Control	1% MSF	2% MSF	3% MSF	1% DSF	2% DSF	3% DSF
Appearance							
7	$4.77\pm0.02^{A,ns}$	$4.05\pm0.55^{AB,ns}$	$3.70\pm0.30^{BC,ns}$	$3.12\pm0.13^{CD,ns}$	$2.88\pm0.13^{D,ns}$	$3.75\pm0.25^{BC,a}$	$3.53\pm0.28^{BCD,ns}$
21	$4.77\pm0.01^{A,ns}$	$4.10\pm0.10^{AB,ns}$	$3.63\pm0.38^{BC,ns}$	$3.10\pm0.30^{C,ns}$	$3.50\pm0.50^{BC,ns}$	$3.10\pm0.10^{C,b}$	$3.10\pm0.10^{C,ns}$
Texture							
7	$4.32\pm0.01^{A,b}$	$3.98\pm0.23^{AB,ns}$	$3.58\pm0.18^{AB,ns}$	$3.73\pm0.53^{AB,ns}$	$3.35\pm0.15^{B,b}$	$4.25\pm0.25^{AB,a}$	$4.40\pm0.60^{A,ns}$
21	$4.43\pm0.03^{A,a}$	$4.43\pm0.18^{A,ns}$	$3.75\pm0.25^{BC,ns}$	$3.62\pm0.38^{BC,ns}$	$4.20\pm0.20^{AB,a}$	$3.43\pm0.18^{C,b}$	$3.65\pm0.15^{BC,ns}$
Mouth feel							
7	$4.45\pm0.05^{A,ns}$	$3.95\pm0.45^{AB,ns}$	$3.68\pm0.08^{B,ns}$	$3.35\pm0.15^{B,ns}$	$3.43\pm0.17^{B,ns}$	$3.90\pm0.10^{AB,a}$	$3.60\pm0.40^{B,a}$
21	$4.38\pm0.03^{A,ns}$	$4.15\pm0.05^{A,ns}$	$3.40\pm0.40^{BC,ns}$	$3.18\pm0.43^{BC,ns}$	$3.68\pm0.08^{AB,ns}$	$3.08\pm0.33^{BC,b}$	$2.88\pm0.13^{C,b}$
Odor							
7	$4.69\pm0.01^{A,ns}$	$4.78\pm0.03^{A,a}$	$4.65\pm0.15^{A,a}$	$3.88\pm0.13^{B,a}$	$3.98\pm0.23^{B,ns}$	$4.10\pm0.10^{B,a}$	$4.08\pm0.33^{B,a}$
21	$4.60\pm0.07^{A,ns}$	$4.05\pm0.05^{AB,b}$	$3.30\pm0.30^{BC,b}$	$3.08\pm0.33^{C,b}$	$3.53\pm0.28^{BC,ns}$	$3.05\pm0.55^{C,b}$	$2.80\pm0.20^{C,b}$
Taste							
7	$4.44\pm0.02^{A,b}$	$4.67\pm0.15^{A,a}$	$4.55\pm0.05^{A,a}$	$3.45\pm0.05^{C,ns}$	$3.88\pm0.13^{B,ns}$	$3.67\pm0.08^{BC,a}$	$3.57\pm0.18^{C,a}$
21	$4.69\pm0.01^{A,a}$	$4.12\pm0.12^{AB,b}$	$3.30\pm0.20^{CD,b}$	$3.02\pm0.27^{DE,ns}$	$3.77\pm0.03^{BC,ns}$	$2.72\pm0.47^{DE,b}$	$2.62\pm0.12^{E,b}$

[1]MSF: whole meal obtained from wheat harvested at milky development stage; [2]DSF: whole meal obtained from wheat harvested at milky development stage Statistically differences were shown different letters ($P<0.05$); ns: not statistically significant.

[A-E]The significant differences between the samples were expressed in capital letters, [a-b]The significant differences between storage times were expressed in lower case letters.

Except for yoghurt samples enriched with 2% DSF that showed lower score in terms of appearance on the 21st day of storage, there was no statistical difference ($p>0.05$) depending on the storage period in all other yoghurt samples ($p>0.05$). On the 7th day of storage, it was seen that the texture values were not statistically different from each other in enriched yoghurt samples and had lower evaluation scores than control yoghurt. However, it was observed that texture scores decreased on the 21st day of storage due to the increasing enrichment ratio, which may be due to improved acidity of yoghurts by activities of yoghurt starter cultures leading for syneresis. Increasing of enrichment rate negatively influenced ($p<0.05$) the scores for mouth feel due to the higher graininess texture of yoghurts, while the storage period had no effect on the mouth feel. Additionally, the enrichment ratio and storage period significantly ($p<0.05$) affected in terms of odor and taste. As a result of the sensory evaluation, the least score in terms of these parameters was taken from yoghurt samples enriched with 3% DSF. As the enrichment ratio increased in yoghurts, the increasingly cereal flavor and taste reduced consumer appreciation. Similar findings are seen in the studies of yoghurt enriched with wheat [34, 35]. Besides, our sensory evaluation results are supported by Terpou, Bekatorou [15] who produced yoghurt using wheat bran as cell immobilization carrier and evaluated sensory attributes of them. The authors reported that although the highest cereal taste was determined in their yoghurt samples which have a less acidic taste and contain wheat bran in which probiotic cultures were immobilized, they had similar scores with yoghurt samples without wheat bran in terms of smell, appearance, and general acceptability.

Conclusion

Considering the findings obtained from this study, the use of immature wheat grain flour in the enrichment of yoghurt had led to significant changes in the taste and aroma compounds of yoghurt. A reduction in the amount of acetaldehyde, which is an important carbonyl compound for yoghurt taste and aroma, was observed with increasing concentrations of MSGF and DSGF. Also, it could be stated that isobutyl 2-methylvalerate determined in yoghurt samples enriched with MSF and DSF caused cereal flavor and taste in the final product, and this taste intensified with increasing enrichment ratios. Except for control yoghurt, %1 MSF yoghurt samples received the best sensory scores and gained the highest appreciation from consumers. As the concentration of MSF and DSF increased in yoghurt formulation, the cereal taste increased and this reduced the overall acceptability. For these reasons, further studies can be carried out by using various flavoring agents to reduce the aroma and flavor defects that occur in yoghurts.

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Functional and technological properties of food nanoadditives based on double oxide of divalent and trivalent iron

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Abstract

Introduction. The water and fat-retaining abilities of food nanoadditives based on the double oxide of divalent and trivalent iron (Fe_3O_4) known as Magnetofood were studied.

Materials and methods. Model systems: starch + magnetofood, egg white+magnetofood, fat + magnetofood. Water and fat retention properties were examined with energy dispersive X-ray (EDX) and IR-Fourier spectroscopies (FTIR). The mass fraction of bound and free moisture was determined using the indicator method (IM) and differential thermal analysis (DTA).

Results and discussion. The ability of Fe_3O_4 food additive nanoparticles is noted to form electrostatic complexes with macromolecular compounds of food systems (proteins, carbohydrates, lipids) — quite stable structures such as "clusters", "clathrates", "cavitates", "supramolecular associates". This property promotes binding and retention of water and fat. Hydrophilic contacts of solvated Fe_3O_4 nanoparticles with water dipoles, molecules of proteins and polysaccharides (carbohydrates) increase the stability of polyphasic systems.

An offset of the IR spectra of the maximum absorption of the Fe–O bond to the high-frequency region by (57±2) cm^{-1} in comparison with the experimental sample of pure food additive Magnetofood – Fe_3O_4 (FAM) indicates the chemical interaction of FAM iron cations with molecules of macromolecular compounds (starch, egg white, fat).

The chemical composition of model systems of macromolecular compounds with FAM was determined in energy dispersive X-ray studies. For pure FAM, particles of Fe comprised 75.5%; O – 24.5%; for the additive particles coated with egg white – Fe 44.7%; O 26.9%; C 21.4%; N 5.9%; S 1.1%; for the additive particles coated with starch – Fe 41.7%; O 35.7%; C 22.6%; for the additive particles coated with linoleic acid – Fe 45.6%; O 34.7%; C 19.7%; for the additive particles coated with sunflower oil – Fe 39.7%; O 36.7%; C 23.67%.

The ratio of bound and free moisture in solvated FAM: 50.5–51.6% of water comprise bound moisture and 48.4–49.5% constitute free, osmotic (swelling water) and physico-mechanical water of the total amount.

Conclusions. For the first time, models of interaction of Fe_3O_4 nanoparticles with water, proteins, fats, and carbohydrates have been suggested for substantiating the mechanisms of water and fat retention of food additive nanoparticles based on double oxide of divalent and trivalent iron.

Introduction

The most important functional and technological properties of food raw materials and food ingredients, which determine the course of technological processes and the quality of finished products, are water-retaining capacity (WRC) and fat-retaining capacity (FRC).

Mineral compounds [1]; special compositions of DSM enzymes [2]; biologically active substances of vegetable, fruit and herbal supplements [3–6]; various polysaccharides (citrus fibers; hydrocolloids of plant origin, cellulose esters) [7–10]; powders based on dairy and egg products [11–14]; functional ingredients derived from industrial by-products (leather, hooves, feathers, offal, seeds, bran, whey, etc.) [15, 16]; bioadditives based on wheat [17], soybeans, chickpeas, enzymes, microalgae, etc. [18–21] are used to increase the WRC of raw materials and food systems. The disadvantages of these additives are their narrow orientation and lack of complex action.

Food additives of various origins are used to improve the FRC of lipid-containing systems. They are nanopowders (silver, oxides of iron, magnetite, titanium and silicon dioxide, zinc oxide) [22–25]; modifications of magnetite nanoparticles with oleic acid [26]; modifications of nanoparticles of iron oxides and gyroxides with higher fatty acids and fats [27]. An adequate FRC of nanometer food additives is associated with high dispersion – this allows not only to bind free fats, but also to keep them on the surface of nanoparticles during cooking, as well as with the good availability of numerous hydrophobic areas [22–27].

An analysis of the scientific papers [1–27] revealed insufficiency of data on substantiating water and fat retention capacities of food nanoadditives, in particular, nanoparticles of food nanoadditives based on double oxide of divalent and trivalent iron ("Magnetofood") in food systems. "Magnetofood" food nanoadditives (Fe_3O_4) are marked with a wide range of functional and technological properties (structural, stabilizing, sorption, etc.) and promising technological applications [23, 28–35].

Therefore, there is a need to study the water and fat retention capacities of the "Magnetofood" food nanoadditive.

The aim of the research is to study the water and fat retention of food additives based on double oxide of divalent and trivalent iron known as "Magnetofood" (FAM).

To achieve this goal, the following tasks are set:

- Analyse the mechanism of interaction between macromolecular compounds (starch, egg white, higher fatty acid, fat) and FAM nanoparticles using FTIR spectroscopy;
- Establish the chemical composition of the experimental samples of FAM – pure FAM, samples covered with starch / egg white / higher fatty acid (linoleic) / sunflower oil applying the method of energy-dispersive X-ray spectroscopy;
- Determine the ratio of bound and free moisture in solvated FAM using the indicator method and differential thermal analysis.

Materials and methods

Materials

Research object: water retention and fat retention capacities of powdered ingredients in food raw materials, namely nanoparticles of food additives based on iron oxides known as "Magnetofood" – Fe_3O_4 (FAM).

Research subject:

- "Magnetofood", food nanoadditive based on iron oxides – Fe_3O_4 (FAM): highly dispersed nanopowder of brown or black colour with a particle size of 70– 80 nm. According to its chemical composition, "Magnetofood" is a double oxide of iron ($FeO \cdot Fe_2O_3$ or Fe_3O_4) obtained by the method of chemical coprecipitation from aqueous solutions of salts of divalent and trivalent iron in an alkaline medium [36, 37];
- Model systems: "starch+magnetofood", "egg white+magnetofood", "linoleic acid+magnetofood", "sunflower oil+magnetofood": a suspension of FAM in 3% starch solution was obtained by introducing a portion of FAM into 3% polysaccharide solution at (55–60) °C while constant stirring n = (2.0– 2.2) s^{-1} for (5–7)×60 s with subsequent cooling of the mixture to a temperature of (18–20) °C and constant stirring n=(2.0–2.2) s^{-1} [32]. A suspension of FAM in a 3% solution of egg white was obtained by introducing a calculated amount of FAM into a 3% solution of egg white at a temperature of (18–20) °C while constant stirring n=(2.0–2.2) s^{-1} for (3–5)×60 s followed by seasoning for (5–7)×60 s [33]. Fatty suspensions of FAM were obtained by peptizing the calculated amount of FAM in oil (linoleic acid) at a temperature of (45–50) °C (rational ratio of components – FAM:fat=50 wt.%:50 wt.%, i. e. 2.5 g of suspension contains 1.25 g FAM) under condition of thorough stirring (n=2.0–2.2 s^{-1}) for (3–4)×60 s, followed by cooling the mixture to a temperature of (18–20) °C and constant stirring n=(2.0–2.2) s^{-1} [34, 35, 38, 39].

Research methods

Fourier-transform infrared spectroscopy (FTIR). The vibrational spectra of the test samples were obtained using Fourier Transform Infrared Spectrometer (FTIR) Bruker Tensor 37 (Germany), controlled by the OPUS software package with standard calibration capabilities within the frequency range of (4000-400) cm^{-1} in the absorption format (Fourier spectra of samples were taken in KBr tablets) [25, 26, 36, 37].

Energy dispersive X-ray spectroscopy (EDX). To determine the chemical composition of the test samples used a scanning electron microscope JSM-820 (JEOL) with the prefix EDX. X-ray spectra were obtained by bombarding the test samples with electrons using an acceleration voltage of 20 kV (according to the lines of the characteristic spectra of Iron, Carbon and Oxygen). Establishment of the elemental composition of the experimental samples was performed by analysis of the obtained spectra of characteristic X-rays [26, 27, 36, 37].

Algorithm for determining the mass fraction of bound and free moisture by the indicator method according to the methods of Knyaginichev and Ermakova [42] and with the differential thermal analysis (DTA) [43]

The idea of the refractometric method is to determine the difference in dry matter (DM) between the indicator-solution of sugar and FAM solvated in sugar solution [42].

Bound moisture was calculated using the following formula (1):

$$X = B \times (b_2 - b_1)/P \times b_2, \quad (1)$$

where X is the amount (g) of bound water per 1 g of dry matter (DM); b_1 and b_2 – initial and final concentrations of sucrose solution,%; B – mass of 20 cm^3 10% sucrose solution, g; P – portion of dry matter (DM), g.

Free moisture was calculated by formula (2):

$$Y=(C_0 - C_1)\times m\times 100/C_1\times g\times W, \quad (2)$$

where Y is the content of free water,% of the total content; C_0 – initial concentration of sucrose solution,%; C_1 – final concentration of sucrose solution,%; m – mass of the initial sucrose solution, g; g – sample weight, g; W – total water content in 1 g of sample, g.

Differential thermal analysis (DTA) [43]. Thermographic determinations were carried out using derivatograph Q-1500 D by "MOM" (Hungry) for a sample weight of 0.5 g in the following modes of taking derivatograms: sensitivity of DTA galvanometer – 250, DTG galvanometer – 500, TG galvanometer – 500, heating temperature change rate – 4°C/60s. The dependences of the change rate for mass α on the temperature *T* were built based on the change curve *TG* which corresponds to the process of dehydration and the temperature curve *T*. To do this, every 5 °C the researchers fixed a change in mass of the sample as well as the total mass fraction of moisture, which was determined by the *TG* curve, at the end of the crystallization process. The change rate for mass α was calculated using the following formula (3):

$$\alpha = \nabla m_T/m, \text{ where } \alpha\text{– rate of change of mass,} \quad (3)$$

where ∇m_T – change in mass of the sample at a temperature T, 10^{-3} g;

m – total mass fraction of moisture contained in the sample, 10^{-3} g

Results and discussion

Chemical interaction of "Magnetofood" nanoparticles (MNP) with the main food ingredients

Previous studies show that the chemical activity of MNP is determined mainly by electrostatic interactions, i.e. dipole–dipole (van der Waals forces) and ion–dipole interactions [29–31]. Donor–acceptor (coordination) interactions, such as hydrogen bonds, are also involved in the adsorption of proteins, fats, carbohydrates, and water on the surface of the MNP [29–31, 36, 37]. In food systems, there are solvated nanoparticles (NP) of Fe_3O_4, which enter into hydrophilic contacts due to hydrogen bonds with water dipoles, molecules of proteins and polysaccharides (carbohydrates) containing hydrophilic groups — C–O, C–N, O–H, S–H [29]. As a result, the stability of such systems as "protein + solvated MNP", "carbohydrate+solvated MNP" increases but the formation of hydrophobic bonds between the fragments of macromolecules is slowed down, which prevents their aggregation [30, 31].

Under the influence of NP of Fe_3O_4 macromolecular compounds (proteins, polysaccharides, higher fatty acids, and fats) undergo structural changes and form electrostatic complexes from NP of Fe_3O_4 [29–31] — quite stable structures such as "clusters", "clathrates", "cavities", and "supramolecular associates" [36, 37]. As a result, WRC and FRC of food systems increase.

Experimental confirmation of the interaction between the food nanoadditive based on double oxide of divalent and trivalent iron known as "Magnetofood" (FAM) and proteins, fats, polysaccharides, water

Fourier-transform infrared spectroscopy (FTIR). Table 1 and Table 2 show the results of IR spectroscopy.

Table 1

Comparison of wavenumbers of individual peaks in IR spectra of the "egg white+magnetofood" complex association and starting materials (egg white and "Magnetofood', food additive known as FAM)

Bond fluctuations	Wavenumber position of maxima, cm^{-1}			Offset, cm^{-1}
	egg white	FAM	"egg white+magnetofood"	
ν(O–H), ν(N–H) – Amide A	3406±5	–	3341±5	-65
ν_{as} (C–H)	2927±4	–	2927±4	0
ν_s(C–H)	–	–	2360±4; 2342±3	–
ν (C=O) – Amide I	1653±3	–	1642±3	-11
δ_{pl}(N–H)– Amide II	1539±3	–	1527±3	-12
δ_{pl}(C–H)	1451±3	–	1442±3	-9
δ_{pl}(C–C)	1239±2	–	1239±2	–
δ_{pl}(C–C)	–	–	1155±2	–
δ_{epl}(C–C)	1079±2	–	1027±2	-52
ν (Fe–O)	–	532±2	588±2	+56

As can be seen from Table 1, the intense broadband with a maximum absorption (3341±4) cm^{-1}, which is shifted in the complex associate to the low-frequency region of cm^{-1} compared with the frequency of free OH groups and amide A (N–H) (3406±4) cm^{-1}, indicates the participation of hydroxyl oxygen and amide nitrogen in the formation of coordination bonds with Fe atoms of FAM [36, 37].

Intense bands with maxima at (2360±4) cm^{-1} and (2342±3) cm^{-1}, which are absent in the spectrum of egg white, are also observed. These peaks can be attributed to symmetric valence (ν_s) oscillations of the C–H bond. This is confirmed by the electrostatic hydrophobic interactions of aliphatic side chains of amino acid residues in "clathrates" and "cavities" that occur under the action of MNP [24, 25, 36, 37].

During the adsorption of egg white on the surface of the MNP, there is an offset of the absorption bands of the valence oscillations of amide I ν(C=O) and planar deformation oscillations of amide II δ_{pl}(N–H) to a lower frequency in the region: ν(C=O)=(1642±3) cm^{-1}; δ_{pl}(N–H)=(1527±3) cm^{-1}, respectively [25, 26, 36, 37].

The absorption bands of planar and extraplanar deformation oscillations δ_{pl}(C–H) and δ_{epl}(C–C)=(1027±2)cm^{-1} to a lower frequency in the region δ_{pl}(C–H)=(1442±3) cm^{-1} and δ_{epl}(C–C)=(1027±2) cm^{-1} respectively. A new absorption band of planar deformation oscillations $\delta_{pl.}$(C–C) (1155±2) cm^{-1} is also observed. This confirms the electrostatic hydrophobic interactions of aliphatic and cyclic amino acid residues in the complex association [24, 27, 36, 37].

In the spectrum of pure FAM (Table 1), there is a line of absorption of the Fe–O bond with a maximum at a value of ~ 532 cm^{-1}, which agrees well with the data presented in the scientific studies, that is ~530 cm^{-1} [36, 37]. The offset of the maximum of the corresponding absorption band of Fe–O valence oscillations in the "egg white+magnetofood" Complex to the region of ~ 588 cm^{-1} is associated with the influence of surface egg protein molecules, their interference in the near-surface layer of Fe_3O_4 nanoparticles and chemical interaction with iron cations. Thus, the results of the studies confirm the formation of a complex between egg white and FAM [36, 37].

Comparison of IR spectra (Table 2) shows that the wave numbers of peaks differ in the spectra of the starting materials (starch, FAM) and the "starch+magnetofood" complex, indicating the chemical interaction in the carbohydrate-magnetofood model system.

Table 2

Comparison of wavenumbers of individual peaks in IR spectra of the "starch+magnetofood" complex association and starting materials (potato starch, FAM)

Bond fluctuations	Wavenumber position of maxima, cm^{-1}			Offset, cm^{-1}
	starch	FAM	"starch+magnetofood"	
ν(O–H)	3443±5	–	3415±5	-28
ν_{as} (C–H)	2927±4	–	2917±4	-10
ν_s(C–H)	–	–	2360±4; 2342±3	–
ν (C–O–C)	1653±3	–	1640±3	-13
δ_{pl}(C–O–C)	1457±3	–	1441±3	-16
δ_{pl}(C–C)	1162±2	–	1152±2	-10
δ_{pl}(C–C)	–	–	1081±2; 1021±2	–
δ_{epl}(C–C)	982±2		922±2	-60
δ_{epl}(C–C)	857±2		847±2	-10
δ_{epl}(C–C)	763±2		753±2	-10
ν (Fe–O)	–	532±2	589±2	+57

As can be seen from Table 2, there is a shift of the intense band of free OH groups (3443±5) cm^{-1} to the low-frequency region (3415±5) cm^{-1} in the spectrum of the "starch+magnetofood" complex – this indicates the participation of hydroxyl in the topic of hydrogen bonds and electrostatic coordination interactions with Fe atoms of FAM [36, 37].

Shift of the peak of valence ν (C–O–C) by (13±3) cm^{-1} and planar deformation oscillations of δ_{pl}(C–O–C) на (16±3) cm^{-1} to the low-frequency region compared to the experimental sample of starch indicates the presence of Coulomb and coordination interactions between Fe atoms of FAM and oxygen (ether, pyranose and hydroxyl) residues of D-glucopyranose [24, 25, 36, 37].

The appearance of new absorption bands in the region (700–1200) cm^{-1}, which characterize the oscillations of the carbon skeleton, and an offset to the region of lower frequencies of some characteristic absorption bands (C–C) of bonds indicate the presence of hydrophobic and dispersive London forces between residues of glucopyranose [25, 26, 36, 37].

An offset of the maximum absorption of the Fe–O bond to the high-frequency region by (57±2) cm^{-1} compared with the experimental sample of pure FAM indicates the chemical interaction of iron cations of FAM with starch molecules [24, 27, 36, 37]. All this confirms the presence of chemical interaction in the "starch+magnetofood" complex association.

The study of chemisorption of linoleic acid and 1-linoleyl-2-oleoyl-3-linolenoylglycerol on the surface of FAM nanoparticles has been reported in previous studies [36, 37]. This indicates the chemical interaction of higher fatty acid and fat with Fe_3O_4 nanoparticles.

Energy dispersive spectroscopy (EDX). The X-ray spectra of all experimental samples displayed the peaks (Figure 1) of about 0.8; 6.3 and 6.8 keV associated with the absorption of the kinetic energy of electrons by the Fe atom. The spectra of MNP covered with protein, linoleic acid, oil and starch (Figure 1, b–e) contain two more peaks: about 0.27 keV and 0.47 keV. These

absorption bands belong to the C and O atoms [24, 26, 36, 37]. Moreover, the peak at 0.47 keV, which is characteristic of the O atom, also finds itself in the spectrum of pure FAM (Figure 1, a); and the peaks of about 0.3 and 1.2 keV are associated with the absorption of kinetic energy by electrons of N and S atoms, respectively (Figure 1, b).

An EDX spectrum analysis of experimental samples (b, c, d, e) shows that Fe, O and C (H cannot be studied) and N and S (for sample b) are the main components in the system of "protein (fat, polysaccharide)+magnetofood".

Thus, systems with MNP have the following chemical composition: *sample a* (FAM) – Fe 75.5%; O 24.5%; *sample b* (MNP, coated with egg white) – Fe 44.7%; O 26.9%; C 21.4%; N 5.9%; S 1.1%; *sample c* (MNP, coated with starch) – Fe 41.7%; O 35.7%; C 22.6%; *sample d* (MNP, coated with linoleic acid) – Fe 45.6%; O 34.7%; C 19.7%; *sample e* (MNP, coated with sunflower oil) – Fe 39.7%; O 36.7%; C 23.67%.

Thus, the experimental samples *(b–e)* obtain a new chemical element (C), and the experimental sample *(b)* acquire two more elements (N and S), which are absent in pure FAM (sample a). The result indicates that FAM nanoparticles were successfully obtained (sample a) and the main substances of food systems such as proteins, fats, and polysaccharides (samples *b–e*) are chemisorbed on FAM particles.

Mass fraction of bound and free moisture. The experimental data presented in Figure 2 show that 1/5 of the water in solvated FAM is chemically bound moisture; 1/2 – bound moisture; 1/10 – free moisture and 1/2 – free, osmotic (swelling water) and physico-mechanical of the total amount of water.

The studies indicate the high hydration capacity of food nanoadditives based on double oxide of divalent and trivalent iron "Magnetofood" (FAM), which can improve the functional and technological properties of heterogeneous dispersed systems in food production technologies.

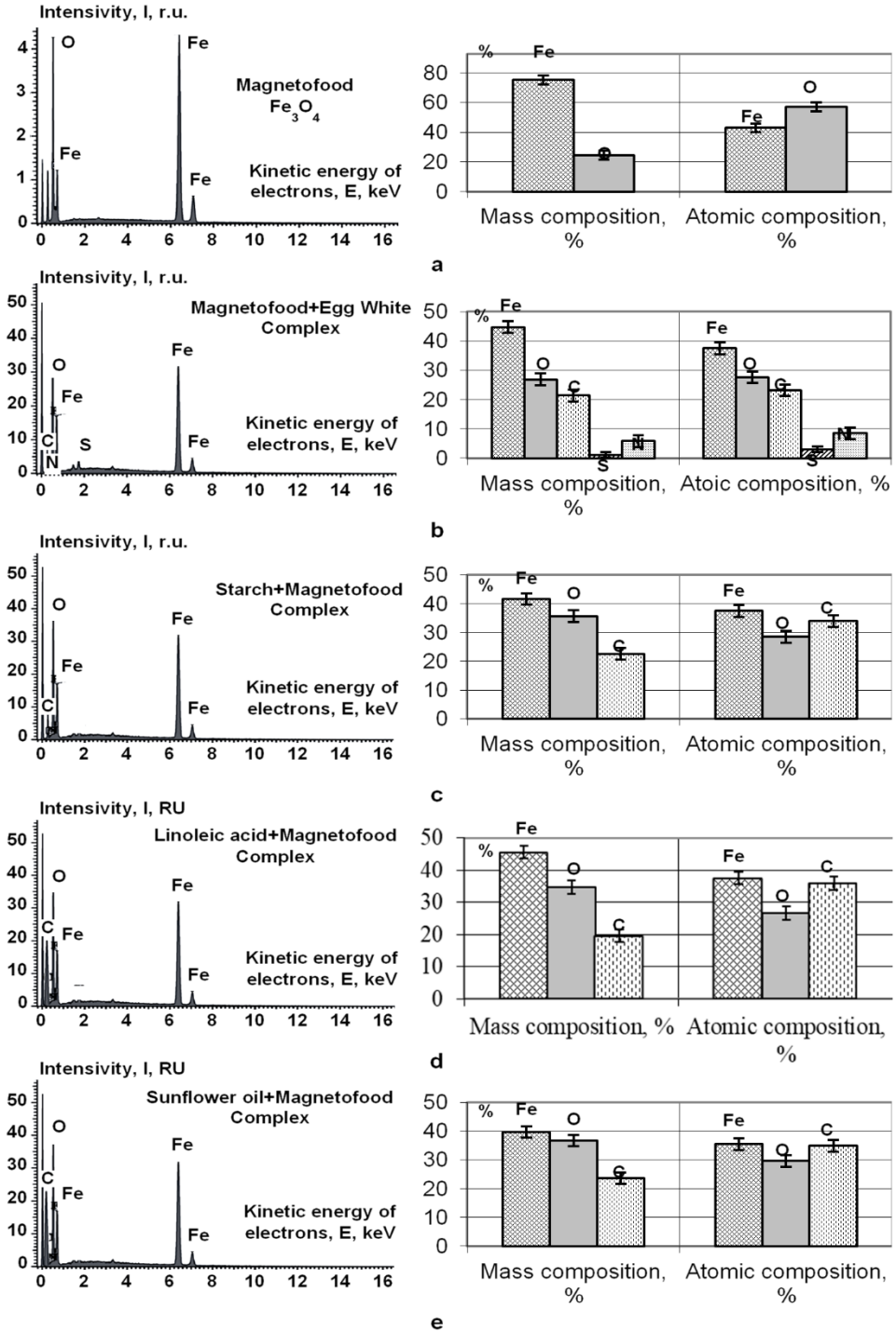

Figure 1. EDX-spectra of model systems with FAM:
a – FAM; b – egg white+magnetofood; c – starch+magnetofood; d – linoleic acid+magnetofood; d – sunflower oil+magnetofood

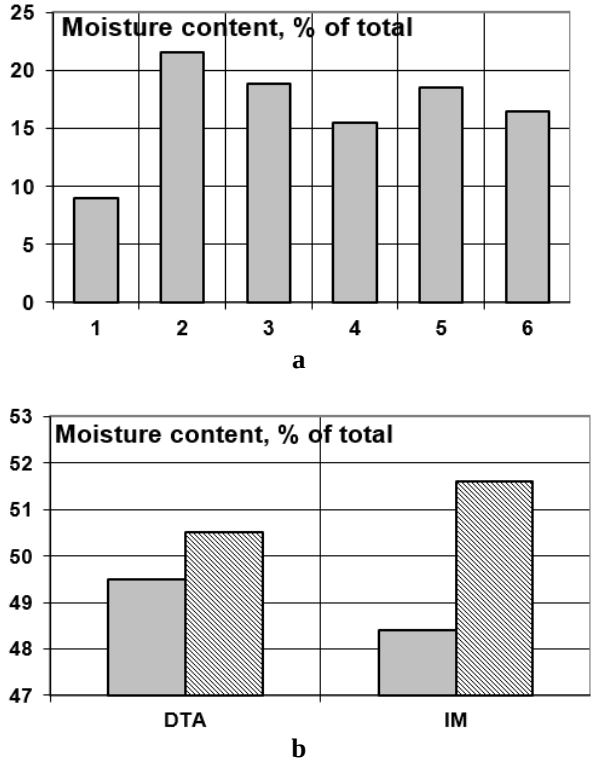

Figure 2. The distribution of water by types of bonds in FAM after swelling determined by the methods: a – DTA (1 – free moisture; 2 – physically and mechanically bound; 3 – osmotically bound (swelling water); 4 – adsorption bound (polymolecular); 5 – adsorption bound (monomolecular); 6 – chemically bound); b – IM and the method of DTA (□ – amount of free, osmotic and physico-mechanical moisture; ▨ – amount of bound moisture)

Conclusions

1. The ability of nanoparticles of food additive Fe_3O_4 was noted to form supramolecular associations with macromolecular compounds of food systems, which promote the binding and retention of water and fat.
2. The interaction of macromolecular compounds (starch, egg white, higher fatty acid, fat) and water with nanoparticles of FAM was studied:
   - Fourier-transform infrared spectroscopy proved chemosorption of macromolecular compounds (starch, egg white, higher fatty acid, triglyceride) on the surface of NP food additive Fe_3O_4: a shift of the maximum of Fe–O bond absorption to the high-frequency region by (57±2) cm^{-1} in comparison with the experimental sample of pure FAM indicates the chemical interaction of FAM iron cations with molecules of macromolecular compounds (starch, egg white, fat, higher fatty acids); the spectrum of macromolecular compound+magnetofood Complexes demonstrates an offset of the intense band of free OH groups (3443±5) cm^{-1} in the low-frequency region by (28±2)

cm^{-1}, which indicates the participation of hydroxyl in the topic of hydrogen bonds and electrostatic coordination interactions with Fe atoms of FAM. The appearance of new absorption bands in the region of (700–1200) cm^{-1}, which characterize the oscillations of the carbon skeleton, and an offset in the region of lower frequencies of some characteristic bands that absorb (C–C) bonds indicate the presence of hydrophobic and dispersion interactions between residues of glucopyranose, aliphatic and cyclic amino acid residues and aliphatic triglyceride residues;

- Energy dispersion X-ray spectroscopy determined the chemical composition of model systems of macromolecular compounds with food additive Fe_3O_4 (FAM): *sample a* (FAM) – Fe 75.5%; O 24.5%; *sample b* (MNP, coated with egg white) – Fe 44.7%; O 26.9%; C 21.4%; N 5.9%; S 1.1%; *sample c* (MNP, coated with starch) – Fe 41.7%; O 35.7%; C 22.6%; *sample d* (MNP, coated with linoleic acid) – Fe 45.6%; O 34.7%; C 19.7%; *sample e* (MNP, coated with sunflower oil) – Fe 39.7%; O 36.7%; C 23.67%. That is, the compounds (samples *b–e*) are chemisorbed on the particles of Fe_3O_4 food additive. And the band absorbing the C atom, which appeared in samples *b–e*, confirms the process of adsorption and chemical interaction between the particles of Fe_3O_4 food additive and macromolecular compounds;
- The ratio of bound and free moisture in solvated FAM was established using the indicator method and differential thermal analysis: 1/5 of water falls on chemically bound moisture; 1/2 – bound moisture; 1/10 – free moisture and 1/2 part – free, osmotic (swelling water) and physico-mechanical water of the total amount.

Recommendations

The studies show the water and fat-retaining ability of food nanoadditives based on double oxide of divalent and trivalent iron known as “Magnetofood” (FAM), which can improve the functional and technological properties of polyphase systems, improve quality and extend the shelf life of finished products in food production technologies.

Knowledge of mechanisms: interaction of FAM nanoparticles with proteins, fats, and carbohydrates; binding and retention of water and fat by raw materials will allow the rational use of new types of food raw materials and predict the behaviour of raw ingredients in food products with a heterogeneous dispersed structure.

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Effect of adding coconut milk on the physicochemical, proximate, microbial and sensory attributes of «Dahi»

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Abstract

Introduction. Plant-based or non-dairy milk alternates are the growing trend in newer food product development. Therefore, the present study was conducted to explore the quality and potential of «Dahi» prepared by cow milk and different levels of coconut milk.

Materials and methods. The obtained formulations, A (Control), B, and C were prepared by mixing cow milk to coconut milk in three different rations (100:0, 50:50, 0:100). The proximate composition, physicochemical, sensorial, and microbial properties were determined to ascertain the quality attributes of the «Dahi» samples. Obtained data were analyzed statistically, and means were compared at 5% level of significance.

Results and discussion. The results of the physicochemical analysis showed increasing trends in the values for pH (4.05–4.33), TSS (14.05–14.90), and Sweetness Index (10.60–20.13) while substituting cow milk with coconut milk. There was also a remarkable increase in the proximate values for moisture (82.75–85.20%), fat (1.57–3.06%) and ash (0.71-2.94%). The results suggested that coconut milk addition leads to a considerable increase in mineral content as well as unsaturated fatty acids that may promote health benefits. A reverse trend was observed for acidity (0.64–0.56%), protein (3.13–2.98%) and carbohydrate (11.85–5.82%) values in coconut enriched «Dahi». The bacterial counts of all the samples (4.51–5.34) $\times 10^5$cfu/ml were within the acceptable standard for fermented dairy products. The results of the current study also demonstrated that the addition of coconut milk significantly improved the «Dahi»s' aroma and consistency. Overall, the acceptability of coconut milk enriched «Dahi» was highly comparable to the control («Dahi» of 100% cow milk).

Conclusions. Thus, «Dahi» from the coconut milk can be a match-able substitute for the conventional dairy-based «Dahi», which could be particularly advantageous to the lactose-intolerant people and high coconut producing regions.

Introduction

«Dahi» is one of the most common fermented food products obtained through the controlled fermentation process of lactose of the milk by mixed culture of lactic acid bacteria, which are classified as probiotics [1]. The anaerobic fermentation of the milk sugar (lactose) causes the characteristic curd and ensures the increased shelf life, microbial safety of the food and also makes food more digestible [2]. In Bangladesh, «Dahi» is more commonly consumed as a desert food item and found as a good source of probiotic lactic acid bacteria that can play major role for beneficial health effects of consumer [3].

Nowadays, allergen, lactose intolerance and calorie concern regarding cow milk induces more preference to vegan diets and has influenced consumers to choose cow milk alternatives [4]. Recent researches are shifting focus to diverse components in fermented dairy products. «Dahi» serves as a good source of vitamin B, protein and calcium content but lacks certain essential nutrients such as high- quality unsaturated lipids, fibers, and antioxidant compounds that are readily found from plant sources. Coconut is a versatile fruit, which is found in most regions of the world, particularly in Southeast Asia [5]. The aqueous emulsion of coconut kernel prepared by hand or mechanical pressing is known as coconut milk. It is a prominent source of dietary protein, energy, calcium, and fat such as myristic acid, oleic acid, lauric acid, linoleic acid, palmitic acid, and capric acid [6]. It is also a rich source of vitamins and minerals [7]. Contrary to widely held opinion, coconut milk exhibits the highest antioxidant activity among goat and cow's milk and may provide many health benefits beyond its nutritional content, due to its fiber and oil content [8, 9].

Thus, researchers have urged to develop new dairy foods using a combination of non-dairy milk i.e. coconut milk. It can be used as a substrate to produce functional «Dahi» with probiotic properties with enhanced flavor [10]. In the context of the local Bangladeshi market, the availability of fruits and flavored «Dahi» is very rare. Besides, the enhanced flavor of coconut can be functionalized as the addition of value for the existing products in the current market at relatively low cost [9]. Thus, the study was carried out to evaluate the feasibility of the formulation of «Dahi» using coconut milk and to analyze the effects of adding coconut milk on the physicochemical, proximate, microbial and sensory attributes of the product.

Materials and methods

Raw Materials Procurement

The coconut fruits were brought from local markets. Raw cow milk and «Dahi», which was used as the starter culture in this study were also purchased from a Superstore of Chattogram city. Potable water was strictly used throughout the study.

Extraction and Preparation of Coconut Milk

The coconut milk was prepared as the method described by Kolapo and Olubamiwa, [11] with slight modifications. The fresh coconuts used in this study were crushed open and the juice poured and stored in a refrigerator. 1 kg of coconut flesh was then removed from the shell, grated and homogenized in a blender (Panasonic, MX-AC300) together with the coconut juice for 3 min. It was then passed through a cheese cloth twice, with the volume adjusted to 750 ml and stored in refrigerated condition. The obtained filtrate is termed as coconut milk. The extracted coconut milk was shifted into a jar and pasteurized or heated at 90°C for 30 min and allowable to cool gradually. The temperature was maintained carefully.

Preparation of «Dahi»

The «Dahi» was prepared from the blends of cow milk and coconut milk. The mixtures were composed according to different proportions, as shown in Table 1.

Table 1

Milk blends and their proportions

Sample codes	Cow milk (mL)	Coconut milk (mL)	Proportions (Cow milk : Coconut milk)
A	100	0	100:0
B	50	50	50:50
C	0	100	0:100

An amount of 8% (8.0 g) of sugar was added to each of the blends to sweeten the mixture. Then they were slightly heated and were inoculated with 1% (1 g) of the starter culture. All the inoculated milk blends were poured into plastic cups and then placed into an incubator (GSP-9080 MBE, Shanghai, China) at 43°C for 6 h to facilitate fermentation and curd formation. Finally, the cups were placed in a refrigerator at 4 °C and stored for further analysis. Coded sample A (dahi of 100% cow milk) was used as the control here in this study.

Determination of Physicochemical Properties

The pH of the «Dahi» samples was measured with a pH meter (HI-98107, Hanna Instrument, Italy). Total soluble solids (TSS) were obtained by using a digital refractometer (HI-96811, Hanna Instrument, Italy). Titratable acidity in terms of the % of lactic acid was measured, according to Hamad et al. [12]. For the determination of titratable acidity, each of the «Dahi» samples (4.5mL) was mixed with an equal amount of distilled water and homogenized. The samples were then titrated against standardized 0.1N NaOH solution by using phenolphthalein indicator (2 mL) until the colors were changed. The percentage of titratable acidity was calculated using the following equation:

$$\text{Titratable acidity (\%)} = \frac{\text{Titre value (mL)} \times 0.009 \times 100}{\text{Weight of samle (mL)}}$$

The sweetness and astringency indexes were also calculated as the ratio of soluble solids to acidity and vice versa [13].

Determination of Proximate Composition

The proximate composition of the «Dahi» samples was determined by the methods described in AOAC Method [14]. The moisture contents were determined by the moisture analyzer. The crude protein contents (Total nitrogen (%) × 6.25) were determined by the Kjeldahl method, the crude fats were estimated by extracting known weight of samples with ethyl ether as the solvent, using a Soxhlet apparatus. Ash contents were determined by igniting the samples in the muffled furnace at 550 ºC (dull red) until grayish-white ash was obtained. Total carbohydrates were calculated by the difference:

% carbohydrate = 100-(% moisture + % ash + % crude protein + % crude fat)

Determination of Microbial Properties

Total bacterial count in «Dahi» samples were measured by serial dilution method using pour plate technique as described by Wang et al. [15]. 1 mL of each samples were serially transferred into 9 mL of the sterile diluent (peptone water) with a sterile pipette and shaken

robustly. Serial dilution was continued until 10^5 dilutions were obtained. The aliquot portion (0.1 mL) of the appropriate dilution was plated on nutrient agar plates. The plates were incubated at 37ºC for 48 h in an incubator (GSP-9080 MBE, Shanghai, China) and colony forming units per mL sample (cfu/mL) were estimated.

Determination of Sensory Properties

The colour, taste (mouth feel), aroma, consistency, and overall acceptability of the «Dahi» samples were analyzed. The samples (15 g) were placed into cups and coded randomly with three-digit random numbers and served to the panelists. Twenty panelists from the undergraduate level with knowledge of sensory analysis were selected. They evaluated the samples using a 9-point Hedonic scale at a range of 1 (extremely dislike) to 9 (extremely like). Water was given to the panelists to rinse their mouths between tasting each sample.

Statistical Analysis

All of the analyses were conducted in triplicates. Obtained data were subjected to one way analysis of variance (ANOVA) and the difference among the means were determined using the Fisher's LSD test ($p<0.05$). The Minitab Version 19.1 Statistical Software was used for data analysis and the results were presented as mean with standard deviation.

Results and discussion

Physicochemical properties of «Dahi»

The physicochemical properties of the «Dahi» samples, including pH, TSS (°Brix), acidity (%), sweetness and astringency indexes are presented in Table 2. The substitution of coconut milk for cow milk at different levels resulted in irregular changes in these parameters. The pH of the «Dahi» samples ranged in between 4.05 to 4.33 and are significantly different ($p<0.05$). Sample A had the lowest pH, when compared to sample B and sample C. In commercial fermented dairy products, Lactic acid bacteria produce lactic acid during fermentation of milk- lactose, thus lowers the pH [16]. The result is in agreement with the previous result published by Amirah et al. [17].

TSS in fermented dairy products is the indication of availability of dry matter content [18, 19]. Results regarding TSS (°Brix); it is cleared that there were significant differences ($P< 0.05$) among the control and coconut milk enriched «Dahi» samples. However, sample C had the highest TSS content followed by sample B and sample A. This variation resulted due to the contribution of additional monosaccharide (sugars) from coconut addition [20]. Similar results were reported by Priya. [21] and Belewu et al. [18] for cow, coconut, tiger-nut, and soybean milk assorted fermented products.

The Titratable acidity values of «Dahi» samples also varied from 0.56 to 0.64%. Sample C reported lower acidity while Sample A and B showed no significant differences in their respective acidity values ($P> 0.05$). This could be due to the secretion of acids as a co-product by fermenting microbes while utilizing lactose and glucose for their metabolic activity during fermentation. However, these values are within an average of 0.6% acidity recommended for fermented dairy products [16]. Similar findings were reported by Isanga et al. [22] who obtained TTA (% lactic acid) value of 0.5 to 0.75 for peanut milk yoghurt. Besides, the study reported an inverse relationship between pH and titratable acidity, which is also supported by earlier researchers [5].

The Sweetness Index (SI) and the Astringency Index (AI) predicts the tartness and sweetness of the acidic foods and modifies both organoleptic and sensorial perception [13]. Foods with sweetness index greater than 19 are regarded as sweet, with less acid by taste [13]. The sweetness indexes of the «Dahi» samples ranged in between 21.95 to 26.66 and are significantly different ($p<0.05$). The sourness of the «Dahi» expresses the level of astringency produced as a result of the Production of lactic acid by the action of lactic acid bacteria using lactose as substrates [9]. However, In the case of astringency index, it is cleared that there were no significant differences ($P> 0.05$) observed among all the «Dahi» samples. These results are in covenant with many previous reports published by Ndife et al. [10] and AKEEM et al. [23].

Table 2

Physicochemical properties of «Dahi»

Parameters	Sample A	Sample B	Sample C
pH	4.05 ± 0.02^{c}	4.22 ± 0.02^{b}	4.33 ± 0.01^{a}
TSS (°Brix)	14.05 ± 0.01^{c}	14.52 ± 0.02^{b}	14.93 ± 0.02^{a}
Acidity (%)	0.64 ± 0.02^{a}	0.61 ± 0.02^{a}	0.56 ± 0.02^{b}
Sweetness	21.95 ± 0.02^{c}	23.82 ± 0.01^{b}	26.66 ± 0.02^{a}
Astringency	0.05 ± 0.01^{a}	0.04 ± 0.01^{a}	0.04 ± 0.01^{a}

*****Data in same raw with different letters are significantly different ($P < 0.05$). A = 100% cow milk dahi, B = 50% cow milk + 50% coconut milk dahi, C= 100% coconut milk dahi

Proximate composition of «Dahi»

The proximate composition of food exerts substantial influences on their physical, nutritional, and sensorial characteristics [24, 25]. Results regarding proximate composition, all the three «Dahi» samples have shown significant differences ($P< 0.05$) in the case of all parameters evaluated in this study (Table 3). Sample C had the highest moisture content (85.20%) followed by Sample B (83.49%) and Sample A (82.75%). These values fall within the acceptable moisture content of 80-86% for fruit yoghurt stated by Ndife et al. [10]. This variation was reported due to the proportion of cow milk to coconut milk used in this study.

The protein content of «Dahi» samples varied from 2.98 to 3.13%. The result depicted that protein content decreased as the proportion of the coconut-milk increased. Sample A reported comparably higher protein value (3.13%), followed by sample B (3.07%) and sample C (2.98%). The result is in agreement with the result published by Amirah et al. [17]. The possible reason for the difference might be denaturation of protein due to heat treatment and homogenizing process of coconut milk [26].

The fat content of «Dahi» samples ranged from 2.31 to 3.06% in the coconut enriched dahi samples when compared to control (1.57%). The medium-chain fatty acid profile of coconut milk has promptly influenced the fat content of coconut enriched «Dahi» samples. Increased fat in coconut may not lead to heart diseases, as it contains several phytocompounds [27]. Besides, the fat contents of the enriched «Dahi» samples were within the standard (<3.5%) for low-fat fermented dairy products [28].

The ash content also increased as the proportion of coconut-milk increased in the «Dahi» samples. This could be due to the higher minerals of coconut by implication reported by Imele and Atemnkeng. [29]. Obtained results are in agreement with results on other plant

substituted fermented dairy products published by other researchers Belewu et al. [18] and Eke et al. [16]. The carbohydrate content of the dahi samples decreased with coconut supplementation from 11.85% in sample A to 9.50% and 5.82% in Sample B and Sample C, respectively. A similar result was also reported by Ndife et al. [10].

Table 3

Proximate composition of «Dahi»

Parameters	Sample A	Sample B	Sample C
Moisture (%)	82.75±0.01^{c}	83.49±0.02^{b}	85.20±0.02^{a}
Ash (%)	0.71±0.02^{c}	1.63±0.01^{b}	2.94±0.02^{a}
Fat (%)	1.57±0.02^{c}	2.31±0.02^{b}	3.06±0.01^{a}
Protein (%)	3.13±0.01^{a}	3.07±0.01^{b}	2.98±0.01^{c}
Carbohydrate (%)	11.85±0.01^{a}	9.50±0.02^{b}	5.82±0.01^{c}

*****Data in same raw with different letters are significantly different ($P < 0.05$). A = 100% cow milk dahi, B = 50% cow milk + 50% coconut milk dahi, C= 100% coconut milk dahi

Sensorial properties of «Dahi»

Table 4 illustrated the mean scores of the sensorial and organoleptic evaluation for the different «Dahi» samples. The statistical analysis exposed that there were significant differences ($p<0.05$) among the samples (A, B and C) in all the observed attributes. Colour determines initial acceptability and purchasing patterns by potential consumers [30]. Sample A had the highest score (8.17), while sample C had the lowest score (7.35) for colour. The panelists showed a preference for the lighter colour of sample A, as coconut enrichment might have darkened the colour a little bit.

The enrichment of the «Dahi» with coconut milk resulted in better consistency and a more pronounced aroma. Sample C had the highest scores of 7.45 for aroma followed by sample A (7.42) and sample B (7.39), while sample B had the highest scores of 7.89 for consistency attribute followed sample C (7.86) and sample A (7.84). Most of the panelists appreciated the enriched aroma, which was attributed due to the oil content of coconut. A previous study reported that fat content considerably influences the sensorial characteristics of fermented yoghurts, as oil acts as an aroma solvent and promotes better rheological properties [28]. There were significant differences in terms of taste profile for the three samples, while sample C was rated lower in scores (7.45) than sample B (7.56) and sample A (7.82), and this was due to the flavor associated with coconut. However, higher carbohydrate content may impart in the increased sweetness of fermented products [31].

The overall acceptability rating measures the consumers' degree of likings and preferences in relation to the control sample. The highest overall acceptability means a score of 8.03 was recorded for the control (sample A), which was closely followed by coconut substituted samples C (7.96) and B (7.79). This might be due to that all the panelists were used to fermented dairy products rather than fruit-based fermented dairy products, which might have influenced their degree of likings for overall acceptability. Previous studies on coconut substitution in fermented yoghurt showed similar preferences as well [23, 31].

Table 4

Sensorial properties of «Dahi»

Parameters	Sample A	Sample B	Sample C
Colour	8.17 ± 0.02^{a}	7.64 ± 0.02^{b}	7.35 ± 0.01^{c}
Taste (Mouthfeel)	7.82 ± 0.02^{a}	7.56 ± 0.02^{b}	7.45 ± 0.02^{c}
Aroma	7.42 ± 0.01^{b}	7.39 ± 0.01^{c}	7.45 ± 0.01^{a}
Consistency	7.84 ± 0.02^{c}	7.89 ± 0.01^{a}	7.86 ± 0.02^{b}
Overall acceptability	8.03 ± 0.01^{a}	7.79 ± 0.01^{c}	7.96 ± 0.02^{b}

*Data in same raw with different letters are significantly different ($P < 0.05$). A = 100% cow milk dahi, B = 50% cow milk + 50% coconut milk dahi, C= 100% coconut milk dahi

Microbial Properties of «Dahi»

Table 5 demonstrated a significant decrease in the total bacterial count while substituting cow milk with coconut milk ($p<0.05$). Sample A had the highest microbial load ($5.34\pm0.01\times10^{5}$cfu/ml) followed by sample B ($4.87\pm0.02\times10^{5}$ cfu/ml) and sample C ($4.51\pm0.01\times10^{5}$ cfu/ml). The microbial status of all the «Dahi» samples was within the acceptable standard ($<1\times10^{6}$ cfu/ml) for fermented dairy products [32, 25].

Table 5

Microbial properties of «Dahi»

Parameters	Sample A	Sample B	Sample C
TBC (cfu/ml)	$5.34\pm0.01\times10^{5a}$	$4.87\pm0.02\times105^{b}$	$4.51\pm0.01\times10^{5\ c}$

*Data in same raw with different letters are significantly different ($P < 0.05$). A = 100% cow milk dahi, B = 50% cow milk + 50% coconut milk dahi, C= 100% coconut milk dahi

Conclusion

The results found in this study indicate that it is feasible to use coconut milk in «Dahi» production, which should be of economic importance since it is relatively inexpensive as well. The coconut enriched «Dahi» was found to have good nutritional value. It may enhance the health benefits of the fermented product, especially those related to lactose intolerants and cardiovascular health. Hence it can be recommended as a promising substitute for «Dahi» made with cow milk. As coconut milk reduced the sensory scores of the «Dahi» in particular attributes, flavoring agents might be used to improve its sensorial acceptability in future development. Future investigation should be carried out in assessing the storage stability of «Dahi» enriched with coconut milk.

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Influence of water temperature and moisture increase on wheat temperature during moistening

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Abstract

Introduction. The purpose of this work is to develop a simplified dependence for determining the grain temperature of wheat during moistening, taking into account the heat capacity coefficients, which relates the grain temperature of the wheat after moistening with its initial temperature, water temperature and the amount of water to moisten the grain.

Materials and methods. The studies were performed on the basis of mathematical modeling using the law of thermal conductivity of grain and water. The experimental data were processed using the least squares method. Checking adequacy obtained depending performed using Fisher's F-test.

Results and discussion. When moistening of wheat grain, the temperature of which increases from -10 °C to 50 °C with water, the temperature of which increases from 5 °C to 60 °C leads to an increase in grain temperature in a linear relationship. This made it possible to develop a linear dependence of the wheat grain temperature after moistening, which takes into account the initial grain temperature and the initial water temperature with a constant amount of water added to the grain.

The dependence of the change in wheat grain temperature on its initial temperature and different amount of added water was investigated. The water temperature was 20 °C. The analysis of the results showed that the wheat grain temperature increases linearly with increasing its temperature and increasing the amount of water added to the grain mass. It is established that linear straight change the angle of inclination relative to the point equal to temperature 10 °C. This made it possible to introduce in a linear relationship an indicator that takes into account the amount of water added to the grain mass.

Checking the adequacy of the obtained linear dependence showed that the equation is adequate. Analysis of the obtained data showed that the deviation of the grain temperature calculated by the linear equation and the physical model varies within 1.0 °C in absolute value.

Conclusion. After conducting a study of the change in the grain temperature during moistening with heated water, we obtained a generalized dependence, which takes into account the thermal conductivity coefficients. The obtained dependence can be recommended for the analysis of the wheat grain temperature in the process of its moistening.

Introduction

Grain temperature in flour milling technology is a factor that determines the conduct of hydrothermal treatment processes [1, 2, 4] and grinding [3, 5, 9].

In winter and in the transition period of the year, when grain with reduced or even negative temperature flows from storage systems to flour mills, the yield of high-grade flour decreases and also its quality. When the grain temperature drops below 15 °C, its technological properties deteriorate significantly, especially at temperatures below 0 °C [4]. In works [4, 8] showed changes in grain temperature in the cold season during grain preparation for grinding.

The mechanical properties of wheat grain are significantly affected by temperature [3, 4]. Cold grain is more brittle [3] than room temperature or high temperature grain, so its strength decreases [4] and microhardness numbers increase [4]. When grinding such a grain, the endosperm is deformed into large particles, and the bran into smaller particles, resulting in the yield of large particles increasing, and the specific energy consumption for grinding 1 kg of grain is reduced [4]. Due to the increased brittleness of the bran they are easily crushed and getting into the flour impairs its color [4]. At the same time, the detaching adhering endosperm particles from the bran deteriorates [4]. When milling grain with a low temperature, its ash content increases by 0.02–0.06% compared to the flour obtained by milling grain in the summer [4]. When grinding cooled grain, both moist and dry, its strength decreases [4]. When milling the bran and endosperm are crushed almost equally, which is contrary to the principles [4] grinding grain during processing it into high-grade flour. In this regard, the processing of grain with low or negative temperature into flour significantly deteriorates the performance of flour mills and reduces their profitability [4]. The energy consumption per unit of the formed surface decreases with decreasing temperature [4].

In conditions of temperate continental climate, moistening of wheat grain in flour milling plants is carried out by heated water [3]. Practical determination of grain temperature in a stream after the addition of heated water to it is a difficult task [3], but it can be solved on the basis of grain thermal conductivity laws.

To determine the grain temperature Egorov G.A. cites dependence, which is based on thermophysical properties of grain [3]. The practical application of this formula is complicated by the fact that it is necessary to take into account the water heat capacity, which varies depending on the water temperature and the grain heat capacity, which changes with the change of moisture and grain temperature. One of the disadvantages of this formula is the need to take into account the mass of grain and water. This complicates the practical use of this dependency. These disadvantages give rise to a simplified dependency that takes into account the above parameters.

Materials and methods

Determination of grain temperature after moistening

The grain temperature after moistening t_g, °C was determined by the formula [3]:

$$t_g = \frac{M_g t_0 c_g + m_w t_w c_w}{\left(M_g + m_w\right) \cdot c_{mg}} \quad (1)$$

where M_g – mass of grain, kg; M_w – mass of water, kg; t_0 – grain temperature before moistening (cold grain), °C; t_w – water temperature, °C; c_g – specific heat capacity of grain,

J/kg·K; c_w – specific heat capacity of water, J/kg·K; c_{mg} – specific heat capacity of moistened grain, J/kg·K; M_g – mass of grain, which is equal to M_g = 1.0 kg; m_w = mass of water added to the grain for its moistening is calculated by the formula 5, kg.

Determination of specific heat capacity of grain

The specific heat capacity of dry grain, c_g, J/кг·K was calculated by the formula [12]:

$$c_g = \left(891.7 + 87.49W - 1.545W^2 + 0.01149W^3\right) \times \\ \times \left[1 + 0.287 \cdot 10^{-3}\left(25 - W\right)\left(t_0 - 28\right)\right] \quad (2)$$

where W – grain moisture by total weight, %; t_0 – grain temperature, °C.

Given that the grain temperature after moistening is unknown and is the subject of research, the formula 2 was not used to calculate the specific heat capacity of the moistened grain.. Specific heat capacity of grain, c_{mg}, J/kg·K after moistening was determined by the formula [11, 12]:

$$c_{mg} = \frac{W}{100} c_w + \frac{100 - W}{100} c_{ds} \quad (3)$$

where W – moisture grain, %; c_w – specific heat capacity of water, calculated by the formula 4, J/kg·K; c_{ds} –specific heat capacity of wheat dry matter, which is equal c_{cp} = 1550 J/kg·K.

Determination of water specific heat capacity

The specific heat capacity of water, c_w, J/kg·K was calculated by the formula proposed by Osborne, Stimson and Ginningson [7]:

$$c_w = c_w\left(15^\circ C\right) \cdot \left[0.99618 + 0.0002874\left(\frac{t_w + 100}{100}\right)^{5.26} + 0.011160 \cdot 10^{-0.036 t_w}\right] \quad (4)$$

where $c_w(15\ °C)$ – specific heat capacity of water at 15 °C, $c_w\left(15^\circ C\right) = 4185.5$ J/kg·K; t_w – water temperature, °C.

Determining the amount of water to grain moistening

The mass of water, m_w, kg was determined by the following formula:

$$m_w = \frac{W_1 - W_0}{100} \quad (5)$$

where W_1 – final predetermined moisture content of the total grain weight, %; W_0 – initially set grain moisture to total weight, %.

Mathematical processing of research results

The dependencies were processed based on the least squares method [6, 10].

The adequacy of the obtained mathematical model was verified by Fisher criterion by comparing the calculated F_c and tabulated F_t values of the criterion. Subject to inequality $F_c \le F_t$, it was concluded that the obtained equation was adequate [6, 10].

Results and discussion

Temperature dependence of wheat grain after its moistening with different water temperature

Figure 1 shows the results of calculating the grain temperature during moistening with different water temperatures and a fixed value of the increase in moisture of 4 %. Water temperature was taken from +5 to +50 °C.

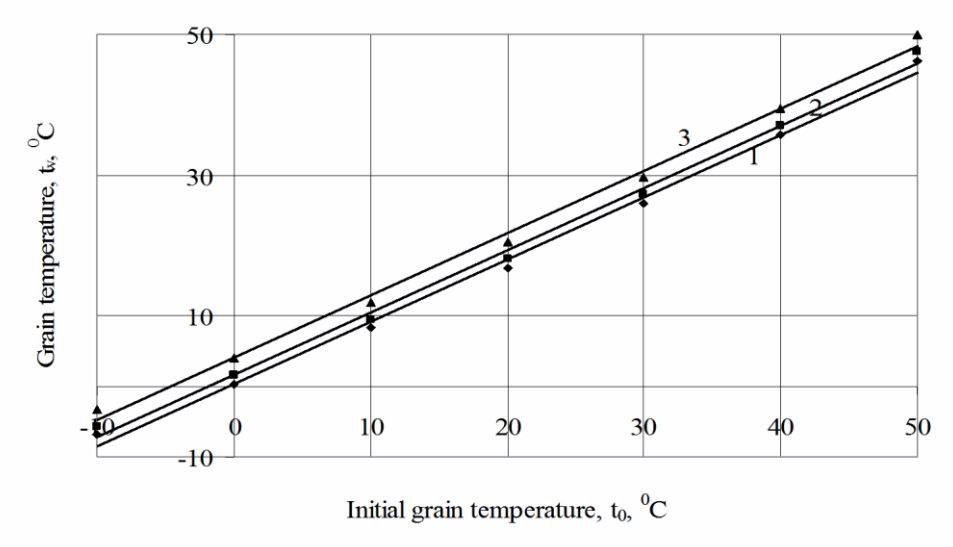

Figure 1. Temperature dependence of moistened wheat on the water temperature and the initial grain temperature (shown only three straight):
1 – water temperature +5 °C; 2 – water temperature +20 °C; 3 – water temperature + 50 °C.

Analysis of the data Figure 1 shows that the nature of the change in the moistened grain temperature can be approximated by linear dependencies for all parameters of grain moistening. The slight deviation from the linear form of the obtained points can be explained by the fact that the calculated formula 1 takes into account the nonlinear dependence of the water heat capacity coefficient, which introduces an error in the calculation of the final grain temperature.

The linear dependences of the grain temperature after moistening, which are shown in Figure 1 are approximated by linear equations:

– for water temperature +5 °C:

$$t_{mg} = 0.885 \cdot t_0 + 0.3857 \quad (6)$$

– for water temperature +10 °C:

$$t_{mg} = 0.886 \cdot t_0 + 0.7928 \quad (7)$$

– for water temperature +20 °C:

$$t_{mg} = 0.886 \cdot t_0 + 1.6357 \quad (8)$$

– for water temperature +30 °C:

$$t_{mg} = 0.886 \cdot t_0 + 2.45 \quad (9)$$

– for water temperature +40 °C:

$$t_{mg} = 0.886 \cdot t_0 + 3.2785 \quad (10)$$

– for water temperature +50 °C:

$$t_{mg} = 0.886 \cdot t_0 + 4.0785 \quad (11)$$

– for water temperature +60 °C:

$$t_{mg} = 0.886 \cdot t_0 + 4.8928 \quad (12)$$

where t_{mg} – temperature of moistened wheat grain, °C; t_0 – initial grain temperature, °C.

The analysis of the obtained equations shows that the free coefficient *b* increases with increasing water temperature, which gives grounds to approximate the value of this coefficient from the change in water temperature and to obtain the corresponding dependence. The coefficient *a*, does not change and is 0.886.

In Figure 2 shows the dependence of the coefficient *b* of the linear equations 6–12 on the water temperature during moistening of wheat grain. As can be seen from Figure 2 his dependence is described by a linear equation:

$$b = 0.082 \cdot t_w - 0.016 \quad (13)$$

where t_w – water temperature, which is added to grain, °C.

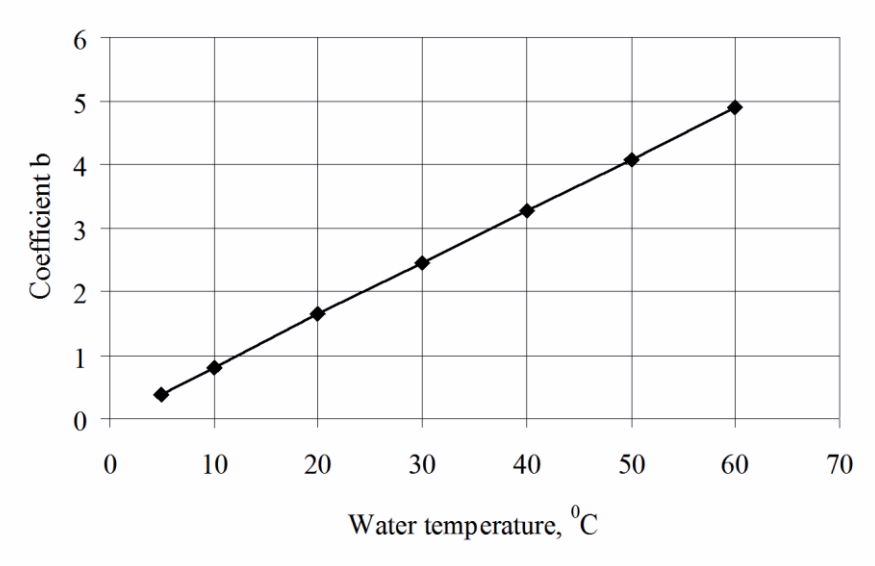

Figure 2. The dependence of the coefficient *b* on the water temperature during moistening of wheat grain

Taking into account equation 9–13, we can write the general equation for calculating the grain temperature of wheat, taking into account its initial temperature and the water temperature at which it is moistened:

$$t_{mg} = 0.886 \cdot t_0 + 0.082 \cdot t_w \quad (14)$$

where t_0 – initial grain temperature, °C; t_w – initial water temperature, °C.

It can be seen from equations 6–12 that at a constant value of moistening but at different temperatures the free term of equations *b*, changes, and the coefficient *a* remains unchanged.

This gives rise to conjecture that coefficient *a* may change with the amount of water added to the grain during moistening. On this basis, it is sufficient to study the change in grain temperature depending on the initial grain temperature and different increase in moisture, but the water temperature must be constant for all parameters. This will allow to analyze the change in the grain heating process for one variant and the results can be transferred to any other conditions, but if the nature of the process is also linear.

Dependence of wheat grain temperature on the amount of water added

Modeling of temperature change at constant temperature, but the different amount of water needed to increase the grain moisture content to 16.0 % indicates that an increase in the amount of water that must be added to the grain during moistening leads to an increase in the grain temperature. That is, with increasing water temperature, the grain temperature also increases. The results of the studies are shown in Figure 3.

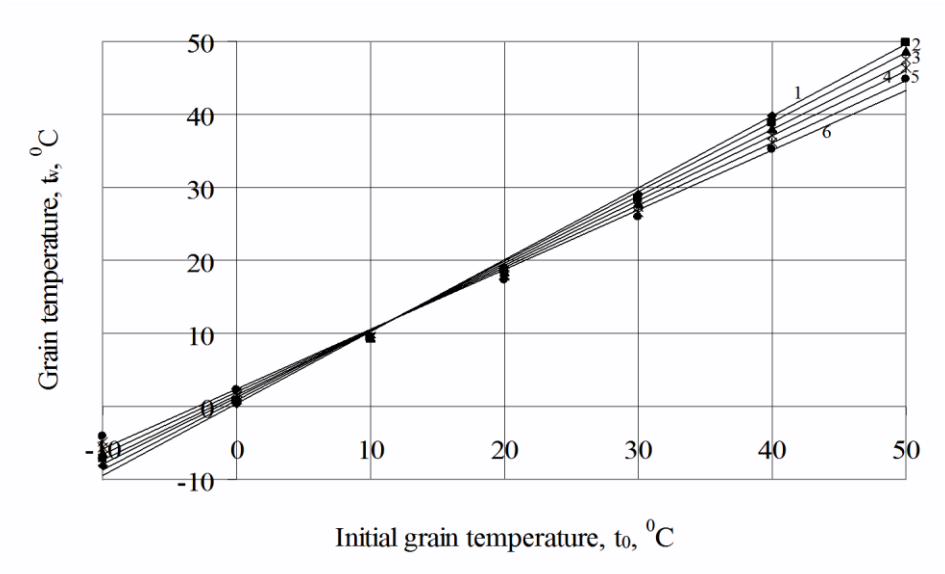

Figure 3. Change in grain temperature when moistened with constant temperature water +20 °C and changes in the initial grain temperature and increase in moisture: 1 – ΔW = 1.0 %; 2 – ΔW = 2.0 %; 3 – ΔW = 3.0 %; 4 – ΔW = 4.0 %; 5 – ΔW = 5.0 %; 6 – ΔW = 6.0 %.

The nature of the temperature change of the moistened grain can be approximated by linear dependences for all moistening parameters.

The linear dependencies (Figure 3) are described by the following equations:

– with increasing moisture ΔW = 1.0 %:

$$t_{mg} = 0.985 \cdot \Delta W + 0.3857 \quad (15)$$

– with increasing moisture ΔW = 2.0 %:

$$t_{mg} = 0.951 \cdot \Delta W + 0.8357 \quad (16)$$

– with increasing moisture ΔW = 3.0 %:

$$t_{mg} = 0.918 \cdot \Delta W + 1.2357 \quad (17)$$

– with increasing moisture ΔW = 4.0 %:

$$t_{mg} = 0.886 \cdot \Delta W + 1.6357 \quad (18)$$

– with increasing moisture ΔW = 5.0 %:

$$t_{mg} = 0.852 \cdot \Delta W + 2.0142 \quad (19)$$

– with increasing moisture ΔW = 6.0 %:

$$t_{mg} = 0.816 \cdot \Delta W + 2.4071 \quad (20)$$

where ΔW – the amount of moisture that is added to the grain in the moistening process, %.

An analysis of equations 15–20 shows that the coefficient *a* in the equations decreases with an increase in the amount of moisture that is added to grain for its moistening.

To enter the moisture increase parameter in equation 14 conduct analysis of coefficient change *a* from the moisture increase. In Figure 4 shows the dependence of the coefficient *a* the equations 15–20 on the increase of moisture in grain.

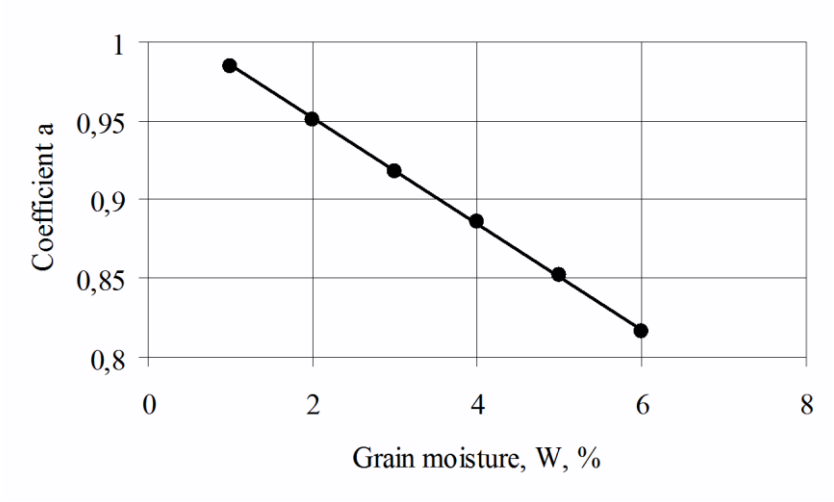

Figure 4. Dependence of the coefficient *a* on increase in moisture ΔW

The linear dependence shown in Figs. 4 is approximated by a linear equation:

$$a = -0.033449 \cdot \Delta W + 1,0189 \quad (21)$$

where ΔW – increase in moisture, $\Delta W = (W_1 - W_0)$ %; W_1 – final (predetermined) grain moisture, %; W_0 – initial grain moisture content, %.

Given the equation 21, equation 14 will take the following form:

$$t_{mg} = (-0.033449 \cdot \Delta W + 1.0189) \cdot t_0 + 0.082 \cdot t_w \quad (22)$$

Equation 22 makes it possible to determine the grain temperature of wheat after its moistening and takes into account the initial grain temperature, the water temperature during moistening, and the increase in moisture. This greatly simplifies the calculations of grain temperature after moistening, since it takes into account the coefficients of grain and water heat capacity. Dependency 22 is recommended for approximate practical application to analyze grain temperature.

Equation 25 is valid only for determining the temperature of the wheat grain during its moistening. For other types of grain, it is necessary to enter other parameters of the grain thermal conductivity.

Checking the adequacy of the obtained mathematical dependence

Let us check the adequacy of the regression equation for Fisher criterion. Calculate the value of the grain temperature after moistening at the initial water temperature $t_w = 55$ °C and moisture increase ΔW = (16.0–12.5) = 3.5 % by formulas 1 and 25. The initial grain temperature is changed from - 10 to 50 °C in 10 ° C increments. The results of the calculation are given in Table 1.

Table 1

Results of the calculation of the grain temperature after moistening for each variant of the initial grain temperature with a constant moisture increase of 3.5%, and the initial water temperature 55 °C.

Initial grain temperature	Moisturized grain temperature, °C	
	by physical model 1 , x_{1i}	by the equation 22, x_{2i}
-10	-3.5	-4.5
0	3.9	4.5
10	12	13.5
20	20.8	22.5
30	30.1	31.5
40	40.1	40.6
50	50.7	49.6
Average value, $\bar{x}$	22.0	22.5

The results of the dispersion calculation are given in table. 2.

Table 2

Intermediate dispersion calculations

№ p / n	$x_{1i} - \bar{x}_1$	$x_{2i} - \bar{x}_2$	$\left(x_{1i} - \bar{x}_1\right)^2$	$\left(x_{2i} - \bar{x}_2\right)^2$
1	-25.5	-27.0	651,0	730,5
2	-18.1	-18.0	328,1	325,0
3	-10.0	-9.0	100,3	81,5
4	-1.2	0.0	1.5	0.0
5	8.1	9.0	65.4	80.5
6	18.1	18.1	327.1	326.6
7	28.7	27.1	822.9	732.9
Σ			2296.2	2277.0

Calculate the dispersion of the values obtained by the physical equation 1:

$$S_1^2 = \frac{\sum_{i=1}^{n}\left(x_{1i} - \bar{x}_1\right)^2}{n-1} = \frac{2296.2}{7-1} = 382.7$$

Calculate the dispersion of the values obtained by the equation 22:

$$S_2^2 = \frac{\sum_{i=1}^{n}\left(x_{2i} - \bar{x}_2\right)^2}{n-1} = \frac{2277.0}{7-1} = 379.5$$

Calculate the estimated value of Fisher criterion [10]:

$$F_e = \frac{S_1^2}{S_2^2} = \frac{382.7}{379.5} = 1.0084$$

Table value of F-Fisher criterion for the degree of freedom of the numerator and denominator is 4.3.

The inequality $F_c < F_t$ holds because 1.0084 < 4.3. On this basis, we can conclude on the adequacy o $f = (7-1) = 6$ f the obtained regression equation 25 to the physical model of process 1, which describes the change in grain temperature after its moistening.

The results are given in table. 1 indicates that the calculation temperature deviation ranges 1.0 °C. Such changes can be explained by the fact that the water heat capacity coefficient has a nonlinear relationship.

Conclusion

1. Therefore, by mathematical modeling of the change in grain temperature during its moistening with heated water, we obtain a generalized dependence:
$$t_{mg} = (-0.033449 \cdot \Delta W + 1.0189) \cdot t_0 + 0.082 \cdot t_w$$
2. The advantages of this dependency are its simplified form, which allows to determine the temperature of wheat grain in moistening with warmed water, taking into account the amount of water added to the grain and the initial temperature of the wheat grain. This does not require consideration of the thermal conductivity coefficients of water and grain, since these coefficients are taken into account when calculating the temperature of grain and water at their different values. The dependence can be used to calculate water temperature more than 60 °C.
3. The calculation error at -10 to 50 °C ranges between 1.0 °C in absolute value.
4. The obtained dependence can be recommended for the analysis of the grain temperature of wheat in its the moistening process.

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Influence of the application of alternating impulses of pressure on the quantitative sensory analysis of pure water, associated liquid aqueous systems and solutions

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Abstract

Introduction. The purpose of research is to determine the effect of alternating impulses of pressure on the quantitative sensory analysis of samples of the pure water, associated liquid aqueous systems and solutions.

Materials and methods. Pure water and associated liquid aqueous systems and solutions were used for investigations and analyzing the change of their physical and chemical parameters and properties during the treatment and processing by the different methods and technological modes. Electrochemical analysis methods were used. A quantitative sensory analysis of the experimental liquid samples of pure water and associated liquid aqueous systems and solutions was performed.

Results and discussion. It is established that a great variety of methods of liquid systems and solutions treatment are widely used in different brunches of food industry. The physical and chemical properties and parameters of water, and liquid mediums, such as: oxidation-reduction potential, pH value, dissolved oxygen and etc. may be changed by the physical methods of energy influence.As a result of the water treatment in the in the conditions of alternating impulses of pressure throughout 1s gave the opportunity to increase general score of a quantitative sensory analysis on 12,12%, the water treatment in the in the conditions of alternating impulses of pressure throughout 30s gave the opportunity to increase general score of a quantitative sensory analysis on 3%, the water treatment in the in the conditions of alternating impulses of pressure during 60s gave the opportunity to increase general score of a quantitative sensory analysis on 9%. It ought to be distinguished that the taste, odor, appearance, color of water has improved in comparison with the control liquid simple of water.

Conclusions. According to the results of organoleptic studies, it is established that water has a higher tasting score and improved organoleptic parameters, which has a positive effect on the quality of the finished product, as compared to the control samples, which obtained by the technology of the enterprise.

Introduction

At the present time organoleptic methods objectively, quickly and reliably give an overall assessment product quality. Touch control allows you to quickly and purposefully affect all stages of food production.

Intensification of agrarian sector and food technologies, application unconventional types of raw materials and new technologies lead to changes, usually negative flavoring properties, texture and other organoleptic food quality indicators.

It is allowing you to quickly and purposefully affect all stages and operations of food production.

Using of innovative technologies gives the possibilities to reduce the energy and recourses consumption of food production. The method of the alternating impulses of pressure may be suitable for technology of water treatment for food and foodstuff production.

The purpose of this scientific work is to investigate the influence of the application of alternating impulses of pressure throughout treatment in foodstuff production by the quantitative sensory analysis of samples of the pure water and associated liquid aqueous systems and solutions.

Materials and methods

Materials

Objects of research are different types of treatment and processing methods end modes of liquid water systems and solutions like as technological water for the application in food industry.

Subjects of study are the changing of the physical and chemical parameters and properties of liquid water systems and solutions which can form hydrogen bonds and associates of different variety [1].

Pure water and associated liquid aqueous systems and solutions were used for investigations and analyzing the change of their physical and chemical parameters and properties during the treatment and processing by the different methods and technological modes. [2]

Experimental installation

The object of this scientific research work was rotary pulsed apparatus in which liquid solutions treat by alternating impulses of pressure, the speeds of shift of a stream, pressures of shift of a stream. Rotary pulsed apparatus was the cylindrical type with the working parts «rotor-stator-rotor» [3].

Methods

General scientific methods and special methods, such as electrochemical analysis methods were used for the analyzing of the results of research work [4].

For the description of physical and chemical parameters of liquid samples of water and solutions which obtained throughout the experimental investigations, chemical methods described in singular literature are used [5]

A quantitative sensory analysis of the experimental liquid samples of pure water and associated liquid aqueous systems and solutions was performed [6].

For the reception related data, liquid samples of water and solutions were analyzed not less than three times with the following statistical processing [7].

Results and discussion

There are many methods of water treatment for changing chemical and physical properties and parameters. In recent years researches and technologists and engineers have turned their interest to employment of the innovative non-traditional technologies and methods in processing of the liquid mediums, solutions, systems, which consists of the water or water solutions.

The physical and chemical properties and parameters of pure water and associated liquid aqueous systems, solutions and mediums, such as: oxidation-reduction potential, pH value, dissolved oxygen and etc. may be changed by the physical methods of energy influence.

The application of sonication treatment using audible sound (20-75 Hz) showed to have a positive effect to improve the quality and consumer acceptability of carbonated water due to the effects of audible wavelengths which increase pressure within the bottle and, therefore, modifies bubble size during formation [8].

That's why hydrodynamic effects occur at water and water binary systems and different water mixtures and solutions treatment by physical and mechanical methods or so-called non reagent (reagentless).

The method of alternating impulses of pressure is one of physical methods of treatment with many hydrodynamic effects, such as power of pressure of shift, cavitations, the effect of explosive boiling, collective effects in assembly of vials, crossness of an interphase surface in gas-liquid bubbly medium, action of hydrodynamic oscillations, alternating impulses of pressure, effects which associated with acceleration of movement of a continuous phase.

The most important effects of the alternating impulses of pressure are allied with increase of velocity of association of a continuous phase of medium.

The method of alternating impulses of pressure can influence on structural and energy transformation in multifarious liquid mediums on micro- and nano- level and gives opportunity to begin physical and chemical alteration in these mediums.

The fundamental nature of alternating impulses of pressure consists in that preliminary permanently entered and any rank the energy distributed in working to accumulate in locally disconnected discrete points of system and further pulse to realise for achievement of necessary physical effects:

- Forcing and dumping of pressure;
- Adiabatic boiling;
- Hydraulic blow;
- Shock waves of pressure or depression;
- Pressure of shift, local turbulence;
- Cavitation and many other effects [9].

Three-dimensional and period concentration of energy gives the possibility to receive the big capacity of pulsation power accomplishment, to release internal energy of substance, to create active energetic processes which take place at microlevel and also at nanolevel.

The development of different microliquid devices for some last decades has caused growth of interest to microscale streams. Rotary pulse apparatus are characterised by small enough sizes of width of channels which gives the possibility to consider them as microchannels with effects of slippage a watercourse on walls and surfaces.

A number of heat and mass technological processes (structuring, crushing, dispersion, emulsification, homogenization, mixing, etc.) are spend in rotary pulse apparatus of cylindrical type which realise principles of alternating impulses of pressure.

Investigating of new methods, apparatus and industrial technologies are concentrating on raise of an overall presentation of procedure and an increase of processes in environments

which involves complex researches on learning of hydrodynamic conditions, modelling of processes in new devices.

In this context, research methods of analysis are very important since this is the main tool for obtaining data. One of the key positions belongs to the sensory analysis method.

The potential value of sensory analysis has often been undermined in the food industry and in foodstuff production. A great variety of forms of sensory-related work can provide an important investigative and informative function in a great number of different areas [10].

Specialized research techniques are available to measure, understand and optimize consumers' sensory experiences, so that products can be designed and marketed to meet consumers' sensory needs, thus reducing the risk of product failure. This scientific field is known as sensory evaluation [11].

It can be production of different types of products: drinks, beverages which include:

- Beer;
- Carbonated water;
- Carbonated soft drinks;
- Sparkling wine, among;
- Others, liquid food goods which can consist from dissimilar solutions.

Emerging technologies, based on the combination of robotics, computer vision, and machine learning as an approach to artificial intelligence, have been developed and applied for the assessment of baverages and beer and, to a lesser extent, sparkling wine [12].

Traditionally, sensory evaluation has often been associated with product experts and specialists, and afterward as a more passive member of the product development team.

Currently, the new challenges facing the food industry are progressively transforming sensory to a more proactive role, responsible for generating new product ideas based on unique sensory properties or unique consumer segments identified only through sensory behavior [13].

Choice of sensory method should be based on better methodological data on how methods perform and at what cost in resources. There is a need for more methodological research to establish the reliability and validity of sensory methods [14].

Nowadays for a continuous monitoring with fast response times and low cost, new measurements techniques have been developed through Electronic Noses (E-noses), given that they are an alternative instrumental measurement, replacing the conventional methods used for the detection and bacteria identification in different types of samples [15].

According to the investigations carried out during the last years about the electronic noses, it is important to mention that this equipment can be used for specific analysis, identification and recognition of complex smells and volatile organic compounds [15].

So authors can show after this sensory analysis and wine tasting that the anti-transpirant product does not affect the wine notes and their characteristic structure [16].

Sensory analysis gives the ability to generate sensory and chemical profiles of commercial wines, and to identify many sensory characteristics for wine: stone fruit, dried fruit, citrus, herbaceous, grassy, apple/pear, confectionary, vanilla, creamy, buttery, wood, and toasty [17].

The sensory analysis revealed a clear vintage, closure and glutathione effect on wines oxidative character after several years of bottle aging [18].

To address the issue of the role of vine water deficit in the overall quality of fine aged wines, a large set of wines from four Bordeaux appellations were subjected to sensory analysis [19].

Fermentation process parameters: pH, total acidity and yield of biomass; chemical composition: organic acids, total phenols and flavonoids and vitamin C content and sensory analysis indicated that SWE were more suitable substrates for successful fermentation [20].

Consequently, the measurement and monitoring of final product quality factors and features are critical for the production of all types of carbonated beverages and drink products.

Taste and odor problems in drinking water frequently occur because of many compounds present in the water [21]. Physical and chemical analysis helps determine this.

Quality control, mainly focused on the assessment of bubble and foam-related parameters, is critical in carbonated beverages, due to their relationship with the chemical components as well as their influence on sensory characteristics such as aroma release, mouthfeel, and perception of tastes and aromas [12].

Microorganisms in drinking water contribute largely to taste, and odor production and drinking water distribution systems are known to harbor biofilms and microorganisms in bulk water, even in the presence of a disinfectant [22]. Importantly, the understanding of types of these microbes and their taste, and odor compound-producing mechanisms is needed to prevent taste, and odor formation during drinking water distribution [22].

Also sulfide and polysulfides are strong nucleophiles and reducing agents that participate in many environmentally significant processes such as the formation of sulfide minerals and volatile organic sulfur compounds.

Their presence in drinking water distribution systems are of particular concern and need to be assessed, since these species consume disinfectants and dissolved oxygen, react with metal ions to produce insoluble metal sulfides, and cause taste and odor problems [23].

To identify the cause of off-odor in bottled water is necessary special methodology. For initial screening, sensory analysis and gas chromatography with mass spectrometry and olfactometric detector were used.

Selected compounds were then analyzed and quantified by selective ion monitoring. 2,4-decadienal, a fatty acid oxidation product, was identified as the source of off-odor [24].

Descriptive sensory analysis is conventionally conducted using a trained panel and has the purpose of developing the sensory profile of a product by evaluating the intensities of the major descriptors.

This category of sensory analysis is more often than not used in innovative product enlargement and to assess the quality of the same formulation in the unusual batches produced.

A quantitative sensory general score of water treated under alternating impulses of pressure depending on the processing time or the duration of treatment.

Comparative analysis of samples of the pure water and associated liquid aqueous systems and solutions was used for data processing.

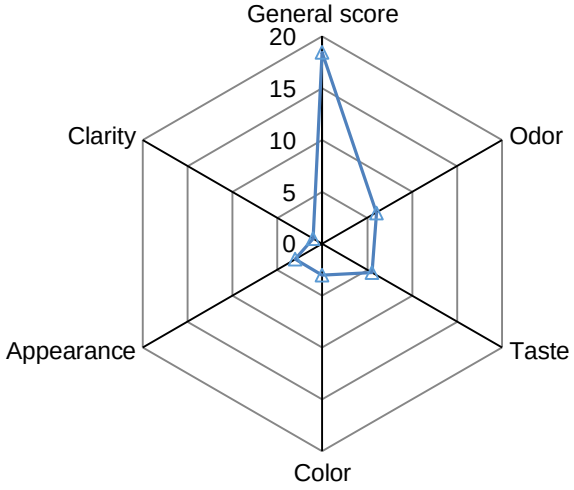
Control liquid samples of water were used for comparative analysis. These were samples obtained according to the enterprise standard methodology.

The general score of control samples was 16,50 and the general score of water solutions which was treated in conditions of alternating impulses of pressure was 18,50 (Figure 1).

In general course an effect of the water treatment in the conditions of alternating impulses of pressure during uninterrupted mode throughout 1 second gave the opportunity to increase general score of a quantitative sensory analysis of water on 12,12%.

It ought to be distinguished that the taste, odor, appearance, color of water and water solutions has improved in comparison with the control liquid simple of water and water solutions.

As a result the general score of control samples was 18,00 and the general score of water which was treated in the conditions of alternating impulses of pressure was 18,5 (Figure 2).



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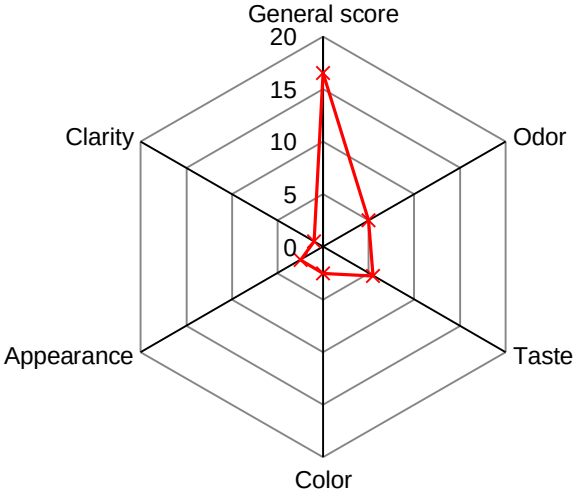

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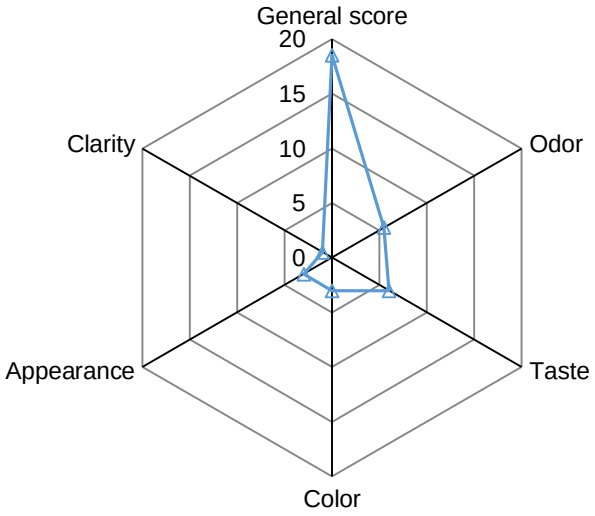
Figure 1. Tasting evaluation of water samples with processing time 1s:
a – liquid simples of water which was treated in the conditions of alternating impulses of pressure;
b – control liquid simples of water



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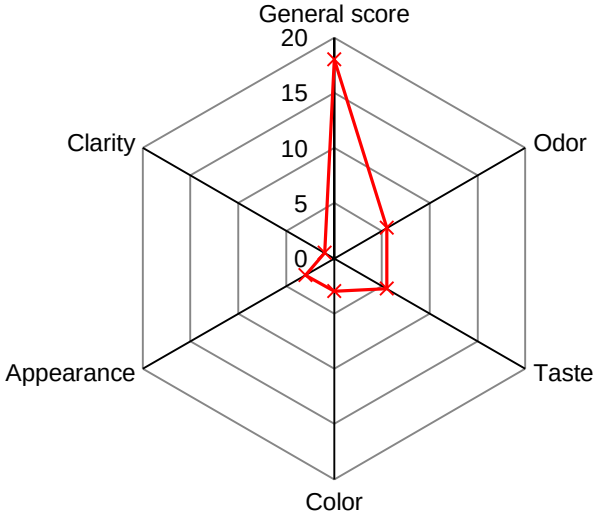

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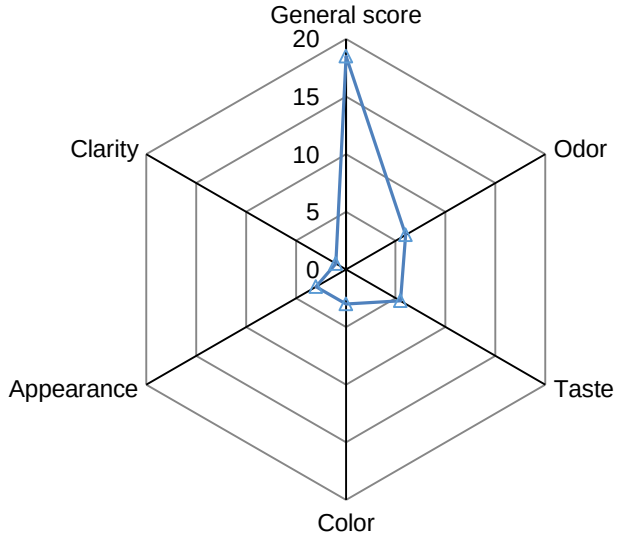
Figure 2. Tasting evaluation of water samples with processing time 30s:
a – liquid simples of water which was treated in the conditions of alternating impulses of pressure
b – control liquid simples of water

The results of research investigations demonstrate that the application of the water solution treatment in the conditions of alternating impulses of pressure throughout 30 seconds gave the opportunity to increase general score of a quantitative sensory analysis of water on 3%.

It ought to be distinguished that the taste of water and water solutions has improved in comparison with the control liquid simple of water without any treatment.

In wide-ranging course the general score of control samples was 17,00 and the general score of water solutions which was treated by alternating impulses of pressure was 18,5 (Figure 3).



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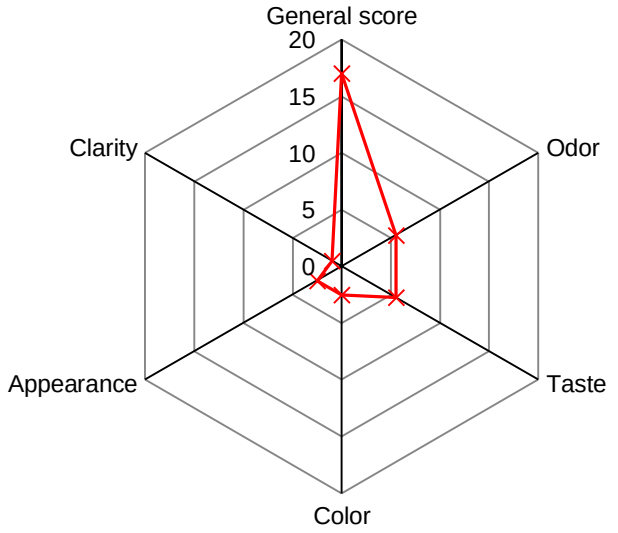


b

Figure 3. Tasting evaluation of water samples with processing time 60s:
a – liquid simples of water which was treated in the conditions of alternating impulses of pressure
b – control liquid simples of water

During the scientific work the result of the water solutions treatment in the conditions of alternating impulses of pressure during 60 seconds gave the opportunity to increase general score of a quantitative sensory analysis and tasting of water and water solution on 9%.

It should be noted that the taste of water has improved in comparison with the control liquid simple of water.

The general score of control samples was 17,00 and the general score of water treated by alternating impulses of pressure was 18,5 (Figure 4).

The duration of the water treatment in the conditions of alternating impulses of pressure by 90s gave the possibility to increase general score of a quantitative sensory analysis on 9%.

It should be noted that the odor of water has improved in comparison with the control liquid simple of water.

It was established that no significant differences between treatments in the conditions of alternating impulses of pressure with the duration process time more than 600s.

The general score is not increase after such time of processing, but energy efficiency and efficiency of raw material using is decrease.

The method of the alternating impulses of pressure is innovative method of treatment to receive water with necessary physical and chemical parameters and properties for food production.

It was established that appliance of the alternating impulses of pressure for water solutions treatment give possibility:

- To decrease reduction-oxidation potential on 20–70%,
- To increase the potential of hydrogen on 13–17%,
- To decrease mass of the dissolved oxygen on 50–55% [2].

Further investigation is needed to better understanding of the change physical and chemical parameters of water systems and technological water solutions during treatment.

In order to obtain more reliable sensory data, the odor thresholds of eighty-four compounds previously characterized as key food odorants were re-evaluated and compared to literature results.

On the basis of a distinct protocol, also the aroma attributes of the odorants were evaluated in order to define an aroma language, which can be used for specific purposes [25].

It will give the possibilities to create and design new energy and power saving technologies, modes, equipment and apparatus of water treatment for foodstuff production.

The importance of the improvement and submission of innovative and emerging technologies in food and foodstuff production were proven by the research investigations.

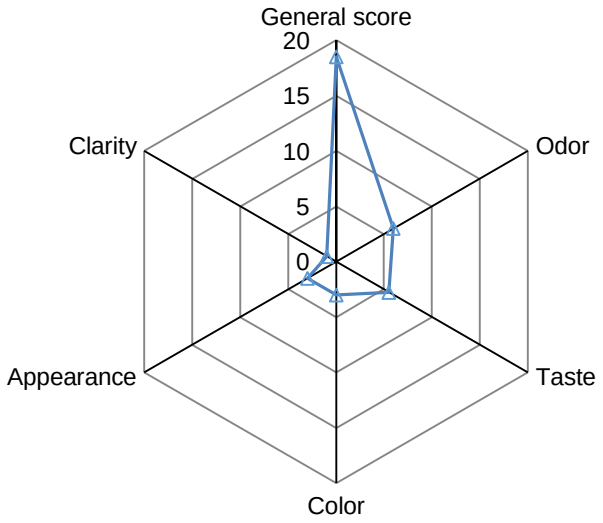
The application of the emerging technologies for quality assessment of water on physical and chemical parameters would potentially allow their implementation in the industry to evaluate the products within the production line in real-time.

The full potential of sensory evaluation is realized when sensory, consumer and and/or instrumental analyses are combined.

The command of sensory evaluation is realized when these two elements are combined to reveal insights into the way in which sensory properties drive consumer acceptance.

A key challenge is to use a highly variable human ‘measuring instrument’ to gather robust, unbiased data [11].

The objective be obliged to be to accomplish a realistic and practical balance between sensory analysis methodology and instrumental methods and to administer the sensory process effectively, if consequences are to be carrying great weight for foodstuff production.



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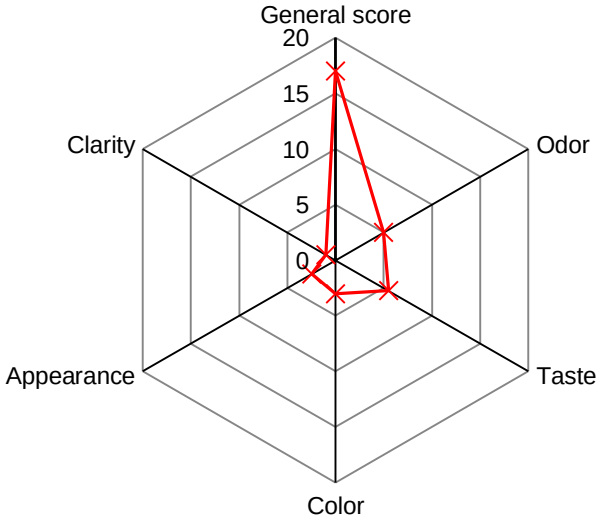

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Figure 4. Tasting evaluation of water samples with processing time 90s:
a – liquid simples of water which was treated in the conditions of alternating impulses of pressure
b – control liquid simples of water

Conclusions

At the present time one of unique and new method and equipment that was used for improvement of water treatment process is the method of alternating impulses of pressure.

New experimental and theoretical studies and modeling have shown that the method of alternating impulses of pressure may possibly be suitable for processing in food industry and foodstuff production, where hydrodynamic effects are found to be an substitute to traditional methods and modes in technological lines, equipment and processes of water and water solutions treatment.

According to the general results of sensory analysis and organoleptic studies, it was established that water solutions has a higher general tasting score and improved organoleptic parameters, which has a positive effect on the quality of the finished product, as compared to the control samples, which obtained by the technology of the enterprise.

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Using of whey in dairy desserts technology

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Abstract

Introduction. Research is underway intensively in the world in the direction of modifying the structure and properties of whey. The purpose is to regulate the characteristics for use in various industries, including the creation of qualitatively new special purpose foods.

Materials and methods. The object of research – whey as a raw material in the production of dairy desserts.

Results and discussion. Work on the implementation of methods of the full cycle processing of whey by isolating, concentrating, modifying its properties and developing innovative technologies for its use in food products, including the intended purpose has a certain resource-saving orientation. This will allow effectively use of the technological properties of fillers, their synergistic interactions with each other and with whey. The ability to improve the functional and technological characteristics of whey. Expanding the possibilities of use in whey-based food production technologies.

Scientists are conducting research on the creation of technologies for the further use of whey in the dairy industry for the production of intermediate goods, process mixtures and functional products, to obtain complete food products for the intended purpose and thus to provide the population with proteins and nutrients in bioavailable form.

The introduction of resource-saving technologies and the production of high-quality and safe products with high consumer properties, contributes to solving the problem of protein deficiency, as well as providing the population of various social groups and living conditions with complete, balanced and bioavailable micronutrient composition, combined and multi-component target food products is of current importance area of research.

Conclusions. The combination of dairy components and fruit and berry fillers will provide the desired technological effect and original organoleptic characteristics of new types of dairy desserts.

Introduction

The development of non-waste technologies with the maximum use of helpful components that are part of the secondary raw materials is relevant for the food industry.

Whey is milk plasma, which is obtained by thermomechanical processing of milk clot during the manufacture of cheese, cottage cheese or casein.

The composition and physico-chemical properties of whey, depending on the type of main product and the features of the technology of its manufacture, are presented in the table 1 [1, 2].

Table 1

Composition and physico-chemical properties of whey

Index	Whey		
	Cheese	**Curd**	**Casein**
Dry matter content, %	4.5–7.2	4.2–7.4	4.2–7.4
Including:			
lactose	3.9–4.9	3.2–5.1	3.5–5.2
nitrogen compounds	0.5–1.1	0.5–1.4	0.5–1.5
mineral substances	0.3–0.8	0.5–0.8	0.3–0.9
milkfat	0.05–0.5	0.05–0.4	0.02–0.1
Acidity (pH), °T	15–25	50–85	50–120
Density, kg/m^3	1018–1027	1019–1026	1020–1025

Lactose is the main component of whey and accounts for about 70% of whey dry matter. A significant amount of biologically valuable whey proteins, free amino acids and minerals passes into the whey. Whey proteins are more finely dispersed than casein, are better absorbed by the human body and contain more essential amino acids [3, 4].

Whey proteins consist primarily of globulins and albumins. The main amongst the whey proteins is β-lactoglobulin, its share is about 10% of the total amount of milk proteins (table 2) [1].

Table 2

Total amino acids in whey

Whey	Amino Acids, mg/dm^3			
	Free		**In proteins**	
	Total	**Including Essential**	**Total**	**Including Essential**
Cheese	132.7	51.0	6490	3326
Curd	450.0	356.0	5590	2849

Milk fat contained in whey is finely dispersed, which has a positive influence on its digestibility. The composition of whey includes almost all the minerals of milk, as well as organic acids [5].

Lactic, citric, nucleic and volatile fatty acids (acetic, formic, propionic, butyric) were found among organic acids in whey. The content of volatile fatty acids in curd whey is higher

than in cheese whey, which is explained by partial hydrolysis of fat in the process of cheese clot formation [6, 7].

The food energy of whey is slightly lower than that of whole milk, and the biological value is even higher, which contributes to its use in dietary nutrition. Water-soluble vitamins almost completely pass into whey, besides there are a few more of them in cheese whey (table 3) [6].

Table 3

Whey Vitamin Content

Whey	Vitamins, mcg/kg								
	β-carotene	**A**	**E**	**B_1**	**B_2**	**B_6**	**choline**	**PP**	**C**
Cheese	13	22	227	315	1389	524	160000	140	500
Curd	75	110	315	263	1107	478	140000	140	500

Due to the insufficient number of innovative developments, a significant part of the nutrients and regulatory substances necessary for the human body is being lost. Research is underway intensively in the world in the direction of modifying the structure and properties of whey. The purpose of which is to regulate the characteristics for use in various industries, including the creation of qualitatively new special purpose foods.

Whey is used for the manufacture of beverages, dairy products, concentrates, milk sugar, dessert products, namely, kysil, jelly, puddings and mousses. World and domestic experience shows the viability of research to improve the nutritional properties of whey-based dessert products. Desserts are made from natural pasteurized whey, concentrated or condensed, with or without the addition of fat-free cheese, sugar, semolina, fruit syrups, stabilizers. This group of products is intended for direct use [8, 9].

The aim of the research is to study the chemical composition, nutritional value and technological properties of whey as a promising raw material for the manufacture of milk desserts.

To achieve this aim, the following tasks were set:

– to justify the choice of raw materials for the manufacture of dairy desserts;

– to study the technological properties of whey as a potentially promising raw material for the production of dairy desserts;

– to substantiate the feasibility of using natural ingredients in the manufacture of milk desserts.

Materials and methods

The object of research – whey as a raw material in the production of dairy desserts.

The scientific-research papers, articles, conference reports, conference abstracts, monographs, various methods, technologies of whey processing were analyzed.

Results and discussion

Analysis of the current state of whey processing

Various fermented whey-based beverages have been developed to reduce waste. However, approaches to increase the preference of whey-based beverages are required because of the low sensory acceptability of whey. Here, we identified the better starting material (whey type), between raw whey (RW) and demineralised whey (DMW), and determined the optimal initial concentration using multiple sensory evaluations to develop acceptable fermented beverages made from sole whey with pure cultured Kluyveromyces marxianus (i.e. without additional ingredients and processing methods). Acceptance tests showed that fermented beverages made from DMW were superior to RW as the starting material. The amounts of ethanol produced were 5.0%, 7.6% and 9.5% v/v from the different initial DMW concentrations of 10%, 15% and 20% w/v, respectively. We observed a significant positive correlation ($r(s) = 0.32$, $P < 0.05$) between the assessment attributes, strength of taste as alcohol beverage and overall acceptability, indicating that higher concentrations of DMW yielded a more desirable product [10].

The replacement of dehydrated products such as whey protein concentrates and isolates (WPC and WPI) by liquid whey protein concentrates (LWPC) obtained by ultrafiltration can be an excellent alternative for the production of innovative dairy products. Thus, the aim of this work is to study the gelation properties of LWPC as raw material for acid-induced dairy gels. Acid-induced gels were produced with non-defatted LWPC, with or without fortification with skimmed milk powder (SMP), by bacterial fermentation and by glucono-delta-lactone (GDL) acidification. The fermented systems (yogurt type acid gels) produced weaker gel structures than the equivalent chemically acidified gels (dessert type acid gels). It was also observed that molecular rearrangement continues during cold storage and that fortification with SMP favored gelation. Whey-based dairy gels obtained by fermentation or by glucono-delta-lactone acidification presented viscoelastic behavior, appealing functional and nutritional properties, and their utilization can effectively contribute to the reduction of waste [11].

At KhDUHT there were developed combined dairy-vegetable functional drinks and dressings based on whey, nanostructured from pumpkin, apples, lemons and oranges with zest. Also as a biocorrector a multiphytocomposition was, which included biologically active substances in ionomolecular form from calendula flowers, leaves of lemon balm, oregano, thyme, marjoram, lemon wormwood, coriander seeds, etc. As a stabilizer of the structure of multicomponent drinks and dressings was nanostructured puree of pumpkin, apples and oranges with zest. They contained water-soluble pectin in active form, and citrus pectin was additionally added to the dressing. The taste and aroma of the drinks were provided by the natural flavoring "Aroma", which is formed during the production of concentrated apple juice and extracts from natural spices. The yellow-orange color was provided by nanostructured pumpkin puree. The drinks were additionally enriched with vitamin C, taking into account the recommendations of the Ministry of Healthcare of Ukraine [12].

Using date syrup, whey permeate, and whey a novel kefir beverage was developed. The levels of the kefir grain inoculum (2–5% w/v), fruit syrup (10–50% w/v), and whey permeate (0–5% w/v) on pH, total phenolic content, antioxidant activity, lactic acid bacteria and yeast counts, and overall acceptability were investigated using central composite design. The use of response surface methodology allowed us to obtain a formulation with acceptable organoleptic properties and high antioxidant activities. The obtained beverages had total phenolic content, % DPPH scavenging activity, and overall acceptability ranging from 24 to

74 mg GAE/mL, from 74.80 to 91.37 mg GAE/mL, and from 3.50 to 6 mg GAE/mL (based on a 1 to 9 preference scale), respectively. Date syrup of 36.76% (w/v), whey permeates of 2.99%, and kefir grains inoculum size of 2.08% were the optimized process conditions achieved [13].

A gel-like emulsion stabilized with whey protein was prepared by microfluidization, and the effects of the oil phase fraction on the physical properties of emulsions were studied. The rheological analysis indicated that these emulsions exhibited thixotropic behavior, and their apparent viscosity and solid-like behavior increased with increasing oil fraction from 0.3 to 0.6 (v/v). The microstructures, droplet size distribution, and thermal stability of these emulsions were also characterized using a light microscope, dynamic light scattering (DLS), and differential scanning calorimetry (DSC), respectively. The viscosity of these emulsions increased in an exponential way versus increasing oil fraction and showed good correlation coefficient (R-2 > 0.99). The size of droplets in the emulsion increased from 301 ± 3.6 to 597 ± 7.3 nm. The DSC results showed that the crystalline peak of these emulsions gradually decreased from -15 to -21 degrees C and started thawing at similar to 3 degrees C. Visually, the textures of these emulsions could be transformed from flexible to rigid by changing the oil fraction, which suggests they could have multiple potential applications. Finally, the semi-solid emulsions were fabricated into delicate shapes using extrusion-based 3D food printing. Based on the results obtained, these emulsions may have the potential to be used as a solid-like fat substitute, which could be used in various applications such as cake decoration or customized functional foods [14].

Systematical consumption of functional products has a significant positive effect on health and can reduce the risk of diseases. The aim of this study was to investigate the possibility of using whey protein hydrolysate (WPH) and pumpkin pectin as ingredients in a functional mousse, to evaluate the mousse's antioxidant and hypotensive activities in vitro, and to evaluate the effect of the long-term intake of mousse samples on the progression of hypertension in spontaneously hypertensive rats (SHRs) and on the microbiome status in Wistar rats with antibiotic-induced dysbiosis. The experimental mousse's in vitro antioxidant activity (oxygen radical absorbance capacity) increased by 1.2 times. The hypotensive (angiotensin-1-converting enzyme inhibitory) activity increased by 6 times in comparison with a commercial mousse. Moreover, the addition of pectin allowed the elimination of the bitter aftertaste of WPH. In vivo testing confirmed the hypotensive properties of the experimental mousse. The systolic blood pressure in SHRs decreased by 18 mmHg and diastolic blood pressure by 12 mmHg. The experimental mousse also showed a pronounced bifidogenic effect. The Bifidobacterium spp. population increased by 3.7 times in rats orally administered with the experimental mousse. The results of these studies confirm that WPH and pumpkin pectin are prospective ingredients for the development of functional mousses [15].

With a long-term nutrition goal for healthy aging, the aim of this study was to compare the bioavailability of amino acids, in particular the leucine, after the ingestion of two solid and isocaloric dairy products (cheese) based either on whey or on caseins, by using pig as an in vivo digestion model. The whey-based cheese contained 25% more leucine than Mozzarella, however its digestion by pigs resulted in a concentration of postprandial plasma leucine between 2 h and 5 h30 twice higher than that produced during the digestion of Mozzarella. Noting that the dry matter of the duodenal effluents were similar after each of the two cheese meals, differences in gastric emptying would not explain the difference in leucine bioavailability. These results suggest the possibility of stimulating more efficiently the muscle synthesis in elderly people with cheese based on whey proteins rather than those based on caseins [16].

Production is relevant of liquid whey protein concentrates by ultrafiltration followed by thermal denaturation and homogenization of the ultrafiltrated concentrate, as well as on the production of ultrafiltrated permeates concentrated by reverse osmosis. Kefir grains (fresh and thawed) and/or commercial probiotic bacteria were inoculated in both liquid whey protein concentrates and concentrated ultrafiltrated permeates and grown at 25 degrees C for 24 h for the manufacture of fermented drinks. The physicochemical characterization (pH, titratable acidity, viscosity, and content of total solids, ash, fat and proteins) of the obtained drinks was then assessed and compared. Enumeration of viable microorganisms was carried out immediately after inoculation (at 0 h), during the fermentation period (at 12 and 24 h) and during refrigerated storage (at 48, 168 and 336 h). The fermented drinks showed acceptable physicochemical and sensorial properties, and contained above 7 log CFU/mL of lactococci and lactobacilli and 6 log CFU/mL of yeasts after 14 days of refrigerated storage, which is in agreement with the standards required by international organizations like European Food Safety Authority (EFSA) and Food and Drug Administration (FDA) for products containing probiotics. In summary, the strategy developed in this work contributes to the expansion of the applications of products derived from whey fractionation for the design of novel functional foods [17].

Natural plant ingredients in dairy technology

In contemporary dairy industry, especially in the cheese or casein production, only 10–20% of processed milk is directly availed for produced cheese and casein, while 80–90% of raw milk is transferred into the main by-product, whey. Due to insufficient utilization, whey was becoming the major polluter, what is entirely inconsistent to its potentials as a raw material. Whey is an excellent source of high quality proteins, minerals, vitamins and lactose that can be used in daily nutrition, or transformed throughout the different technological processes into the numerous valuable food products. The main goal of paper is to test the possibility of carrot juice use in the production of functional fermented drinks based on whey, as well as to estimate the possibility of inclusion of its production within the process of cheese production. Materials and methods – ased on previous laboratory tests, conducted at the Faculty of Technology and Metallurgy-Belgrade University, that were focused on increase of utilization of available raw materials in dairy industry, dairy drink based on cow whey and carrot juice has been established. Later, according to realistic data (input values), using the SuperPro Designer program (software), the simulation and economical evaluation of the establishment of created fermented drink production process was done. Integrated production process of cow cheese that includes production of fermented drink based on whey and carrot juice has shown greater economic sustainability compared to basic process of cheese production. Establishment of mentioned production process could enables extra short payback period (PP), (0.15 years), as well as high level of net present value (NPV), (10,464.04 x 106 US$) and internal rate of return (IRR), (384.61%). Besides, inclusion of line for beverage production within the process of cheese production enables achieving of improved quality product that can be in line to most requirements of highly sophisticated consumers, increasing the totally achieved profit (economic efficiency) of dairy industry. The production of functional fermented whey-based beverages represents one of the efficient alternatives related to better whey utilization. Created type of functional beverage production covered by unique production process leads to the utilization of all whey potentials that has as a raw material, material which also represents biologically strong pollutant. So, besides removal of certain quantity of whey from environment, it could be got a cheap, nutritionally valuable, healthy and fully natural product [18].

Research, gum Arabic (GA) and whey protein nanofibrils (WPN) were employed for the encapsulation of curcumin as a bioactive compound with low water solubility through the complex coacervation method. The optimum conditions for the formation of complex coacervates were found at WPN/GA weight ratio of 1:1 and pH value of 3.0. The resulting complexes showed a high ability for loading of curcumin as a bioactive cargo. Fluorescence spectroscopy showed that the curcumin was loaded in the hydrophobic core of WPN/GA coacervates. The characteristics of curcumin-loaded coacervates were also evaluated by XRD and FT-IR analysis. The curcumin-loaded complex coacervates dispersions showed a shear thinning behavior. They also showed a good surface activity which makes them excellent candidates to fabricate new functional food emulsions and beverages. The results indicated that the antioxidant activity and photo-stability of curcumin were significantly improved by encapsulation into WPN/GA complexes. A sustained-release profile also was investigated for curcumin from WPN/GA complexes in the simulated gastrointestinal conditions. This study suggested that the WPN/GA electrostatic-driven complexes can be used as efficient carriers for curcumin delivery [19]. The results of researches to substantiate the rational parameters of the extraction of biologically active substances from flowers *Tagetes patula* are presented. The recipe composition of the health-improving beverage based on curd whey, an infusion of *Tagetes patula* flowers, and berry filling «Forest Berry» (Lisova Yahoda) has been optimized. Recommendations on the development of technologies for non-fermented and fermented whey and vegetable drinks for health purposes are given. Substantiated rational parameters of the process of extracting biologically active substances from *Tagetes patula* flowers by drinking water: temperature (95 ± 5) ° C, duration 60 min., duty of water 10. The obtained infusion of marigold flowers contains 2.0% of dry matters, including flavonoids – 42.1–42.3 mg / 100 g, which causes high biological activity – 230–232 enzyme units. Therefore, the infusion of *Tagetes patul*a flowers is recommended to use as a physiologically functional food ingredient in the production of health beverages based on curd whey [20].

In recent years, the sphere of manufacture of dairy functional products and the use of dietary supplements in their production has been developing rapidly. Use of phytonutrients will significantly expand the range of traditional products, which will have the properties of the base product and the filler that is used, and the result of their joint action. Currently, preference will be given to those products that have the ability to cleanse body of radionuclides, heavy metals, toxins, ensure optimal functioning of the consumer's body and increase its resistance to adverse environmental factors. In recent years, cryopowders have been actively involved in the list of natural dietary supplements. Traditional cryopowders are powders, concentrates of fruit pulp and juice, which are immediately absorbed by the body. Moreover, they are able to remove radionuclides, cholesterol, toxins and contain 6–10 times more nutrients than canned fruits or vegetables. Considering the biocompatibility, almost (practical) non-toxicity, there is a possibility of prolonged use of cryopowders for treatment and preventive care purposes in the form of impurities in food. These dietary supplements can be used as a natural enhancer to enrich food with vitamins, microelements, organic acids, carbohydrates, dietary fiber in the manufacture of dairy products, sweet foods (jellies, mousses, sambuca, kysil), cooking, jams, various beverages. Cryopowders from edible plant raw materials contain a wide range of carbohydrates, pectin, as well as vitamins, amino acids, fiber, polyphenolic compounds. The complex structure of chemical and biochemical compounds, that are part of cryopowders, allows them to be classified as products with a wide range of treatment and preventive, radioprotective properties, including types of domestic curd mass, desserts, processed cheeses and fermented milk beverages [21].

The use of barley malt extract as a recipe part of the product contributes to the solution one of the problems of the dairy industry – creation of technology for new fermented dairy products with a combined composition of raw materials. Such products are characterized with increased nutritional and biological value without the addition of sugar. The concentration of barley malt extract influences the physico-chemical parameters of milk base: acidity, water content, water holding capacity [22].

The possibility of using pear and cinnamon in the technology of kefir made by thermostatic method is substantiated. Natural sources of plant raw materials were selected – pear, which contains sugar, organic acids, enzymes, fiber, tannins, nitrogen and pectin, vitamins C, B1, PP, carotene, flavonoids, volatile and cinnamon, which contains essential oils, tannins, resins, minerals and dietary fiber. The technology of cooking of pear fillers, namely, pear puree and pear jam, has been developed [23].

The dairy industry produces a wide range of dairy products, a significant share of which is occupied by products with various flavoring components. Not all of them are natural and have certain restrictions on consumption. Consequently, the task today is to create products of a balanced composition for nutrition of school-age children, corresponding to physiological needs in nutrients and energy, and contain only natural ingredients. To give products a pleasant taste and aroma, the use of fruit and berry processing products is promising. Particularly noteworthy are fruits of wild plants, which often contain useful biologically active substances, even more then in garden species, and have a lower cost [24].

The most accessible raw materials in Ukraine are fruits such as apples, which are characterized by a high content of low molecular weight phenolic compounds, such as ursolic acid, quercetin, rutin, caffeic, ferulic, quinic acids, etc. They have healing properties on the human body. They are also natural antioxidants and immunomodulators, strengthen the capillaries of the heart and brain, remove heavy metal ions from the gastrointestinal tract, etc. In addition, apples contain a significant amount of such Biologically Active Compounds (BAC) as vitamin C, pectin, tannins, and others. Besides, on Ukrainian market due to export, there are inexpensive vitamin tropical fruits, such as oranges, lemons, bananas, etc. They are consumed mainly fresh. Food additives in the form of pastes or frozen purees, cooked of them, are absent. Hence, it is important to create additives from these fruits in the form of frozen puree with maximum preservation of BAC and to use them in health foods, including ice cream. So far, we have not found any data on the production of frozen additives in the form of puree. The influence of "shock" freezing and low-temperature grinding on changes in the main BAC during the processing of plant raw materials has not been studied either [25].

Characteristics of Biologically Active Compounds in frozen finely dispersed fruit supplements compared to fresh raw materials are given in table 4 [25].

Due to the peculiarities of the chemical composition, fruit and berry raw materials not only enricht taste and color of milkshakes, but, having certain surface-active properties, participates in the formation of foam structures, due to the content of pectin substances [26, 27]. Pectin, which is a part of fruit and berry raw materials, is a surfactant. Its molecules have a diphilic structure, i.e, they contain lyophilic and lyophobic (usually hydrophilic and hydrophobic) atomic groups. Hydrophilic groups provide its solubility in water, hydrophobic at a sufficiently high molecular weight help to dissolve surfactant in a nonpolar environment. At the phase boundary, hydrophilic groups are oriented toward the polar phase, hydrophobic – toward the nonpolar (gas) phase. Thus, an interfacial boundary layer is formed, due to which the surface tension is reduced and the foams formation becomes possible or facilitated. In this way, the surface-active properties of pectin influence foaming ability of fruit and berry raw materials, which is an important factor in the development of milkshake technology [28].

Table 4

Comparative characteristics of content of biologically active compounds of raw materials

Product	Mass fraction, mg in 100 g				Pectin, %
	L-ascorbic acid	Phenolic compounds (chlorogenic acid)	Flavonol glycosides (rutin)	Tannins	
Fresh apples of «Snow Calvil» variety	11.3±0.6	1720.2±1.3	540.0±3.5	843.8±6.3	1.1±0.01
Nanostructured puree of apples of the «Snow Calvil» variety	45.7±3.2	2541.0±13.8	980.3±6.4	1170.5±10.3	2.8±0.02
Fresh apples of «Semerenko» variety	50.0±5.1	1830.8±11.4	620.5±3.6	923.5±5.2	1.2±0.01
Fresh bananas	13.2±0.7	1100.5±9.8	610.0±3.6	530.0±3.1	1.0±0.01
Nanostructured puree of bananas	48.6±3.4	1901.3±11.8	1003.3±6.4	965.0±7.6	2.5±0.02

It is known that vegetable and fruit raw material has a high content of nutrients that reveal functional properties.

In terms of accumulation of sugars (mainly glucose), grapes have no equal among other fruit and berry plants (up to 30% in some varieties). Grapes contain 10–20% sugars and 0.6–2.0% acids, mainly tartaric and malic. Except sugars and acids, berries contain pectin substances (on average 0.2%), vitamins, potassium salts, calcium, magnesium, iron, manganese, copper, cobalt, etc. Rind contains tannins and dyes from the group of anthocyanins, as well as essential oil; in seeds – 4–19% and 1.8–8.0% of tannins [29].

Vitamins of group B, K, C, carotene, surfactants were found in grapes, but there are quite few of them in berries. For example, vitamin B is 0.06 mg / 100 g, carotene is not higher than 0.5 mg/100 g, and the average amount of vitamin C does not exceed 4 mg/100 g. Among the entire group of biologically active substances contained in fruits, only three deserve attention: vitamins B_9 (folate) – up to 0.5 mg/100 g, surfactants (up to 450 mg/100 g) and vitamin K (phylloquinone) – up to 2 mg/100 g. In trace elements contained in the pulp of berries a large quantities of iron (up to 600 μg/100 g), manganese (up to 90 μg/ 00 g), copper (up to 80 μg/100 g) were found [29].

Molecular identification and genetic analysis of cherry are necessary for solving the problem of synonyms and homonyms that occur in cherry production. In this study, capillary electrophoresis with fluorescent-labeled simple sequence repeat (SSR) primers was used to identify 63 cherry cultivars (varieties and rootstocks) planted in Shaanxi province, China. A total of 146 alleles were amplified by 10 SSR primer pairs, ranging from 10 to 20 per locus (mean: 14); among the SSR primer pairs, genotype number ranged from 12 to 26 (mean: 18). The mean values of gene diversity, heterozygosity, and polymorphism information content were 0.7549 (range 0.4011–0.8782), 0.5952 (range 0.3810–0.9683), and 0.7355 (range

0.3937–0.8697), respectively. An unweighted pair-group method with arithmetic average cluster analysis was used to separate the cherry cultivars. A model-based structure analysis separated the cultivars into three populations, which was consistent with the results of a phylogenic and principal component analysis. Based on Bayes' rule, the cultivars were further subdivided into seven populations. Some of the 63 cherry cultivars that are often confused in production were distinguished, and DNA fingerprinting of cherry cultivars was established. This research will significantly assist in the identification of cherry cultivars at the molecular level [30].

Sweet cherries contain 10.0–13.5% sugars and very little acids (0.3–0.6%, predominant malic). That is why their fruits are sweeter than the fruits of cherries and southern varieties of cherries, their amount of organic acids reaches 1.3–1.6%. Her fruits have the same or slightly less vitamins than cherries. An increased levels of surfactants were observed only in varieties with dark-colored pulp. Their seeds, like cherries, contain bitter glycoside amygdalin [31].

Persimmon fruits have greater nutritional value mainly due to their content of glucose and sucrose (up to 25%). Food energy of 100 g of edible part of the fruit is 56–78 kcal. Persimmon also contains vitamin C, provitamin A, malic and citric acid, a lot of iron, calcium, copper, manganese and potassium. It has 16.3–21.8% of dry matter; 0.6–0.8% protein; 0.2–2.4% fat; 1.2–1.9% fiber; 0.4–0.9% ash. The mineral composition of the fruit is represented by calcium (6–10 mg / 100 g), phosphorus (10–26), iron (0.3–3.0), sodium (2–6), iodine (up to 50 mg/100 g), potassium (174–176 mg/100 g). The vitamin complex consists of vitamin C – 10–20 mg/100 g, β-carotene – 600–1 626 mg/kg, vitamins B_1 – 0.03–0.05 mg/100 g, B_2 – 0.02–0.05 and B_5 – 0.05–0.3 mg/100 g [31].

Persimmons contain much more antioxidants than apples. And although there is more copper and zinc in apples, persimmon is the first in terms of sodium, potassium, magnesium, calcium, and iron. As well persimmon has more β-carotene, which protects against cancer, and 2 times more dietary fibers and minerals than apples [31].

Quince in raw form is not very edible due to the viscous taste caused by high content of tannins. Among the organic acids, citric dominates. It has little sugars from 0.8 to 2.0%. By the content of tannins, it is close to wild apples, the amount of pectin takes one of the first places among other fruits and berries. Ripe fruits of only certain Transcaucasian and Central Asian varieties are used for food, which have few tannins and sugars content reaches 15%. After 5–6 months of storage, they become soft and suitable for fresh consumption and are well preserved until January-March [31].

Apricot fruits are delicious and nutritious. They contain 4.7–20% sugars, 0.3–2.6% organic acids, 0.5–1.6% pectin, vitamins B_1, B_2, C, carotene, biologically active phenolic compounds. The carotene content is 1.6 mg/100 g. Among sugars, sucrose prevails, the main acids are malic and citric. The seed kernel in some varieties is sweet, in others it is bitter, it contains up to 25% protein and 45–58% sweet-tasting high-value vegetable oil. The sweet kernel of apricot seeds is used as a substitute for almonds [31].

Apricots are high in potassium (up to 305 mg/100 g) and copper. Potassium has a positive effect on the heart muscle, prevents fluid retention in body tissues. Apricot fruit is used to make varenya, jam, powidl, jelly, compot, marmalade, succades, juices, dried fruits – dried apricots (kuraga – seedless fruits) and uryuk (seed fruits), in which level of sugars increases to 52–93% [31].

Peaches in chemical composition are close to apricots. Peach fruits contain many mineral salts that are quite useful for the body. They are also high in vitamins and enzymes. Peach fruits are high in carotene, potassium and iron (iron in these fruits is in an easily digestible form for the human body). They also have a lot of amino acids, vitamins B_1, B_2,

C, E, P, PP, folic acid. Peaches have sugars (up to 15%), malic, tartaric, citric, quinic, chlorogenic acids, vitamins A (0.62%) and C (12–20 mg/100 g), dyes (carotenoids: lycopene, cryptoxanthin, zeaxanthin), and essential oils, which influence smell of peaches. Chemical composition of its seeds includes fatty oil – up to 57% (consisting of oleic, palmitic and stearic acids: and sitosterols), glycoside amygdalin, and bitter almond essential oil (0.4–0.7%) [31].

Banana's pulp food energy is quite high from 80 to 240 kcal for 100 g. Banana pulp in raw form contains 30% of dry matter, 27% – carbohydrates, including 15–25% sugars, 7–20% – starch, 0.5% – fiber and pectin, 0.3–0.6% essential oil. The pulp has up to 1.3% of proteins, which contain the essential amino acid tryptophan. Isovaleric, isoamyl and isoamyl ethers give a peculiar aroma to the fruit. Vitamin complex consists of vitamin C – 37–53 mg/100 g, β-carotene – up to 30 mg/kg, vitamins B_1 – 0.04–0.07 mg/100 g, B_2 – 0.02 and B_3 – 0, 2–0.3 mg/100 g, as well as vitamins B_6, PP, E. The mineral composition of bananas is big and varied. It is represented by calcium (8–33 mg/100 g), phosphorus (21–38), iron (0.4–1.4), sodium (1–5), magnesium (42), copper (0.16), zinc (0.2), and potassium (370–401 mg/100 g). Moreover, bananas have biologically active compounds: catecholamines, serotonin, norepinephrine, dopamine, as well as ephedrine. An enzyme, helping to absorb carbohydrates, has been found in bananas. There are a lot of tannins and carotene in the fruit rind [31].

The pulp of fresh pineapple contains 13.0–14.7% dry matter, 0.4–0.7% proteins, 11.6–13.7% carbohydrates, 0.4–0.5% fiber, from 8 to 18% sugars, mainly sucrose, 0.4–1.4% – free organic acids, mainly citric, 0.3–0.4% – ash. Pineapples are quite high in potassium (125–321 mg/100 g), calcium (17–18 mg / 100 g), magnesium, phosphorus (8–12 mg/100g). Also they have iron (0,5 mg/100 g) and copper [31].

Dates have high food energy 142–274 kcal for 100 g of edible part of fruits, if it's dried dates than – 340 kcal. Dates contain from 40.0 to 77.5% of dry matter; 26–55% of sugars, mainly glucose and fructose; 0.9–2.9% protein; 0.3–1.0% of fats; 1.7–6.5% of fiber. Dates contain 1.0–1.9 of ash constituents, they are represented by phosphorus (30–350 mg/100 g), calcium (34–60 mg/100 g), iron (0.7–6.0 mg/100 g), potassium (up to 700 mg/100 g), sodium (up to 1 mg/100 g). Vitamin complex of dates consists of β-carotene (30–145 mg/kg), vitamins B_1 (0.07–0.09 mg/100 g), B_2 (0.05–0.1 mg/100 g), B_5 (0.1–2.2 mg/100 g), vitamin C (up to 30 mg/100 g), E. The seeds contain an average of 23.2% fat and 5.8% protein [32].

Figs have similar chemical composition to dates. Due to its high fiber content (12.5%) it is a good stimulant of bowel and liver functions. Fresh figs fruits consists of pulp (84%) and rind (16%). They have from 12.3 to 22.5% dry matter, up to 20.3% carbohydrates, including 11.2–18.0% sugars (glucose and fructose), 0.5% organic acids (mainly malic and lemon, as well as pyruvic, tartaric, etc.), 0.7–1.6% protein, 1.2–1.9% fiber, 0.2–0.4% fat, up to 2.5% pectin. The protein contains an essential amino acid tryptophan. The vitamin complex is represented by β-carotene – 60–200 mg/kg, vitamins B_1 and B_3 – 0.02–0.5 mg/100 g, rutin – 60–80 mg/100 g, vitamin C – 2–25 mg/100 g, vitamin P – 0.5 mg/100 g. In figs were others biologically active compounds – carotenoids, bioflavonoids, tocopherols, various enzymes. In terms of minerals, figs take one of the first places among fruits and berries. 14 mineral elements were found in the fruits: 177–286 mg/100 g of potassium; 1.6–1.8 – sodium; 34–52 – calcium; 20.0 – magnesium; 32.2 – phosphorus; 0.4–3.2 – iron; 0.06 – copper; 12.9 – sulfur and others. Food energy of fresh figs is low – 40–80 kcal/100 g [31].

Strawberries contain from 5.5 to 9.2% sugar, 0.56–1.57% organic acids, vitamin C – up to 80 mg/100 g (but there are also varieties in which the content of ascorbic acid in the fruit does not exceed 15–30 mg/100 g), carotene (0.03 mg/100 g). Reactive compounds (catechins, anthocyanins, flavones, etc.) – from 250 to 750 mg/100 g, 0.064–0.128% of tannins and dyes.

In strawberries were also found such organic acids as malic (dominates), citric, quinic, oxalic, succinic, and salicylic. Pectin makes up 0,75 % of strawberries' cheamicl composition. The berries contain a fairly significant amount of vitamin E (0.54 mg/100 g), surpassing oranges, tangerines, red currants, bananas, cherries, sweet cherries and a number of other fruits and berries [31].

Sugars are mainly represented with glucose and fructose, sucrose is much less. It was established that amount of sugar in berries depends on the time of collection. Thus, more sugars are found in the berries of the first harvest and much less in the fruits of the second harvest. The third harvest takes a medium position. Compounds of potassium, calcium, magnesium, sodium, sulfur, phosphorus, and chlorine were found in the berries. In terms of amount of potassium strawberries, however, are inferior to many fruit and berry crops – gooseberries, raspberries, black currants, plums, apples, apricots, peaches, grapes. Among trace elements in strawberries there is iron, boron, vanadium, iodine, cobalt, manganese, copper, molybdenum, zinc, etc. Strawberry leaves contain ascorbic acid (up to 300 mg/100 g), tannin, alkaloids (traces), glycoside fragmentarin, carotene, polysaccharide, ash (8.12%), macronutrients (mg / 100 g); potassium – 21.90, calcium – 14.70, magnesium – 4.50, iron – 0.60. A lot of iron was found in the seeds, tannins and iron were found in the rhizomes [31].

Raspberries contain 5–9% of sugars (approximately equal amounts of glucose and fructose), 1–3% of organic acids (mainly malic and little bit of citric, salicylic, oxalic, formic, etc.), 0.9–1.2 % of pectin, 0.03–0.13% of tannins and dyes, also up to 5% fiber, that stimulates the intestinal motor function and helps to remove cholesterol from the body. Among vitamins, ascorbic (25–30 mg/100 g), folic acids (6 μg/100 g) and P-active compounds (50–100 mg/100 g in yellow fruit and 200–300 mg/100 g in red fruit) are the main. The pulp of the berry is high in iron [31].

Depending on growing conditions, cornelian cherry contains 6.4–10.2% of sugars (mainly glucose and fructose), 1.4–3.0% of organic acids (with the predominance of malic), 0.2–0.4% tannins and dyes, on average about 60 mg/100 g of vitamin C. Pulp yield – 68–81%. Fresh leaves have vitamins E and C. Due to the presence of phytoncide, fruits, leaves and bark have bactericidal properties [31].

Viburnum berries contain 6.5–7.8% of sugars (mainly glucose and fructose), 1.7–1.9% of organic acids (malic, valeric), 0.4–0.6% of pectin. The peculiar aroma of fresh berries of viburnum is caused by valeric acid, essential and other compounds. Viburnum berries are quite high in carotene (1.4–2.5 mg/100 g), ascorbic acid (up to 50–75 mg/100 g in the best selected forms) and P-active compounds (300–500 mg/100 g) [31].

Sorbus (rowan) contains 5.9–8.0% sugars (fructose predominates), 1.8–3.6% organic acids (malic, in small quantities parasorbic, tartaric, succinic and oxalic), 0.3–0.6% pectin. In addition to fructose, glucose and sucrose in fruits were found up to 3% of sorbitol, which is a substitute for sugar. Rowan is a multivitamin plant. Ripe fruits contain significant amounts of carotene (more than some varieties of carrots and sea buckthorn) ascorbic acid, P-active compounds and vitamin E (up to 5.1 mg/100 g) [31].

Blackcurrant contains 5–12% of sugars (mainly fructose), 3–4% organic acids (citric prevails), 0.8–1.4% of nitrous, 1.1–1.7% – pectin, nearly 0.4 % tannins, as well as up to 3% of fiber. The berries, leaves and buds of blackcurrant, in their chemical composition, are a natural and complex concentrate of vitamins. Amount of vitamin C (up to 300-340 mg/100 g) in blackcurrant fruits (second only to rose hips and actinidia) is 4–5 times higher than in strawberries and citrus fruits, 8–10 times than in gooseberries and raspberries, 15–20 times higher than in apples, cherries and plums and the most rich in vitamin C green berries. As they ripen, C-vitamin activity decreases and reaches the lowest level in overripe fruits. The high content of P-active compounds (1000–1.200 mg/100 g and higher) in combination with

vitamin C has a beneficial effect on the activity of the human cardiovascular system, helping to maintain the elasticity of capillary blood vessels. In berries quite a lot of vitamins E and K (0.7–0.9 mg/100 g). In terms of vitamin E, blackcurrant surpasses almost all fruit and berry crops, second only to sea buckthorn, rosehip and chokeberry. Black currant berries have many useful salts of potassium, calcium, iron, phosphorus, magnesium and numerous trace elements, which are part of organic compounds and are easily absorbed by the body. Among other fruits black currant has a high level of potassium (more than 370 mg/100 g). Iron in berries is much more than in citrus fruits, grapes, gooseberries, plums, apples, apricots and others [31].

Chokeberries have, on average, about 1.2% of acids, 7.5% of sugars (mainly glucose and fructose), 17% – dry matter, 0.5% pectin and up to 0.4% tannins (hence the tart-viscous taste). There are 3.5% of sorbitol – a sugar substitute for patients with diabetes. Amount of vitamin C in chokeberry is low (10–25 mg/100 g), but the amount of P-active compounds reaches, on average, 1.500–2.500 mg/100 g. According to this indicator, chokeberry cannot be surpassed by any fruit and berry crop. Also such biologically active compounds in the fruit were found: carotene, vitamin K, nicotinic acid, vitamin E, B vitamins. Chokeberries also have high level of trace elements: boron, cobalt, copper, molybdenum, fluorine and others. The pulp contains, on average, 1.2 mg/100 g of iron, 0.5 mg/100 g of manganese. In terms of iodine content, chokeberry is 2–3 times superior to other fruits and berries [31].

A review of recent researches has shown that with help of complex processing of fruit and berry raw materials, it is possible to expand and improve the production of dairy products.

Conclusion

1. The high biological value of whey, its functional properties and the possibility of using it as a basis for various food products, determine the relevance of creating new dairy desserts.
2. The analysis of literature shows that development of innovative whey technologies, and its complex use with food from animal and vegetable raw materials is a promising direction in the development of resource-saving food technologies.
3. The mechanism of joint work milk components with fruit and berry fillers requires a theoretical explanation, which provides desired technological effect and original organoleptic characteristics of the products.

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Simulation of nanoparticle aggregation process in heterogeneous dispersed systems

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Abstract

Introduction. The study of particle aggregation is relevant and studied in chemical technology, biophysics, in solving problems of purification from aerosol or colloidal contaminants.

Materials and methods. The influence of nanoparticles on the aggregation kinetics of dispersed phases in suspension is considered. Models based on modifications of the particle dynamics method taking into account Van der Waals forces, gravity, Brownie and Stokes forces based on semi-empirical dependences for the rate of aggregation and disaggregation in collisions are used.

Results and discussion. Based on the analysis of the Smolukhovsky equation, molecular kinetic and local-isotropic turbulence of Kolmogorov's theories, the dynamics of simultaneous turbulent and Brownian transfer to the process of "rapid coagulation" and the mechanism of influence of nanoparticles on their accumulative ability in colloidal heterogeneous dispersion are proposed.

The developed equations for the rate of kinetic energy scattering in a suspension makes it possible to determine the particle dispersion in which the Brownian diffusion of particles in the coagulation mechanism predominates. This means, the more intense the process of mixing the suspension, the greater the role in the process of coagulation, precipitation and filtration play particles of the nanoscale range, which are included in the rapid movement of the vortex. These results are useful for practical application in control of intensity of coagulation processes in mixing devices.

Conclusions. The mechanism of influence of nanoparticles on their aggregation ability in colloidal heterogeneous disperse systems is offered.

Introduction

There is high interest in the study of nanosized particles, due to the fact that they have special mechanical, optical, electrical and magnetic properties that differ from the properties of conventional macroparticles [1–4]. Studies conducted in recent years have shown the high efficiency of the use of colloidal solutions of nanosized particles of biologically active metals in medicine, biology, veterinary medicine and agriculture [3, 6].

The most commonly used are colloidal suspensions of nanoparticles Al_2O_3, CuO, SiO_2, ZnO with a particle diameter d_p=20–60 nm based on water, glycerin, ethylene glycol and fullerene suspensions (d_p=1,6–1,8 nm), nanotubes (d_p=5–100 nm), nanocrystals and other particles [7, 8]. Nanofluids have unique thermomechanical, electrical and magnetic properties even at low (<5..10%) nanoparticle concentrations. Adding Ch = 1.8% of nanoparticles Al_2O_3 in the coolant leads to a heat increase dissipation from the PC processor by 32% [9]. The optimum concentration at which the thermal conductivity of a liquid becomes high and the dynamic viscosity becomes low depends on the nature of the particles, their size, shape, roughness, and surface adhesion. [8, 10]. In the review [11] the dependences of the efficiency of different nanofluids in the range Re = 1 ... 1200 are given.

It is known that during the operation of such liquids, nanoparticles become unstable and prone to aggregation [12, 13]. To prevent aggregation and subsequent gravitational deposition, nanoparticles are stabilized by methods and substances that are safe to use and provide their chemical and aggregative stability during synthesis [14].

Combining the particles of the dispersed phase into one, when they converge and collide, is the basis of aggregation (coagulation, coalescence). Particle collisions and their adhesion or fusion (in the case of liquid particles and gas bubbles) can be caused by various consequences: chaotic (Brownian or violent) oscillations, convergence under the force of electric, magnetic, gravitational, hydrodynamic and other forces. Random collisions do not always lead to the interaction of particles, because in the dispersion phase they acquire the same surface electric charges and repel each other. Aggregation and coagulation underlie the processes of aggregation-sediment instability of dispersed systems, their stratification into solid and liquid phases, precipitation or transition from sol to gel. The study of particle aggregation is relevant and is studied in chemical technology, biophysics, in solving problems of purification from aerosol or colloidal contaminants. [15–18].

Materials and methods

This work considers mathematical models of aggregation kinetics in multiphase dispersed systems, investigates the dynamics of simultaneous turbulent and Brownian transfer to the process of "fast coagulation" and the mechanism of influence of nanoparticles on their aggregation ability in colloidal heterogeneous dispersed systems is proposed.

The influence of nanoparticles on the aggregation kinetics of dispersed phases in suspension is considered (Figure 1).

In this work, we study the dynamics of the simultaneous turbulent and Brownian transition to the process of "rapid coagulation" and propose a mechanism for the influence of nanoparticles on the aggregation capacity of suspensions..

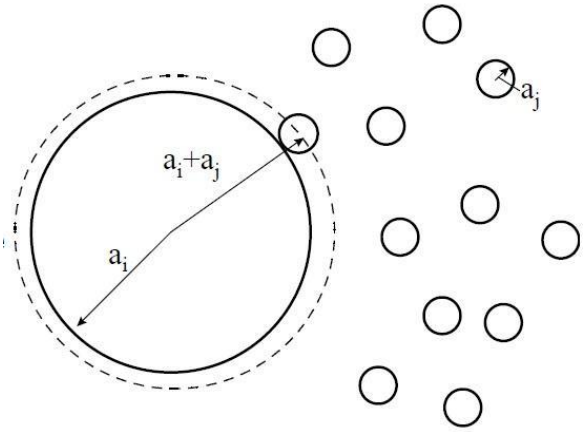

Figure 1. Schematic representation of Brownian coagulation particles:
a – radius of the particle;
i and j – respectively particle and particle flow;
$a_i + a_j$ – the distance between the centers of the two contacting particles.

The influence of nanoparticles on the aggregation kinetics of dispersed phases in suspension is considered.

Modeling is based on modifications of the particle dynamics method taking into account Van der Waals forces, gravity, Brownie and Stokes forces based on semi-empirical dependences for the rate of aggregation and disaggregation in collisions are used.

Results and discussions

The concentration of particles is considered to be quite high (C <0.05), so they do not settle [5]. With additional surface stabilization and the absence of electrostatic interactions, such suspensions can be stable and stay in a suspended state for a long time [3, 4]. When used in microfluidic systems, the number of collisions increases and, due to the high adhesion of particle surfaces, they often form aggregates. Thus, the threshold concentration of C, at which aggregation and sedimentation of particles is observed, is determined by a significant number of factors, but, according to various estimates, close to C ~ 0.05 [3–5].

Thus, in an aqueous suspension of zero-valent metal nanoparticles with d_p = 20 nm at a concentration of 2 mg / l and 60 mg / l after 10 min, aggregates with an average radius of 125 nm and 1200 nm, respectively, are formed, which rapidly settle in water [19]. For multiphase dispersed systems (usually underground drivers, drinking water), for aggregation and production of aggregate nanoparticles with pH, ionic strength and available impurities [20]. Zinc oxide nanoparticles of ZnO form aggregates and precipitate rapidly when d_m> 50 nm [21].

The nanoparticle suspension models available in the literature are based on modifications of the particle dynamics method taking into account Van der Waals forces, gravity, Brown and Stokes forces based on semi-empirical dependences for the aggregation rate and disaggregation in collisions. [22–24].

In practical conditions, the most important transport mechanisms of particles are Brownian diffusion caused by their random motion induced by the internal energy of the

system in the absence of fluid motion. Particle aggregation due to these collisions is known as perikinetic flocculation. Transport of particles due to Brownian motion is important mainly for submicron particles, as other transport mechanisms begin to predominate in the case of large particles.

M. Smolukhovsky [25], considering Brown's coagulation in colloids, estimated the frequency of particle collisions for perikinetic aggregation. Diffusion coefficients for a spherical particle of radius ai are obtained on the basis of the Stokes-Einstein equation [26]:

$$D_i = \frac{k_B T}{6\pi a_i \eta}, \quad (1)$$

where k_B – Boltzmann's constant, which is defined by Stokes' law ($\gamma = 6\pi\eta a$); T – absolute temperature; a_i – particle radius; η – dynamic viscosity of the dispersion medium.

The total number of collisions per unit volume and per unit time for scattered particles is:

$$J_{ij} = 4\pi R_j (D_i + D_j) n_i n_j, \quad (2)$$

where R_{ij} – the distance between the centers of the particles *i* and*j*, on which they are supposed to be in contact (fig.1). Assuming that $R_{ij} = a_i + a_j$, then the total number of collisions will be:

$$J_{ij} = \frac{2k_B T}{3\eta} \frac{(a_i + a_j)^2}{a_i a_j} n_i n_j. \quad (3)$$

Velocity constant for collisions between particles *i* and *j* with perikinetic aggregation will be [22]:

$$k_{ij} = \left(\frac{2k_B T}{3\eta}\right) \frac{(a_i + a_j)^2}{a_i a_j}. \quad (4)$$

Thus, the frequency of particle collisions during Brownian motion increases with the temperature of the dispersion medium, while the effect of particle size is less obvious. When the radii of the particles increase, the diffusion coefficient (1) decreases, and the contact radius, R_{ij} increases in such a way that the effect of particle size is somewhat canceled, and $\frac{(a_i + a_j)^2}{a_i a_j} \approx$ has a constant value for different particles.

The movement of a liquid, regardless of whether it is associated with mixing or organized movement of the liquid, can significantly increase the speed of collision between particles, and hence the speed of aggregation. Aggregation through superimposed gradients of mixing rate or fluid flow is known as orthokinetic flocculation.

For the laminar velocity field, M. Smoluchowski's approach predicted that orthokinetic aggregation estimates that particles move by fluid flows with a velocity gradient *G*, and collide as they approach the distance $a_i + a_j$ between their centers (fig.1).

Therefore, the rate constant for orthokinetic aggregation is estimated as:

$$k_{i,j} = \left(\frac{4}{3}\right) G (a_i + a_j)^3. \quad (5)$$

This method of aggregation effectively promotes the collision of larger particles, because the collision velocity significantly depends not only on the velocity gradient, but also on the particle size.

When particles of different sizes and densities settle in the suspension, different settling rates can promote particle aggregation. Larger particles settle faster and are more likely to capture smaller particles when they settle.

Assuming that particles fall vertically before colliding with other particles, the simplest estimate of the collision frequency for spherical particles of the same density is based on Stokes' law:

$$k_{i,j} = \left(\frac{2\pi g}{9\eta}\right)(\rho_s - \rho)\left(a_i + a_j\right)^3\left(a_i - a_j\right), \quad (6)$$

where ρ – fluid density, g – acceleration due to gravity, $a_i > a_j$.

Accordingly, differentiated sedimentation mainly depends on the size and density of the particles, and this transport mechanism is dominant, especially when the particles are large and dense. This process usually occurs at a later stage of flocculation, when aggregates of different sizes are formed, which settle at different rates.

An approach similar to molecular diffusion was used to determine the collision probability of two particles. Let's consider a dispersed medium containing in units of volume N_0 spherical particles of the same size (fig.1). N_0 is such that the number of collisions of more than 2 particles is excluded. The liquid, by definition, is stationary.

One of the particles with a diameter (test) will be considered stationary. If we define a sphere with radius R around this particle such that ($\frac{a}{2} < R << H$), where H – the distance between the centers of the nearest particles, we believe that every second particle crossing the surface of this sphere is captured by the investigated particle. Accordingly, on the surface R the concentration of particles will be zero. On the surface R, as a result there is a concentration gradient of particles.

Then the Brownian flow of particles to R will be described by an analogue of the molecular diffusion equation (diffusion equation):

$$\frac{\partial n}{\partial t} = D\frac{1}{r}\frac{\partial}{\partial r}\left(r^2\frac{\partial n}{\partial t}\right), \quad (7)$$

where r – spherical coordinate with the center in the center of the investigated lobe; D – the coefficient of "Brownian" diffusion of particles to the surface R.

In extreme conditions:

$$n = n_0 \Rightarrow r > R;\ t = 0\ n = 0 \Rightarrow r = R;\ t > 0\ n = n_0 \Rightarrow r \to \infty.$$

Integrating the problem, we get an expression of the flow of particles through the surface, which determines the number of collisions of "rapid coagulation" with part of the test:

$$J = D\left(\frac{\partial n}{\partial t}\right)_{r=R} = \frac{Dn_0}{R}\left[1 + \frac{R}{\sqrt{\pi Dt}}\right]. \quad (8)$$

For coagulation that does not occur in an organized stream of dispersed medium when the liquid is in a "quasi-equilibrium state", it will meet the condition:

$$\underline{U} = \frac{G}{\rho F} \ll \upsilon_\lambda, \quad (9)$$

where $\underline{U}$ – macroscopic speed scale; G – fluid flow; ρ – fluid density; F – the cross-sectional area of the apparatus; υ_λ – internal scale of turbulent pulsations.

We will analyze this problem under the following conditions:

- the radius of coagulation of the investigated particle is much smaller than the internal scale of turbulence $\lambda = \left(\frac{\nu^3}{\varepsilon}\right)^{\frac{1}{4}}$, ε – the rate of scattering of the kinetic energy of turbulence; ν – kinematic viscosity of the liquid;
- all particles are involved in the rapid exchange of energy;
- turbulence is isotropic, homogeneous;
- the problem has a stationary quasi-equilibrium character.

Because turbulent isotropic motion is disordered, the motion of particles is similar to and superimposed on Brownian motion. That is, particles coagulate simultaneously by Brownian and turbulent isotropic mechanisms.

By analogy with Brownian motion, we introduce, according to Bussinesque's hypothesis, the concept of "turbulent diffusion coefficient", and we formulate the diffusion problem under the condition of a stationary process. [27]:

$$div(D_{eff}gradn) = 0. \quad (10)$$

Since the problem is fixed, n – is the average time of particle concentration time. Then the effective diffusion coefficient Deff according to previous statements will be following:

$$D_{eff} = D + D_{т}, \quad (11)$$

where D – molecular diffusion coefficient, the so-called "Brownian"; $D_{т}$ – turbulent diffusion coefficient.

Boundary conditions of the task:

$$n = 0 \Rightarrow r = R;\ n = n_0 \Rightarrow r \to \infty.$$

To determine the diffusion coefficient $D_{т}$ we use the analogy between energy pulse transmission and mass. Then, according to L. Prandtl's theory of "mixing path length" [28] $D_{т}$ – can be written as follows:

$$D_{т} \approx v'l, \quad (12)$$

where v' – average pulsation of speed; l – the length of the mixing path.

This expression is similar to the expression for molecular diffusion obtained in molecular kinetic theory, however, in contrast to the well-defined path length of the molecule $l_{т}$ for turbulent motion, the length of the mixing path is not clearly defined. The pulsation velocity can be determined less clearly.

Based on the fact that only three-dimensional vortices with a characteristic size l and a certain difference in velocities $\Delta\underline{U}$, can overcome the inertial-gravitational forces in the liquid, and according to the scale l turbulence will be three-dimensional isotropic. According to Kolmogorov's theory of local-isotropic turbulence [29] $\Delta\underline{U}$ is written in the form :

$$\Delta\underline{U} \sim (\varepsilon l)^{1/3}. \quad (13)$$

It should be noted that in Kolmogorov's statistical theory the parameters of turbulence are determined on the basis of dimensional considerations and the hypothesis of stepwise energy transfer from the largest to the smallest vortex in which the kinetic energy of turbulence is scattered.

If the turbulence to a certain determinant scale l_o is three-dimensional isotropic, then the only determinant parameters for processes not exceeding this scale will be ε and l. In this case, for dimensional reasons, we obtain the isotropic diffusion coefficient:

$$D_{т} = K_1 \varepsilon^{1/3} / l^{4/3}, \quad (14)$$

whereK_1- some universal dimensionless constant.

This expression is obviously obtained for the range$l > \lambda$, when reaching the size in the diffusion range$l \approx \lambda$ small-scale vortices begin to play an active role in energy dissipation.

According to equation (14) the turbulence coefficient increases with increasing process scale to power 4/3. It is obvious that this process will take place on the scale l_0, after which the growth of $D_{т}$ should stop. Accordingly, the maximum value of $D_{т}$ will look like:

$$D_{т}^{max} = K_1 \varepsilon^{1/3} / l_0^{4/3}. \quad (15)$$

However, in this range$l > \lambda$ the value $D_{т}$ significantly exceeds the diffusion-molecular component D, respectively, the main diffusion resistance is in the region of small scales $l < \lambda$ we can conclude that in the range $l > \lambda$ the gradient concentration of particles goes to zero from $l = \infty$.

In the range $\frac{a}{2} < l < \lambda$ the diffusion turbulence coefficient decreases in the range, and, according to Prandtl's theory of "mixing path length", we obtain the expression:

$$0 < D_{т} < K_1 \varepsilon^{1/3} / \lambda^{4/3}, \quad (16)$$

According to Kolmogorov's theory, this range can be conditionally called the region of "turbulence attenuation", and Le Chatelier-Brown's "principles of mobile thermodynamic

equilibrium" in the form of "attenuation equation" ("relaxation equation") can be used to analyze changes in turbulent transfer coefficient. [30].

Let's enter dimensionless variables:

$$l' = \frac{l}{a/2}; \qquad D'_{\text{т}} = \frac{D_{\text{т}}}{D_{\text{т}\infty}}. \tag{17}$$

The attenuation coefficient is defined as:

$$z = 1 - D'_{\text{т}}.$$

The attenuation equation and the boundary condition are written in the form, respectively:

$$\frac{dz}{dl} = c_1 z \text{ and } z = 1 \text{ at } l' = 1.$$

As a result, the turbulent diffusion coefficient is written as:

$$D'_{\text{т}} = 1 - z = 1 - exp[c_1(l' - 1)]. \tag{18}$$

To determine c_1 we write the condition:

$$D_{\text{т}} = D_{\text{т}\lambda} = K\varepsilon^{1/3}/\lambda^{4/3} \text{ at } l' = l'_\lambda = \frac{\lambda}{a/2}. \tag{19}$$

As a result, we get:

$$c_1 = \frac{ln(1-D'_{\text{т}\lambda})}{l'_\lambda - 1}. \tag{20}$$

As a result of approximation of the above equations by the "pseudo-Newtonian method" [30] within:

$$\frac{a}{2} < l' < \lambda, \text{ where } \frac{a}{2} \approx 10^{-7}m;\ \lambda \approx 10^{-5}m;\ D_{\text{т}\lambda} \approx 0{,}8D_{\text{т}\infty}.$$

we obtain the equation of the coefficient of turbulent diffusion:

$$D'_{\text{т}} = 0{,}0368(l')^{0{,}677}, \tag{21}$$

Consider the particle concentration field in the region $\frac{a}{2} < l < \lambda$. In this region $D_{\text{т}}$ decreases as expected with decreasing turbulent pulsations. It is obvious that at a certain value of the pulsation scale $D_{\text{т}}$ becomes less than D_{br}. If you define this scale as:

$$D_{\text{т}\lambda} 0{,}0368\left(\frac{l_1}{\lambda}\right)^{0{,}677} = D_{br}, \tag{22}$$

then at $l < l_1 \Rightarrow D_{\text{т}} < D_{br}$;

at $l_1 < l \Rightarrow D_{br} < D_{\text{т}}$.

That is, if the coagulation radius around the particle R is such that $R > l$, then preferably the diffusion is carried out by a turbulent mechanism.

Consider the case:

$$R > l_1 = (27{,}2 \cdot \frac{D_{br}}{D_{\text{т}\lambda}})^{1{,}48} \cdot \lambda. \tag{23}$$

Assuming that the solution of the boundary value problem is determined only by the radius of the vector r, we integrate the transfer equation into cylindrical coordinates under the appropriate boundary conditions::

$$\frac{1}{r}\frac{\partial}{\partial r}\left(D_{ef} r \frac{\partial n}{\partial r}\right) = 0. \tag{24}$$

The first integration allows you to get $R > l_1$:

$$D_{\text{т}1} r^2 \frac{dn}{dr} = C. \tag{25}$$

Substituting the value of $D_{\text{т}}$ for the corresponding areas, we obtain:

$$K_1 \varepsilon^{1/3} r^{10/3} \frac{dn}{dr} = C_2; \text{ at } r > \lambda; \tag{26}$$

$$0{,}037 K_1 \varepsilon^{0.17} \nu^{1{,}95} r^{2.68} \frac{dn}{dr} = C_3; \text{ at} r < \lambda. \tag{27}$$

The integration of the last expression must be performed using numerical methods due to the complexity of the two-layer scheme with conjugation of flows at the layer boundary.

For a preliminary analysis, we simplify the calculation scheme by approximating the dependence of $r < \lambda$ on the domain by a linear function and assuming that $n = n_0$ at $r = \lambda\zeta$.

Due to the qualitative nature of the analysis, these simplifications will give a rough picture of the process, which gives a general idea of the nature of the particle diffusion process.

As a result of integration for the range$R < r < \lambda$ we obtain the expression for the particle concentration field:

$$n = \frac{n_0 R^2 \lambda^2}{\lambda^2 - R^2}\left(\frac{1}{R^2} - \frac{1}{r^2}\right). \quad (28)$$

Particle flux density on the surface of the coagulation sphere $r = R$:

$$j = D_{\text{т}}\left(\frac{\partial n}{\partial r}\right)_{r=R} = K_2 n_0 \frac{1}{R} K_1 R = K_1 K_2 n_0, \quad (29)$$

where $K_1 = 8 \cdot 10^{-3} K \varepsilon^{0,17} \nu^{1,95}$;

$K_2 = \frac{R^2\lambda^2}{\lambda^2 - R^2}$.

That is, the particle flux density through the coagulation sphere depends only to a small extent on the size of the sphere.

At the same time, the total flow of particles, the intensity of "rapid" coagulation by the turbulent mechanism, will be defined as:

$$N_{\text{т}} = 4\pi R^2 j = 4\pi R^2 n_0 K_1 K_2. \quad (30)$$

When the value of the dissipation rate of the kinetic energy of turbulence is of the order of 10^2–10^4 $\left(\frac{m}{s}\right)^2$ the value $R > l_1$ and, accordingly, $N_{\text{т}} > N_{,r}$ for particles whose size in the mechanism is 10^{-7}–10^{-8} m coagulation of small particles is dominated by Brownian particle diffusion mechanism. That means, the more intense the process of mixing the suspension is, the greater the role in the process of coagulation, precipitation and filtration play particles of the nanoscale range, which are included in the rapid movement of the vortex.

Conclusion

This work provides a brief overview and analysis of mathematical models of aggregation kinetics in multiphase dispersed systems based on modifications of the particle dynamics method taking into account Van der Waals forces, gravity, Brownian and Stokes forces.

Based on the analysis of the Smolukhovsky equation, molecular kinetic and local-isotropic turbulence of Kolmogorov's theories, the dynamics of simultaneous turbulent and Brownian transfer to the process of "fast coagulation" and the mechanism of influence of nanoparticles on their aggregate formation are investigated ability to colloidal heterogeneous dispersion.

The development of equations for the rate of kinetic energy scattering in a suspension makes it possible to determine the particle dispersion in which the Brownian diffusion of particles in the coagulation mechanism predominates. It means, the more intense the process of mixing the suspension is, the greater the role in the process of coagulation, precipitation and filtration play particles of the nanoscale range, which are included in the turbulent vortex motion. These results are useful for practical application in controlling the intensity of coagulation processes in mixing devices.

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Synthesis of intelligent power management system of food manufacturing processes with power consumption prediction

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Abstract

Introduction. The study is done to justify the methods of intelligent power management system of food manufacturing processes (FMP) devoted to increase the effectiveness of electric power use.

Materials and methods. The study is based on intelligent control methods, power consumption prediction algorithm using artificial neural networks and active identification method of load static load characteristics.

Results and discussion. Based on the system analysis of FMP control it is determined control criteria and functions. To implement the control functions in intelligent power management system of FMP it is used: model of predicting power consumption, making decision algorithms of power management, procedure of forming the optimal list of consumers-regulators and calculating the rational modes of power consumption.

To predict the power consumption of food manufacturing process the multilayer perceptron is chosen from the set of artificial neural network architectures. It is shown that the optimal configuration of the neural network in the task is three layered perceptron with hidden layer where the number of elements equals to the half-sum of the elements of the input and output layers. Perceptron training is carried out by combined backpropagation/Cauchy machine method. The computational experiment with prediction of power consumption of food manufacturing process on the next year has the learning error in the range of 0.05-0.06.

The algorithm of determining the optimal voltage, which provides energy efficient operating modes of power system, uses static load characteristics. To make the algorithm more accurate and effective it is used procedure of static load characteristics identification in the interactive mode for the main modes of the technological process, taking into account the state of consumers-regulators and the degree of compensation of reactive power with the help of transformer equipped with the electronic switch.

Conclusions. The algorithms of intelligent power management system of FMP become more efficient with the use of power consumption prediction and static load characteristics identification algorithms.

Glossary

FMP – food manufacturing processes
SLC – static load characteristics
IACS PSC – intelligent automated control system of power supply and consumption
DMS – decision-making system
CIS – computer information system
DFD – data-flow diagram
SFS – shop floor substation
OLTC – on load tap changing
MS – main substation
LV – low voltage
HV – high voltage

Introduction

Efficient use of electric power in food manufacturing processes (FMP) is the main part of the problem of reducing electricity consumption that cannot be solved without control automation of transmission, distribution and consumption of electricity in FMP power system. The implementation of a new electricity market model, methods of managing electricity demand and renewable energy sources necessitates the use of methods for prediction of electricity consumption and power management. The main provisions for the synthesis of electric power measurement and control systems are presented in [1, 2, 3]. The issues of power consumption and load control with the use of consumers-regulators, their mathematical models and technological resources are covered in [4, 5]. Power supply control methods and tools are discussed in [6, 7, 8].

However, despite the large amount of researches, there is no single methodological approach to designing efficient power supply and distribution management systems based on system analysis and managed process predicting, as well as on the consideration of dynamic factors of production process. Moreover, there is no full use of the interconnected systems of mathematical models and methods of predicting, normalizing, planning and controlling the operating modes of FMP electric power system. Therefore, the development of methods for designing automated control systems for power consumption and supply of FMP that use sophisticated mathematical models, intelligent control algorithms, and software based on the latest information technologies that ensure the efficiency of transmission and consumption of electric power, is an urgent scientific and technical task [9].

Materials and methods

Materials

Object of the study is intelligent automated energy management system of FMP with power consumption prediction, designed to provide energy saving without losing performance.

In this study it is used:

- Methods of electric power consumption prediction;
- Control methods of electric power supply of manufacturing processes.

Methods

Plan of studies

The studies were conducted in the following order:

1. Choosing control criteria of FMP power control system;
2. Determining of control tasks of power supply and distribution of FMP;
3. Designing and justification the method for prediction of FMP power consumption;
4. Synthesizing the structure of the power consumption control system;
5. Developing and justification the control methods of FMP power supply using static load characteristics.

Method for prediction of FMP electric power consumption. The value of electricity consumption of FMP consists of the power consumption w_i of all N currently operating power loads and electricity losses ΔW in the network elements:

$$W = \sum_{i=1}^{N} w_i + \Delta W \tag{1}$$

Electricity losses, in its turn, in the main elements of power supply systems: lines and transformers, will depend on the electrical parameters of these elements (their active and reactive resistances) and the power transmitted through them:

$$\Delta W = f\left(W_a, W_p, R, X\right) \tag{2}$$

During the operation of the power supply system, the support of its elements can be considered almost unchanged. Thus, the change in the current power loss in the power network will occur due to changes in the total capacity of electrical receivers when they are turned on, off or change the mode of operation.

The power consumption w_i of each receiver, or group of receivers, in turn, can be presented as follows:

$$w_i = f\left(\lambda_1, \lambda_2, \ldots, \lambda_n\right) \tag{3}$$

where $\lambda_1, \lambda_2, \ldots, \lambda_n$ – the parameters that affect electricity consumption.

The number of power-consuming units (primarily asynchronous and synchronous motors) in FMP can reach hundreds and thousands. For each unit, the parameters that affect its power consumption may be different. Development of a forecasting model of FMP power consumption, which takes into account the parameters that affect the power consumption of each unit, is not possible due to the large number of correlated input parameters in such a model. The most optimal way to create such a model is the combination of power-consuming units to groups on any grounds (technological, electrical), followed by the identification of parameters that affect the power consumption of each group. In turn, the set of affecting parameters of each group will be a set of input parameters for the forecasting model of electricity consumption of the enterprise as a whole.

The multilayer perceptron was chosen from the set of artificial neural network architectures to predict the power consumption of FMP.

Method of determining the static load characteristics. The determining of static load characteristics (SLC) is carried out using the regression equation of SLC for active and reactive power in the form of second-order polynomials:

$$P^* = a_0 + a_1 U^* + a_2 \left(U^*\right)^2 \quad (4)$$

$$Q^* = b_0 + b_1 U^* + b_2 \left(U^*\right)^2 \quad (5)$$

where a_0, a_1, a_2 and b_0, b_1, b_2 are the coefficients of SLC polynomials of voltage, by active and reactive powers, respectively, and also, $a_0 + a_1 + a_2 = 1$ and $b_0 + b_1 + b_2 = 1$.

By the method of least squares [14] the system of equations of the form (4), for example, for active power has the following form

$$\begin{bmatrix} P_{*0} \\ P_{*1} \\ \dots \\ P_{*Mp+1} \end{bmatrix} = \begin{bmatrix} 1 & U_{*0} & U_{*0}^2 \\ 1 & U_{*1} & U_{*1}^2 \\ \bullet & \bullet & \bullet \\ 1 & U_{*M\ p+1} & U_{*M\ p+1}^2 \end{bmatrix} \cdot \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} \quad (6)$$

The system of equations (6) refers to overdetermined systems of linear algebraic equations. Testing the hypothesis of the adequacy of regression models is carried out using Fisher's test, for which the residual variance is calculated.

$$D_{res}^2 = \frac{\sum_{i=1}^{n} \left(Y_i - \hat{Y}_i\right)^2}{n - p - 1} \quad (7)$$

where D_{res}^2 is the residual variance; Y_i – experimental data of power consumption (active or reactive); $\hat{Y}_i$ – experimental data of power consumption (active or reactive); n – the number of experiments; p – the number of factors of the regression equation.

The resulting values of the coefficients of polynomials a_0, a_1, a_2 and b_0, b_1, b_2 are the first approximation.

Results and discussion

System analysis and methods of the FMP control process

The task of managing power supply and power consumption is to minimize the set of technical and economic criteria: the losses from disconnecting or switching to the reduced operating mode of active power consumers-regulators; the number of commutations of consumers-regulators; the power losses in the electric power system due to leakage reactance; under following restrictions: the active load; the voltage of the electricity consumers; the parameters of electrical power quality.

To develop the intelligent control system the authors performed system analysis of control process of electric power transmission, distribution and consumption, which consists in the following. At the set-theoretic level, the process of managing organizational and technical objects is represented as a mapping of separate stages:

$$F_n : \{L \times K \times Z \times P_{in}\} \to P_{out}, n = 1,\ 2, \dots, N \quad (8)$$

where L – the stage of forming basic control functions; K and Z – accordingly, the forming stages of possible combinations of basic conditions and mechanisms of control functions

implementation; $P = P_{in} \cup P_{out}$ – the forming stage of possible combinations of the main data flows; P_{in} and P_{out} – sets of input and output data flows.

The system analysis results of control of power transmission, distribution and consumption processes are presented in the form of mappings for individual actions:

- Registration of power consumption, status of the electric grid, and power quality indices, as well as verification of measurement data reliability;
- Model selection and prediction of electricity consumption: forming a list of consumers-regulators and their optimal combination;
- Deciding on electricity costs: deciding on changing the configuration and operating modes optimization, normalizing of power quality indices;
- Recording and up-to-date maintenance of electric power cost management database.

The results of the system analysis have become the basis for the design of automated control system of FMP power supply and consumption.

The purpose of management is the efficient (reliable and conservative) supply and use of electricity in FMP. The control criterion that optimizes payment for electricity under existing relationships with the power supply company can be taken as

$$J = \lambda_W W + \lambda_W \Delta W + k_W \lambda_W W + Y_p(\Delta P, t_{ml}) + Y_{TR}(y_{UO}, M) \rightarrow min \quad (9)$$

where λ_W and W – respectively, the tariff for electricity and its consumption volume by FMP (including losses in the grid); λ_W and ΔW – respectively, the tariff for electricity consumed above the contract and its consumption volume; k_W – the factor of payment for the consumed (or generated) reactive energy in excess of the values stipulated in the contract (to be approved by the tariff regulator); Y_p – costs for regulation of active power in hours of maximum load of the power system; Y_{TR} – losses from unreliable operation of electrical equipment y_{UO} and unscheduled maintenance of the equipment M.

The functional structure of the intelligent automated control system of power supply and consumption of FMP (IACS PSC) has been developed (Figure 1).

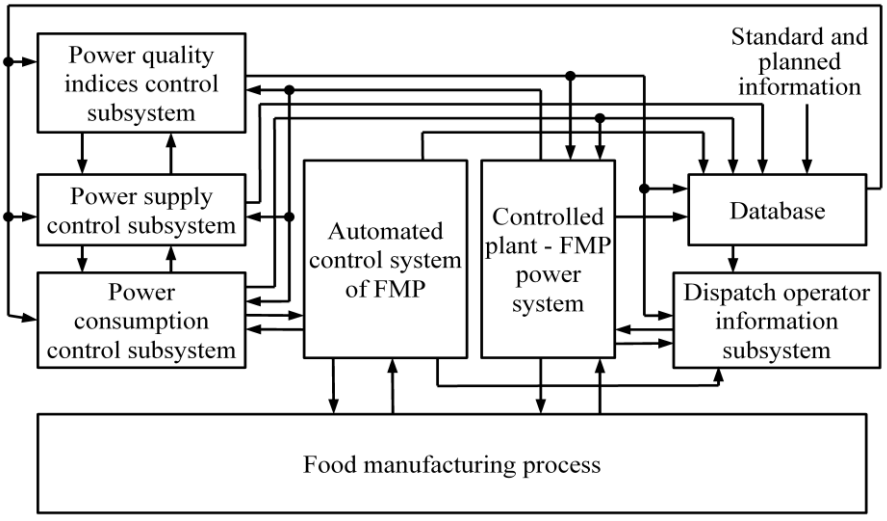

Figure 1. Functional structure of IACS PSC

As design stage of IACS PSC the authors have performed the decomposition of the main control goal into partial control goals, which made it possible to create a reasonable choice and implementation of individual components of the task and is carried out using the method of ensuring compatibility and integration. Synthesis is based on the presentation of individual subsystems in the form of a set of interconnected structures: decision-making system (DMS), functional, organizational, technical and informational structures.

I was developed methods and tools for power consumption management in FMP with the use of DMS. The DMS of FMP power management solves the following tasks: establishment of restrictions on the power consumption mode; planning of electricity consumption indicators of FMP; ensuring reliable functioning of the electrical equipment of FMP. Meeting the requirements of the power system in terms of electricity consumption with the minimum cost for FMP is achieved by changing the operating mode of power consuming equipment of consumers-regulators (taking off-line or switching to reduced operating mode) [4]. The following algorithm for controlling the mode of FMP power consumption is proposed [10]. In the normal operating mode, scanning of electricity meters every fixed time interval is initiated by the computer information system (CIS) at the upper level of the consumption mode control subsystem, and then it is performed determination and calculation of actual electricity consumption at the current moment by the elements of the lower level of consumption mode control subsystem. Decisions are made depending on the predicted value of power consumption. As follows from the above procedure, power management consists of:

- Solving the problems of predicting power consumption and selecting the optimal configuration of consumers for its regulation (the upper level of consumption mode control subsystem);
- Solving the problem of supporting the consumption of selected objects within the specified time limits during the billing period (the lower level of the consumption mode control subsystem).

To implement the control functions it is used: model of predicting power consumption, algorithms of making decisions on power management, forming the optimal list of consumers-regulators and calculating the rational modes of power consumption.

The choice of the composition of electrical equipment for regulating power consumption is made using the vector criterion $F(x)$ with components

$$F_1(x) = \sum_{j=1}^{n} \sum_{i=1}^{m_j} y_{ij} k_{ij} \, , F_2(x) = \sum_{j=1}^{n} \sum_{i=1}^{m_j} k_{ij} \tag{10}$$

where y_{ij} is the loss from the use for regulating i-th consumer at the j-th level of FMP power system; y_{ij} – a Boolean variable that takes a value equal to 1 if i-th consumer is used at j-th level to adjust the load and 0 otherwise; m_j – the number of consumers allocated for regulation at j-th level.

Forming a list of consumers-regulators to control the active load is based on the solution of the integer programming problem with Boolean variables using a heuristic algorithm. The choice of consumers for load regulation is made from the top level which contains at least one consumer with the load that is less than load to be switch off. Optimization at j-th level is performed according to criterion (11)

$$\sum_{i=1}^{m_j} (y_{ij} / W_{ij}) k_{ij} \to \min \tag{11}$$

where W_{ij} – electric power consumption of i-th consumer at j-th level of power system.

Justification of algorithm for prediction of FMP electricity consumption

As was mentioned in the Methods it was chosen the multilayer perceptron to predict the FMP power consumption.

The basis for determining the dimensions of the input and output layers of the perceptron is based on the following considerations:

- The input layer contains the number of neurons corresponding to the total amount of retrospective data, including daily electricity consumption, average daily temperature, illuminance and humidity during the working days of the year before the day when the prediction is computed, as well as the coefficient of change of the FMP production volume with respect to previous year;
- The output layer should contain neurons that determine the predicted values of electricity consumption for the next year.

The coefficient of FMP production volume change is calculated by the ratio

$$K_{npi} = \frac{V_l}{V_{l+1}} \tag{12}$$

where V_l - production volume that is produced on *l*-th year.

Selection of the number of hidden layers and its elements was carried out experimentally so that for different input and output data sets a minimum prediction error was achieved.

It is established that to predict power consumption it is advisable to use one hidden layer with the number of elements equal to the half-sum of the elements of the input and output layers of the perceptron.

$$n_H = \left[\left(n_X + n_Y \right) / 2 \right] \tag{13}$$

where n_H is the number of elements in the hidden layer, and n_X , n_Y – the number of elements in the input and output layers of the perceptron.

Thus, the perceptron for predicting power consumption contains three layers, while the input layer contains 529 neurons, hidden – 392, and the output – 264 neurons.

The set of weighting coefficients of the perceptron is presented by a synoptic map *W*, the weight of the connection between each neuron of adjacent layers is denoted as w_{ij}^1, w_{ij}^2 , where *i*, *j* – index numbers of neurons in the initial and final layer, respectively; $W_1,...,W_N$ and $T_1,...,T_N$ – input values of daily electricity consumption and last year's daily average ambient temperature; K_{npi} – coefficient of change of production volumes; $Y_1^{'},...,Y_{N'}^{'}$ – output signals of neural network, the corresponding forecasted values of power consumption.

The accuracy of forecasting electricity consumption of FMP largely depends on the size of the retrospective sample used to train the perceptron. Studies have shown that a retrospective sample of FMP consumption and meteorological data for a period of four years is sufficient to obtain the required accuracy of forecasts.

A retrospective sampling of power consumption values includes a sequence of training pairs

$$L^m(\mathbf{K^m}, \mathbf{Y_b^m}) \tag{14}$$

where $\mathbf{K^m} = \left[W_1^j,...,W_k^j, T_1^j,...,T_k^j \right]$ – the input data vector (input signal); $\mathbf{Y_b^m}$ – the vector of expected output values for $L^m, m = 1,2,\ldots,N$, (*N* – the number of learning data sets).

When constructing the input vector I of the retrospective data sample, it's taken into account all values of daily power consumption, average daily temperature and light for each working day preceding the forecast year.

At the output of the perceptron, the predicted value W^I for the I-th input vector of signals determines the predicted values of power consumption of FMP for the next year.

The following formula is used to normalize the input data

$$P_m^H = (P_m - P_{\min}) / (P_{\max} - P_{\min}) \tag{15}$$

where $P_{\min}$ and $P_{\max}$ are the minimum and maximum value of the input data in this sample, P_m and P_m^H – non-normalized and normalized values of the perceptron m-th input.

The behavior of the perceptron, in addition to the weight coefficients, also significantly depends on the type of activation function that converts the input signal of the neuron into the output.

Sigmoid function is accepted as activation function

$$f(u) = 1/(1+e^{-au}) \tag{16}$$

where a – the neuron's parameter.

The selection of the sigmoid activation function is due to the fact that this function has continuous derivatives that are required for the operation of the inverse error backpropagation algorithm and amplifies weak signals to a greater extent than strong ones, which is important for high prediction accuracy.

The evaluation of perceptron quality is performed by the following expression:

$$\varepsilon = \sum_{i=1}^{R} \varepsilon^j; \quad \varepsilon^j = \left| Y_{np}^j - Y^j \right|^2 \tag{17}$$

where ε is the learning error, Y_{np}^j and Y^j – the values of the predicted and actual outputs of the perceptron.

Perceptron training is carried out by one of the fastest algorithms – the error backpropagation algorithm based on the gradient descent method.

The expression is used to adjust the weights

$$\Delta w_{lm}^{(k)} = -\zeta \, \partial\varepsilon / \partial w_{lm} \tag{18}$$

where w_{lm} is the weight coefficient of synaptic connection between l-th neuron of the k-1-th layer and m-th neuron of the k-th layer; ζ – learning speed ratio.

To increase the efficiency of the algorithm, the order of observations in the training samples of different iterations is varied (in order to reduce the probability of hitting the local minimum and eliminate the effect of retraining); it is performed linear variation of learning speed from 0.25 to 0.01.

Despite the fact that the method of error back propagation is widely used in the artificial neural network learning, it has a significant drawback – it does not cope well with local minima [15, 16], which can lead to deterioration of their work. To get out of the local minima, a statistical method of training is used – the Cauchy machine [15, 16], in which a random change of the neural network weighting factors is performed. However, this method is not effective due to slow convergence, as many steps of its implementation are performed in the wrong direction.

Combining the above algorithm of error backpropagation with the Cauchy machine method [11] allows obtaining a combined learning algorithm, which quickly finds the global minimum of learning error.

Figure 2 shows the generalized scheme for power consumption predicting using the perceptron and Figure 3 presents the results of prediction using a perceptron.

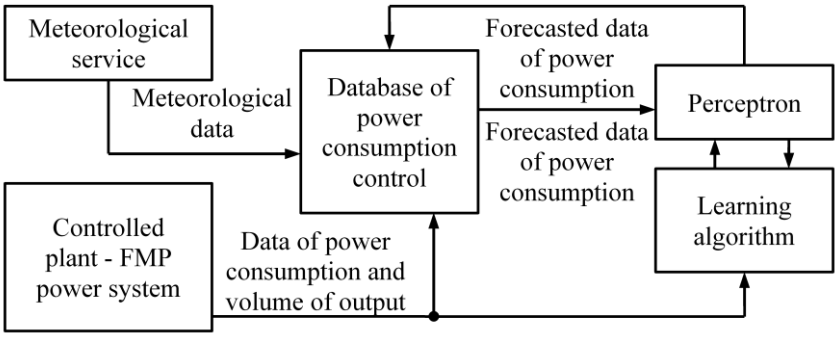

Figure 2. Generalized diagram for predicting power consumption using a perceptron

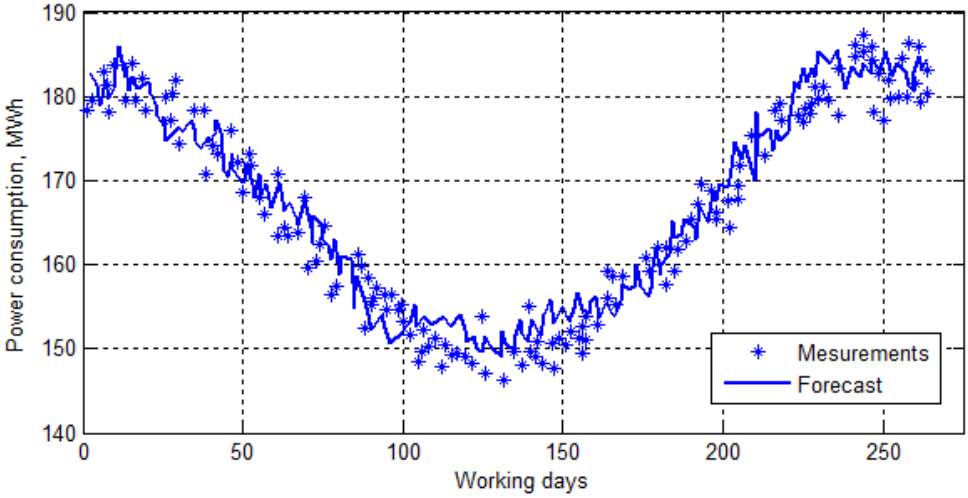

Figure 3. The result of prediction using a perceptron

The learning error is in the range of 0.05-0.06. The maximum relative error is 0.702-0.951%, and the root mean square error is 0.304-0.433%.

Synthesis of structure of the power consumption control system

The subsystem for FMP power consumption is developed (Figure 4), which is a set of interacting units – forecasting, rationing and planning of electricity consumption, selecting of the optimal composition of consumers and the dialog subsystem for decision-making to manage electricity consumption [10].

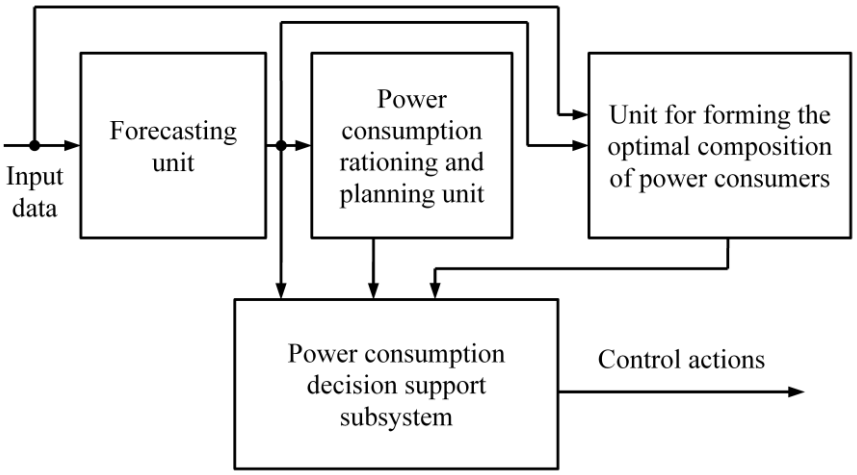

Figure 4. Structure of the control subsystem of FMP power consumption

Consider the features and purpose of individual functional units.

Unit of power consumption forecasting. On the basis of the data arriving from the database of management of FMP expenses, by means of the three-layer perceptron, forecasting of power consumption of production divisions and FMP as a whole is carried out. Predicted values of electricity consumption for these objects are included in the block of rationing and planning of electricity consumption.

Power consumption rationing and planning unit. On the basis of the received forecast values the total rate of expense and total planned electricity expenses of production divisions, and also a rate of expense and planned electricity expense in FMP as a whole are defined.

The obtained data are contained in the database of electricity flow management. It also contains calculated on their basis the total planned costs of electricity for non-production units of FMP.

Control system gives the chance to make automatically and operatively annual, quarterly and monthly electric balances in FMP and on the most energy-consuming units and production divisions.

On the basis of these balances the analysis of electricity use is carried out, directions of economy are defined, possibilities of reduction of unproductive expenses and electrical energy losses are revealed and actions for improvement of its use are defined.

The unit for forming the optimal composition of power consumers. Based on the data received from the database for the electricity cost management, as well as the requirements of the power system, a list of consumers-regulators is formed, which will ensure compliance with the requirements of the power system for electricity consumption. The list of consumers-regulators and volumes of electricity consumption is transferred to the decision support subsystem.

Power consumption decision support subsystem. From the database of the electricity consumption management it is received data on the actual and planned electricity consumption by production units and FMP as a whole, as well as the optimal composition of electrical energy consumers.

Relevant options for decisions (management effects of control actions), which are a set of organizational and technical measures aimed at adjusting the plans for electrical energy

consumption in FMP and production units during the period that appeared before the end of the year, are transferred to the decision maker.

Application of methods of power consumption forecasting, decision-making procedures and algorithm of formation of power consumption rational modes allows adjusting technological process, to form optimum structure of consumers-regulators and to provide standard levels of power consumption.

The general diagram of the decision-making process using the dialog subsystem of decision-making support is presented in Figure 5.

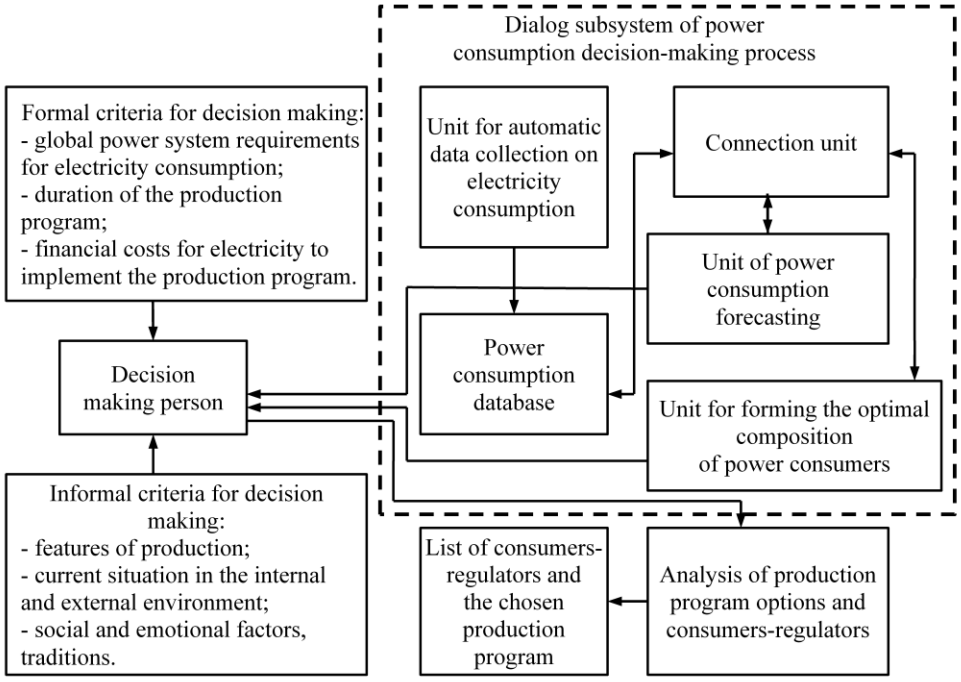

Figure 5. Power consumption decision-making process using the dialog subsystem

The general scheme of the power management decision-making process can be represented as follows:

$$J(t_0) \to (F,V) \to E \to ERP \to v^*(t_k) \quad (19)$$

where V is the set of alternative solutions generated using predicted power consumption values; F – objective function (optimality criterion), in our case, the criterion of optimality is the minimum electricity consumption in the production process; E – expertise of alternative production plans generated; ERP – expertise results processing using the predicted values of electricity consumption; v^* – the optimal solution.

At the stage of forming the goals of FMP it is determined the desired state of the management object, i.e. what should be achieved as a result of management decisions. When forming a system of goals, it is necessary to ensure their appropriate subordination, completeness, interconnectedness, certainty and actuality. Usually the global (strategic) goals of FMP are developed first, and then their ranking according to the degree of importance and terms of realization is carried out. The main purpose of short-term (tactical) management

decisions on production is the organization of production activities of FMP, which ensures the rational use of available resources and maximizing profits.

The usage of methods of forecasting electricity consumption and the formation of the optimal composition of electricity consumers in the process of preparing management decisions to form a production program on the criterion of minimizing electricity consumption is necessary and justified for the following reasons:

- A huge number of alternatives that require comprehensive assessment;
- The difficulty of taking into account random factors in the process of decision preparation and implementation;
- The need to operate with large amounts of information about the functioning of FMP.

In Figure 6 presents the consolidated graphs of actual and planned electricity consumption, obtained as a result of the implementation of the proposed decision-making algorithm for power consumption management of FMP.

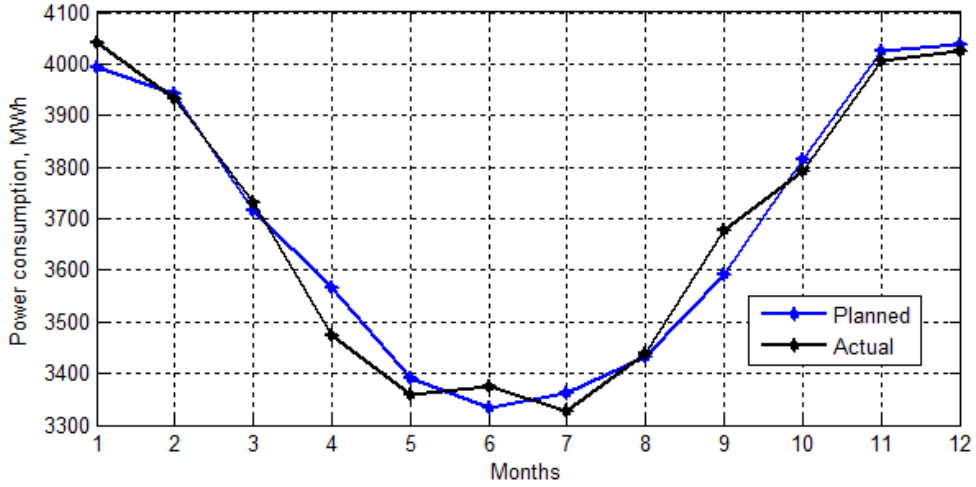

Figure 6. Planned and actual electricity consumption of FMP

On the basis of the system analysis, the data structure of the power management subsystem was synthesized using the presented methods. In Figure 7 the data structure is represented in the form of data-flow diagram (DFD). This structure is the base of a single information space, which is required for designing of the hardware and software system and forming a database for managing power consumption.

Application of power consumption prediction methods, decision-making procedure and algorithm of calculating power consumption optimal modes allows adjusting the technological process, forming the optimal configuration of consumers-regulators and providing standard levels of power consumption.

Control methods of FMP power supply using static load characteristics

The power management subsystem provides the solution to the problems of choosing optimal configuration, energy efficient operating modes, reactive power compensation, maintaining the standard values of electricity quality indices. Methods and tools have been developed to control the power supply of FMP. The objective function of the power management to provide energy-efficient modes is:

$$J = \frac{M}{T}\int_0^T \left\{ \sum_{j=1}^{nm} P_j + K_Q \sum_{j=1}^{m} Q_j + \sum_{i=1}^{n} \Delta P_S + K_Q \sum_{i=1}^{n} \Delta Q_S \right\} dt$$
$$J \to \min_{X(t)\in\Omega} \quad (20)$$

where M – expected value of active and reactive power losses; T – estimate time interval; P_S and Q_S – loss of active and reactive power at the main substation level; P_j and Q_j – the loss of active and reactive power in the j-th load node; K_Q is the ratio of reactive power loss to active power loss.

The controlled object in the management system of power supply and distribution of FMP is a multilevel system of transmission, distribution and consumption of electric energy. On the basis of the system analysis, the functional diagram and data structure (Figure 8) of the power supply subsystem was synthesized using the presented methods.

On the basis of mathematical model of power system it is calculated the power supply system operating modes for the main modes of the technological process, taking into account the state of consumers-regulators. The method of determination of the optimal voltage on 0.4 kV buses of shop floor substation (SFS) is developed, which provides energy efficient operating modes of power system, using static load characteristics.

Identification of SLC is carried out in the interactive mode for the main modes of the technological process, taking into account the state of consumers-regulators and the degree of compensation of reactive power with the help of SFS transformer equipped with the electronic switch.

Given the normal law of distribution of a random variable, it is used the least squares method to determine SLC [14] as it is described in the Methods.

Graphs of voltage and active power changes during the active experiment on the 0.4 kV bus-bars of 1000 kVA shop floor transformer are presented in Figure 9.

Maintenance of energy efficient voltage in the power system is provided by a two-level voltage regulation subsystem with fuzzy controllers. At the upper level, fuzzy regulators determine the farthest and closest connection and maintain the given voltage level in the distribution 6-10kV network using the on load tap changing (OLTC) transformer of main substation (MS) by a fuzzy controller based on Mamdani algorithm depending on the electrical distance SFS from MS, the load on the transformers and the voltage on the HV side of MS transformer. Using the Mamdani algorithm [12], the connection modes are determined, and the Sugeno algorithm [12] selects substations that have the electrically closest and most distant location from the power source (MS). Input signals of the controller: the voltage on HV buses of SFSs, electrically farthest and closest to MS; the value of the current tap of the MS transformer; the number of switches of OLTC system since the beginning of the current day. Output signals: movement direction of the tap changer and delay of actuation. At the lower level, a fuzzy controller and the SFS transformer with electronic switch maintains energy efficient voltage in the shop floor network. Fuzzy controller input signals: difference of rational voltage and current voltage values; is derived from the voltage value on the SFS LV buses. Output signals: transformer output voltage and time value after which the tap switching should be carried out. In order to ensure efficient operation, it is advisable to perform the construction of IACS PSC on the basis of a digital transformer substation [13]. The authors performed computer simulation of IACS PSC with the classical tap changer and fuzzy controllers for power system of meat-processing plant with two 25MVA transformers using MATLAB Simulink. The results of simulation showed that the use of a fuzzy controller allows reducing electricity losses by 4-6% compared to the classical voltage control algorithm.

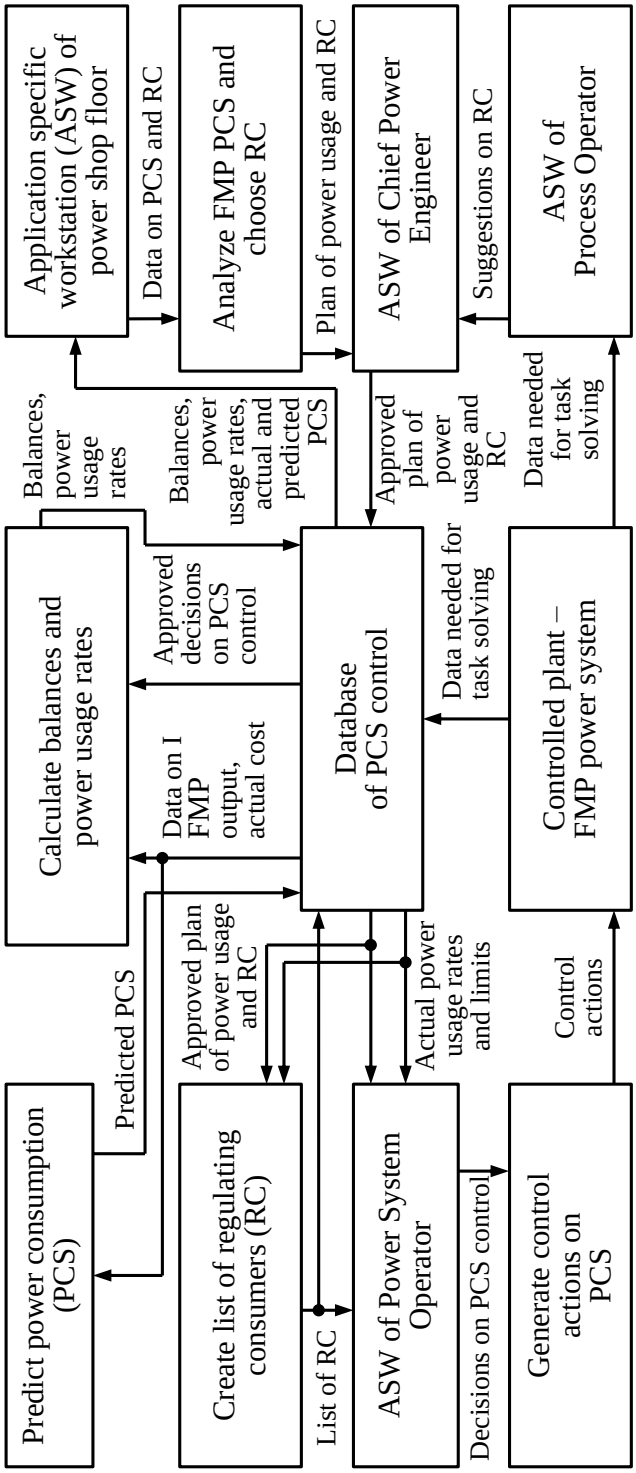

Figure 7. DFD diagram of power consumption control subsystem

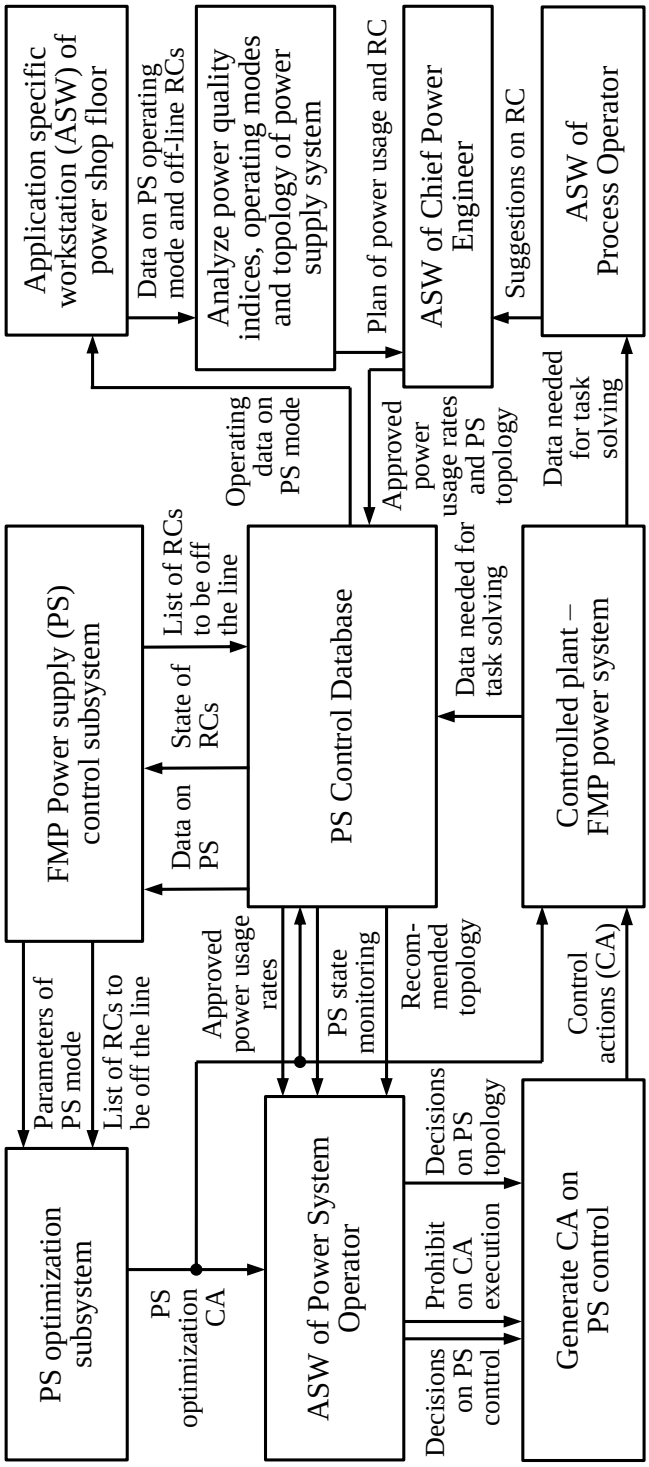

Figure 8. DFD diagram of power supply control subsystem

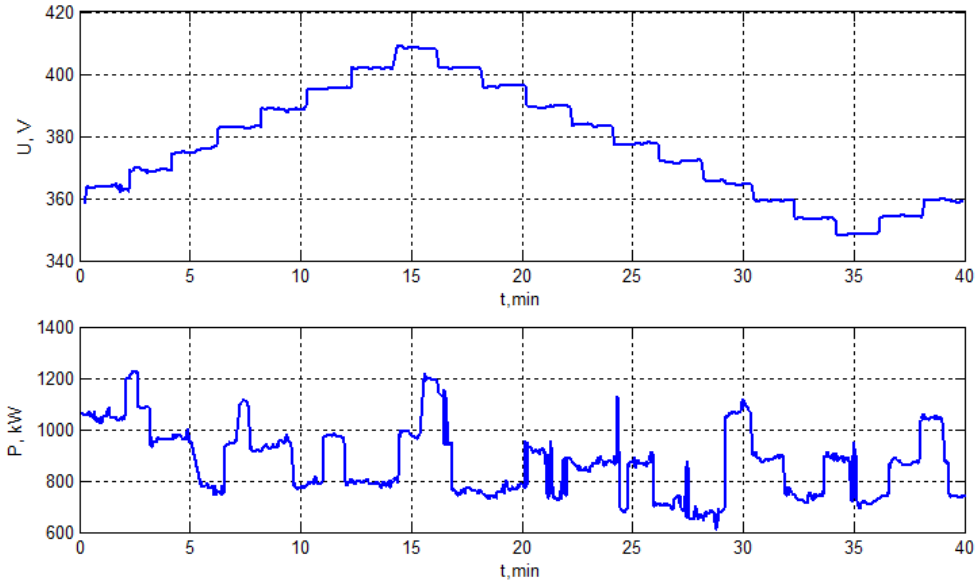

Figure 9. Graphs of voltage and active power change during the active experiment on the 0.4 kV bus-bars of 1000 kVA shop floor transformer

Based on the results of calculations performed according to the method described above, the coefficients of SLC on active and reactive power are determined and conclusions are made about the adequacy of both the coefficients themselves and the model as a whole. For the performed active experiment the SLC of active power (Figure 10) and the coefficients $a_0 = 1.458$, $a_1 = -2.233$ and $a_2 = 1.775$ are determined.

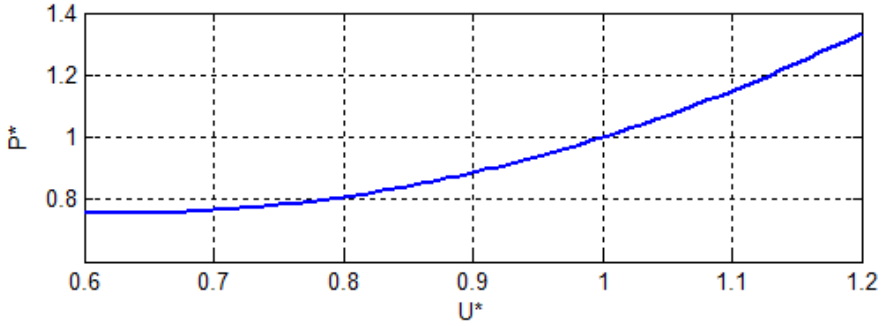

Figure 10. Static load characteristic: the dependence of active power of the voltage

Conclusion

In the paper the authors have developed the structure, the algorithms and the methods of the intelligent automated control system built on the basis of system analysis of the control process to provide energy efficient modes of power supply and consumption control of FMP as well as reduce electricity losses. The single information space of developed system allows implementing its efficient hardware and software design. The subsystem of power consumption control is based on the decision-making system, which uses heuristic methods of choosing consumers-regulators and power consumption prediction by artificial neural networks. The power supply control subsystem is able to maintain energy-efficient operating modes by means of fuzzy regulators that control rational voltage levels determined for the main process modes, the state of the consumers-regulators, and the degree of reactive power compensation. The results of computer simulation have proved efficiency of designed system comparing with classical approach.

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Comprehensive analysis of innovative devices based on shape memory alloys in food technology apparatuses

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Abstract

Introduction. The purpose of this study is to conduct a comprehensive analysis of innovative devices based on shape memory alloys (SMA's) for use in food technology apparatuses.

Materials and methods. Physical and mathematical processes modeling, principles of the theory of automatic control, the theory of fuzzy logic were used.

Results and discussion. The complex analysis of devices based on materials with shape memory effect (SME), which can be applied to food industry apparatuses, is made. In particular, design and principle of operation of the thermal valves, characterized by simplicity of construction and reliability, were analyzed. Design and principle of operation of the critical temperature increase indicator for machine's casing and the nut-indicator for overheating of sectional casing of technological machine, which increase the reliability of apparatuses were analized. Design and principle of operation of the thermal drives which can be effectively used in factories that need to utilize low-temperature thermal energy were analized. Design and principle of operation of the heliodrive were analized.

Design of the critical temperature increase indicator for machine's casing is highly technological and reliable.

Many factories need to utilize heat energy at relatively low temperature difference. These requirements are met by the design of the thermal drive.

Power elements based on SME alloys have significant advantages: less mass, they can work in a wide temperature range, they have small dimensions, smooth movement of working parts, lower cost, high sensitivity.

Drives based on heat-sensitive elements with SME are effective in solar power installations.

Introduction

SME materials can be used in food industry to optimize the operation of its apparatuses (improving their reliability, preventing their failure, recycling secondary energy, etc.) [1-3].

Among the Ukrainian developments on this topic the thermal valves, the critical temperature increase indicator for machine's casing, semaphore-light indicator of heating of current-carrying elements and contact connections of technological apparatus can be mentioned (patent of Ukraine №17994, F03G 7/06./Ukrayinets A.I. Shesterenko V.Ye., patent of Ukraine №19634/Ukrayinets A.I. Shesterenko V.Ye., patent of Ukraine № 42169, H01R 11/00. /Ukrayinets A.I. Shesterenko V.Ye.). Among the foreign developments, similar in function to the overheating indicator is, for example, Temperature-sensitive indicator nut (Chinese patent CN105157861A).

The problem is that these developments are not widespread and described in detail. There are some researches devoted to use of SME materials as actuators [4-17], but not in food industry. To understand the advantages or disadvantages of using SME materials in devices to improve the efficiency of food industry apparatuses, the task of analyzing these devices is urgent.

Thus, the purpose of this study is to conduct a comprehensive analysis of innovative devices based on shape memory alloys (SMA's) for use in food technology apparatuses.

Materials and methods.

Two Cu–Al–Ni alloys containing 15% Al, 9% Ni (alloy I) and 14% Al, 5% Ni (alloy II) were taken for the study. The alloys were quenched from 900°C in NaOH solution. The grain size of the β phase is 0,3–0,6 mm. Phase composition of the alloys after quenching was determined by X-ray imaging, and the temperature intervals β_1–γ^1 of the transformation were determined along the curves of change of electrical resistance during heating and cooling. The martensitic point of the alloy I is +10°C, for the alloy II it is +110°C. Samples of size 2,0x0,7x40mm were loaded according to the scheme of four-point bending and by the curve of the section loaded with constant bending moment, the radius of curvature was found (deflection was determined to within 0,02 mm). The research was conducted on equipment of NAS of Ukraine.

Deformation is determined by the radius of curvature, assuming that after deformation cross section remains flat. Maximal stresses in the samples deformed above A_f were determined taking into account deviation of dependence between stress and deformation from the Hooke's law [18], and it was considered that the deformations in the compressed and stretched sections of the beam (sample) were equal. This assumption is justified by the fact that deviation from the Hooke's law in this case is caused by the martensitic transformation. The samples were loaded under isothermal conditions in temperature range from –196°C to +200°C.

Elastic properties of the taken bronze change significantly with temperature.

As long as applied load is insufficient to cause formation of martensitic crystals at given temperature, the dependence of $\delta(\varepsilon)$ is linear.

The beginning of deviation from this linear dependence coincides with the appearance of the martensitic phase in the sample.

An X-ray analysis confirmed that the sample of the alloy I bent at room temperature contained a significant amount of the martensitic phase.

When unloaded, the martensite crystals disappear with a certain hysteresis and, if the deformation was carried out at a temperature above +20°C (temperature A_f for the alloy I),

the sample completely restores its original shape. Above 150°C, the dependence of $\delta(\varepsilon)$ is linear. In the temperature range of 20–150°C, stress at which the martensitic deformation mechanism begins to act increases linearly with temperature.

Thermal effect of the transformation was determined by change in heat capacity of the alloy II with high-speed heating. In the temperature range of the reverse transformation there is a sharp decrease in heat capacity associated with emission of latent heat of the transformation. If at some temperature higher than A_f we load the sample in such a way that it causes appearance of the martensitic phase and then (without removing the load) heat it, the deformation will change. As the temperature rises, martensite gradually disappears, leading to the deformation (restoration of the initial shape) of the sample.

After deformation in the temperature range below A_f, the unloading does not end with complete restoration of the form (shape). The original shape is restored only when heated as a result of the reverse martensitic transformation. If deformation is carried out at a temperature below the martensitic point (M_s), then to obtain a certain degree of final deformation the higher loads are required at the lower temperatures.

The small hysteresis between the loading and unloading curves can be explained by the elastic twinning in martensite observed in these alloys experimentally [19-21].

It should be noted that in all cases of deformation below A_f, the samples while retaining the final deformation after unloading, restored their original shape after heating.

Since the main cause of the stop of crystal growth during martensitic transformation is the accumulation of elastic energy, it is of interest to estimate the possible level of stresses arising in the material during martensitic rearrangement. The change in thermodynamic potential caused by the growing crystal of martensite is expressed as follows:

$$\Delta W = -\Delta\Phi + S_\gamma + E, \tag{1}$$

where $\Delta\Phi$ – chemical thermodynamic driving force of transformation, S_γ – surface energy at the interface, E – elastic energy.

$$\frac{dT_0}{d\delta} = \frac{1}{\rho} = \frac{T_0 \cdot \varepsilon}{\Delta H \cdot A}, \tag{2}$$

where T_0 – thermodynamic equilibrium temperature, δ – external stress, ε – transformation deformation (ε=0,11), ρ – density, ΔH – thermal effect of transformation, A – mechanical equivalent of heat.

The authors manufactured thermomechanical converters with SME made of aluminum bronze Cu–Al–Ni (12÷16% Al; 0÷10% Ni). The elements (D_{out}=5 mm; d_{in}≈3 mm; l=4 mm; t=1,5 mm; s=0,7 mm) had the form of a coiled spring with a rectangular cross-section of the coil. They were examined on a special stand, which allows to measure the load on the element, its temperature and deformation. The elements were cooled in vapor of boiling liquid nitrogen at an average rate of 10°K/s. Measurement techniques, sensors and secondary devices provided a maximum standard deviation of $\bar{\sigma} \leq 1.5\%$. The experiment determined the effect of temperature and loading conditions on magnitude of output signal of the elements and force created by them.

On Figure 1 there is typical characteristic of deformation of an element with its change in temperature for specific example presented. Temperatures of the beginning and the end of the direct martensitic transformation accordingly M_s=108,5°K; M_f=93°K and temperatures of the beginning and the end of the reverse martensitic transformation accordingly A_s=115°K; A_f=125,5°K.

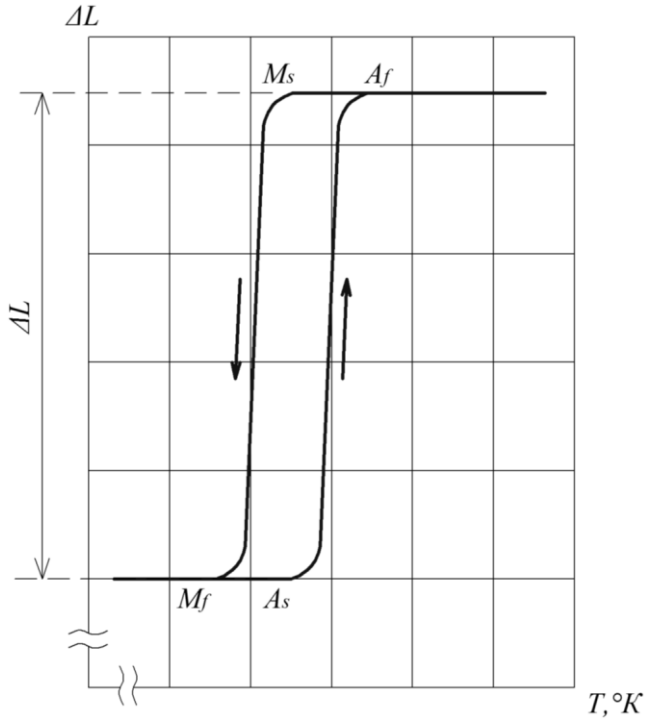

Figure 1. Phase transformations

To clearly show the adwantages of the new thermo-mechanical drives on Figure 2 values of relative temperature deformations $\varepsilon_t = \frac{l_t - l_0}{l_0} = M(T)$ of the elements that are made of Cu-Al-Ni alloy (right scale – experimental dependence) and brass, plastic (left scale – theoretical dependence) are given.

Comparison of curves shows that in the range of operating temperatures 290°–320°K, the sensitivity of an element with SME is greater than other samples in 200–400 times. Calculation of sensitivity:

$$x = \varepsilon_t \frac{l_0}{\Delta T} \tag{3}$$

It is found that the value of triggering temperature of the elements (beginning of the direct – M_s and the reverse – A_s transformations) is changing with the load (Figure 3) [2].

This means that by varying the load on the element, the working point of the element shifts. It is important to take this fact into account while designing and making calculations of the devices that are based on the elements with SME.

The equasion for the coefficient of the energy transition in an element with SME:

$$\eta_{n.ф.} = \frac{\Delta H}{c'_m} \frac{\ln(1+\frac{\Delta T_{ф.п.}}{T})}{\frac{\Delta T_{ф.п.}}{T}(T - T_{o.c.})}, \tag{4}$$

where c'_m – averaged thermal capacity of an element in temperature range of the phase transformation $\Delta T_{ф.п.} = A_f - A_s$.

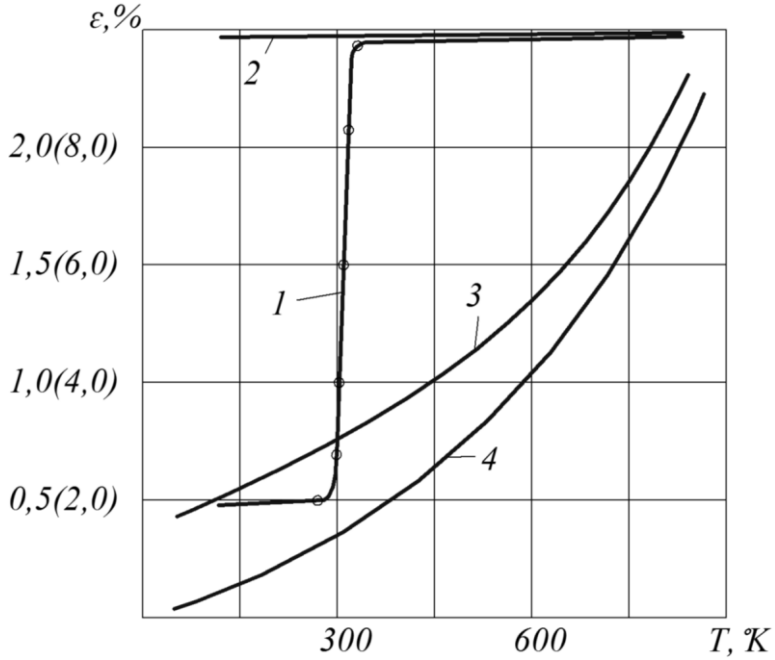

Figure 2. Relative temperature deformations of thermosensitive elements made of materials: 1 – SMA (deformation in brackets); 2 – brass; 3 – teflon (PTFE); 4 – polyethylene (PE).

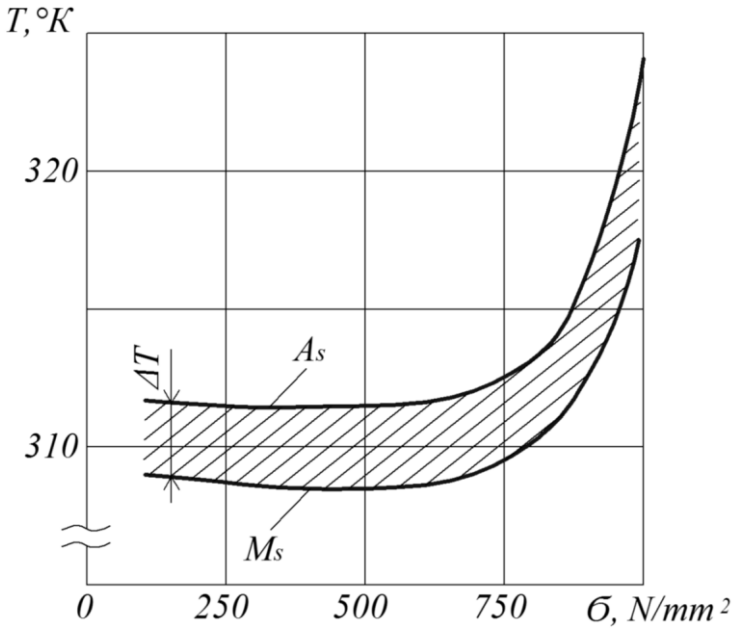

Figure 3. Dependance of SMA triggering temeratures from applied load

Force that is created by the element:

$$P_t = \sigma_\gamma Q, \quad (5)$$

where σ_γ – tension that is generated during the process of shape restoration.

$$\sigma_\gamma = \frac{\Delta H \rho}{\varepsilon_t} \ln \frac{A_f}{A_s}, \quad (6)$$

where ΔH – thermal effect of phase transition for Cu-Al-Ni alloy that was calculated out of the change in themal capacity, equals $8{,}5 \cdot 10^3$ J/kg; ρ – density; ε_t – value of relative deformation.

The calculation for the specific element using equation (4) (T=115 °K and $\Delta T_{ф.п.}$=10 °K) returns $\eta_{п.ф.}$=13%. It is higher by a degree than η of dilatometric converter. After calculation of σ_γ using (5) we get for our example P_t=50 H.

Therefore elements with SME have high sensitivity and can create forces that can be compared with forces that are created by dilatometric converters.

The temperature of phase transformation and form of hysteresis is determined by the composition of the alloys and their heat treatment. Also SMA's are characterized by high strength and manufacturability [2, 4, 19-21].

Results and discussion

Elements made from SME materials are characterized by high sensitivity.

If these materials are used in the manufacture of valves and other regulating equipment they can significantly simplify food production.

Analysis of design and operation of thermal valves based on the SME elements.

Figure 4a shows the construction of the thermal valve. By changing the alloys composition, we can achieve any triggering point in a wide range from –110°C to +600°C. Therefore, when the temperature of the medium flowing through the valve and heating the power element made of SMA rises, the power element, due to the appearance of elastic forces, restores its original shape and closes the pipeline. When the temperature decreases, the power element becomes plastic and under the action of the medium (liquid in the pipeline) opens the pipeline.

The advantages of this valve are its constant readiness to work due to the heating of the flowing fluid, and small energy requirement.

The second type of valve is shown on Figure 4b. This is a thermal-electric valve. In the initial state the valve is closed and held at the saddle with a spring 5, which is simultaneously a directed load of the drive 6, made in the form of a spring made of SME material. To open the valve, the heat source (spiral 7) needs to be turned on. When heated, the actuator 6 increases its linear dimensions, compressing the spring 5 with the help of a rod 3, and the valve 2 opens. The liquid flows through the pipe 1 and the cavity 4 [2].

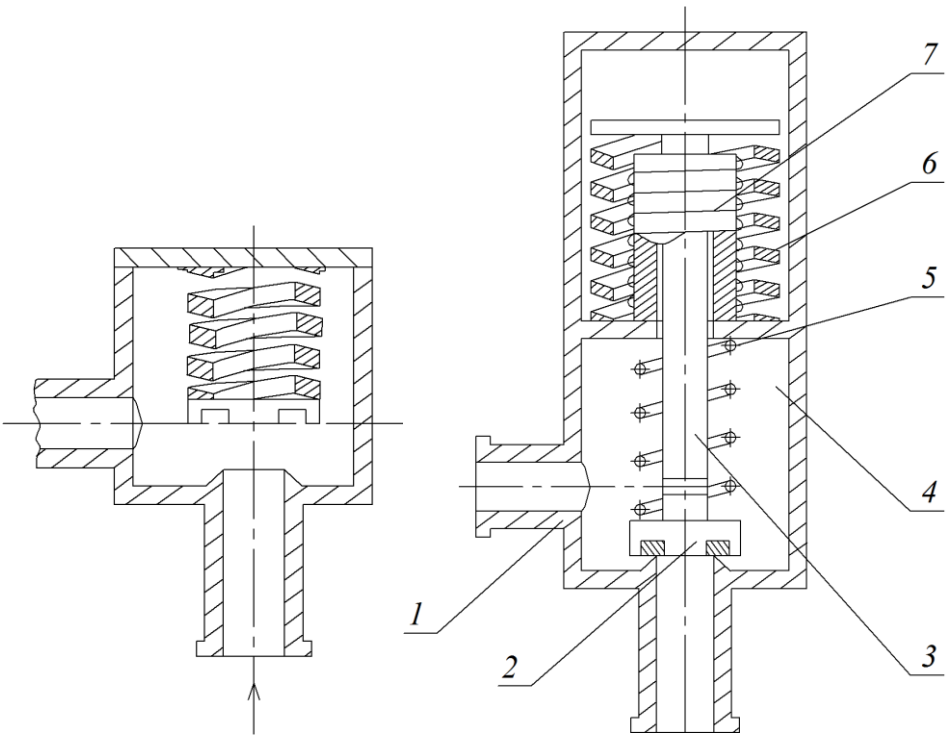

Figure 4. Thermal valves with SME elements used as drives
a – energy source – liquid; b – energy source – electrical current.

Analysis of design and operation of critical temperature increase indicator for machine′s casing

Technical essence of the proposed indicating device is explained by Figure 5.

The temperature of reverse martensitic transformation of the material with SME is equal to the maximum permissible temperature of the machine. When the normal mode of operation of the machine is violated, its temperature starts to rise. Bolt 1 is a heat conductor and it heats the spring 7 that is made of the material with SME. Upon reaching the temperature of reverse martensitic transformation, the spring material 7 rapidly changes its characteristics and tries to restore its original form. The spring 7 substantially increases its length and pushes the cylinder out of the ring groove 5 outwards. The bright fluorescent coating of the outer surface of cylinder 6 allows the staff to respond quickly to the damage. After the temperature of the machine decreases, the material with SME loses its elastic properties, but does not return in the initial position by itself. This is a significant advantage of the device, because the fault of the equipment operating in automatic mode is detected by the staff during maintenance work. The return of the cylinder 6 to the groove 5 is carried out manually during the repair work.

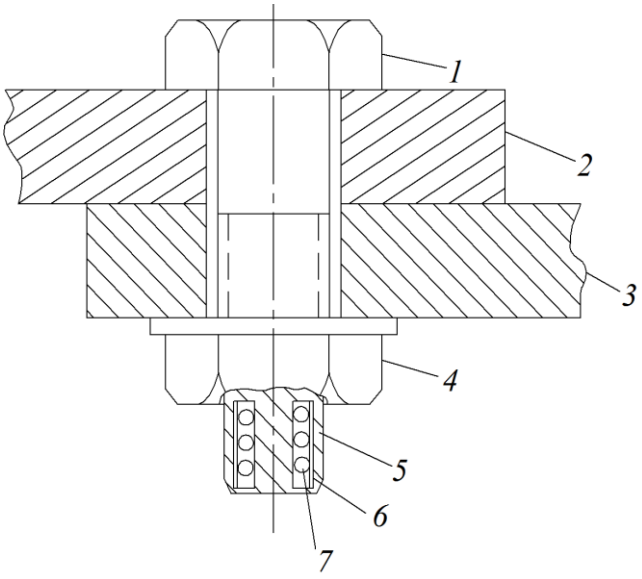

Figure 5. Critical temperature increase indicator for machine's casing in assembled state
Here: 1 – bolt that connects the elements of the casing of the machine 2 and 3, 4 – nut, 5 – ring groove in the tail part of the bolt, 6 – cylinder with surface that has bright fluorescent coating, 7 – cylindrical spring made of the material with SME, one end of the spring 7 is fixed to the bottom of the groove 5, another end is fixed to the cylinder 6.

Analysis of design and operation of nut-indicator for overheating of sectional casing of technological machine

Nut-indicator for overheating of sectional casing of technological machine that would work with high degree of reliability can be created using SME material. The elements of the critical temperature indicator can be made of this material. The technical essence of the proposed indicating device is explained by the Figure 6.

The temperature of reverse martensitic transformation of the material with SME is equal to the maximum permissible temperature of the machine. When the normal mode of operation of the machine is violated, its temperature starts to rise. The bolt 8 is a heat conductor and it heats the washer 7 that is made of the SME material. When the temperature reaches the starting point of reverse martensitic transformation, the washer 7 rapidly changes its characteristics and tries to acquire the shape which it had during its manufacture. Washer 7 bends, increases its height substantially and pushes the flag 6 out of the shank 2, the flag 6 removes the protective cap 3 from the shank 2 of the nut 1. The magnet 4 located on the cap 3 moves relative to the reed switch 5 causing a change in the position of the contacts of the reed switch 5. This sends a signal to the alarm system of technological machine. Fluorescent coating of the outer surface of the flag 6 allows service staff to quickly locate the place of damage of technological machine. After the temperature of the device decreases, the material with SME loses its elastic properties, but does not return to the starting position by itself. This is a significant advantage of the device, because the failure of the equipment operating in automatic mode can be noticed by service staff during maintenance work. Returning of the flag 6 to the shank of the nut 1 is carried out manually during repair work.

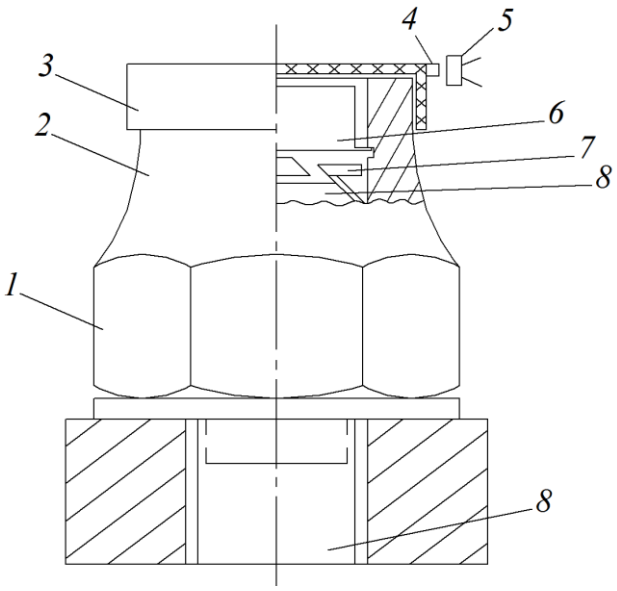

Figure 6. Nut-indicator for overheating of sectional casing of technological machine in assembled state

Here: 1 – nut, 2 – shank of a nut, 3 – protective cap, 4 – magnet, 5 – reed switch, 6 – rectangular signal flag, the outer surface of which has a bright fluorescing coating, 7 – thermosensitive element made of SME material in the form of a round unlatched washer, 8 – bolt.

Analysis of design and operation of thermal drives

Thermal drives with a power element based on SMA have significant advantages: less mass, they can work in a wide range of temperatures, small dimensions, smooth movement of working elements, lower cost. For example, the speed of the thermal-electric drive actuator increases due to the fixing device, which holds the leading element after heating and releases it to perform the working stroke under the influence of elastic deformation.

On Figure 7 a drive that is structurally manufactured as a single unit with a pump is shown.

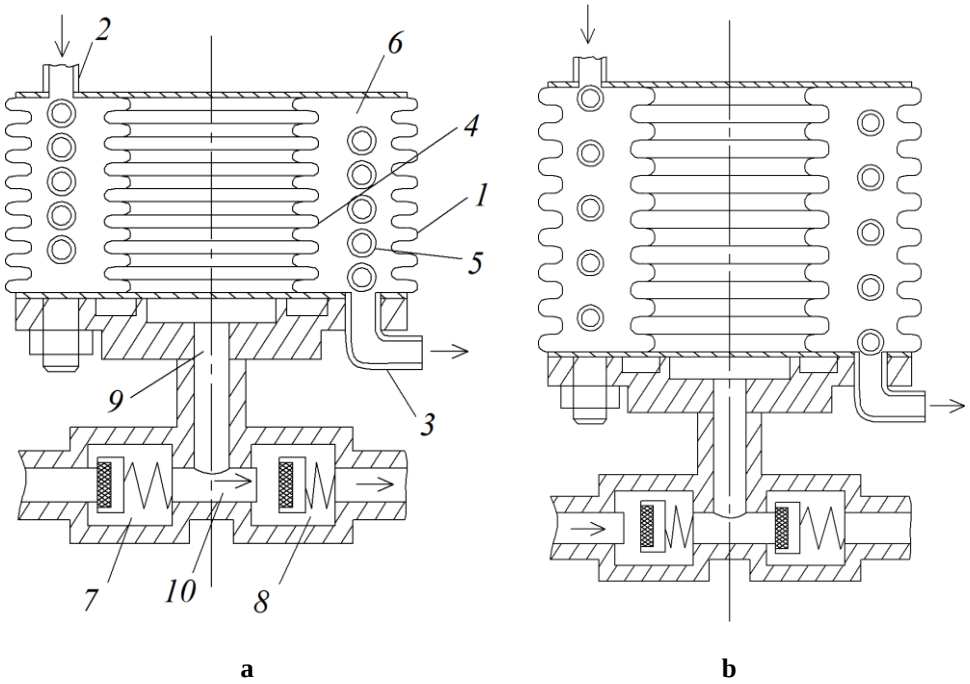

Figure 7. Pump
a – fluid suction mode; b – fluid discharge mode;
1 – bellows, 2,3 – pipes, 4 – piston, 5 – spring, 6 – round cavity, 7, 8 – valves,
9 – channel, 10 – cavity between valves.

The pump consists of a housing made as bellows 1 with pipes 2,3 for supply and release of heat transfer fluid, a piston that is also made in the form of bellows 4, a spring 5 that is made of SME material and a round cavity 6 between bellows 1 and 4.

When warm water (gas) is transfered to the heat-sensitive spring 5 through the pipe 2, the spring is heated to the starting point of reverse martensitic transformation. The length of the spring increases, and the bellows 1 and 4 straighten up. Fluid is sucked through the valve 7 to the cavity 10, the channel 9 and the bellows 4. At the end of the suction process, the supply of hot fluid is stopped and cold water (gas) is supplied to the spring 5. In this case there is direct martensitic transformation. The material of the spring rapidly changes its shape due to the anomalous change in its elasticity and plasticity. In this case, the spring shrinks, and the bellows 1 and 4 are compressed under the action of atmospheric pressure, fluid pushes out through the valve 8. Thereby, the pump operation is carried out by direct conversion of thermal energy into mechanical energy [2].

Work that is performed by the power element of the pump:

$$W = \sigma V \ln(1 + \varepsilon), \tag{7}$$

or

$$W = \Delta Q \frac{\Delta T_0}{T_0} \frac{\ln(1+\varepsilon)}{\varepsilon}, \tag{8}$$

where Ϭ – power that is generated by the SME material during its shape restoration, V,Ɛ – volume and relative linear deformation of the power element, respectively,
ΔQ – hidden heat of martensitic transformation, T_0, ΔT_0 – temperature of the thermodynamic equilibrium and its dislocation, caused by an external load, respectively.

The amount of heat that needs to be transferred to the working element to perform the mechanical work W:

$$Q \approx m(\Delta Q + \int_{M_f}^{A_s} C_p dT + \int_{A_s}^{A_f} C_p dT) \approx m(\Delta Q + C_p \Delta T_0) \quad (9)$$

where m – mass of the power element, C_p – heat capacity of the SME material, A_s, A_f, M_f – temperatures of the beginning and the end of reverse martensitic transformation and the temperature of the end of direct martensitic transformation, respectively.

W means maximum possible work. For nitinol alloy it is: $2 \cdot 10^4$ kJ/m^3.

Efficiency of the power element:

$$\eta = \frac{\ln(1+\varepsilon)}{\varepsilon} \frac{1}{T_0} \frac{1}{\frac{1}{\Delta T_0} + \frac{C_p}{\Delta Q}} \quad (10)$$

Analysis of design and operation of heliodrive

Construction of the heliodrive is shown on the Figure 8.

The main element of the drive is a heat-sensitive power element 1 made of SME material. Lens 6 is used as a sun-ray concentrator. A spring 5 returns the power element 1 to the initial position.

When sun rays hit the heat-sensitive element 1, it heats up to the starting point of reverse martensitic transformation. The shape of the element 1 is changed (Figure 8c) and it forces the rod 4 to move, compressing the spring 5. Joint nodes 2, 3 of the power element 1 allow the element to be moved at a certain distance and it falls into shadow. The heat-sensitive element is cooled over a certain period of time. This causes direct martensitic transformation. The material of the power element loses its original shape due to the rapid change in elasticity and plasticity. Under the action of the spring 5, the power element returns to its initial position. The drive is ready to work again. The frequency of operation cycles depends on the conditions of heating and cooling of the power element.

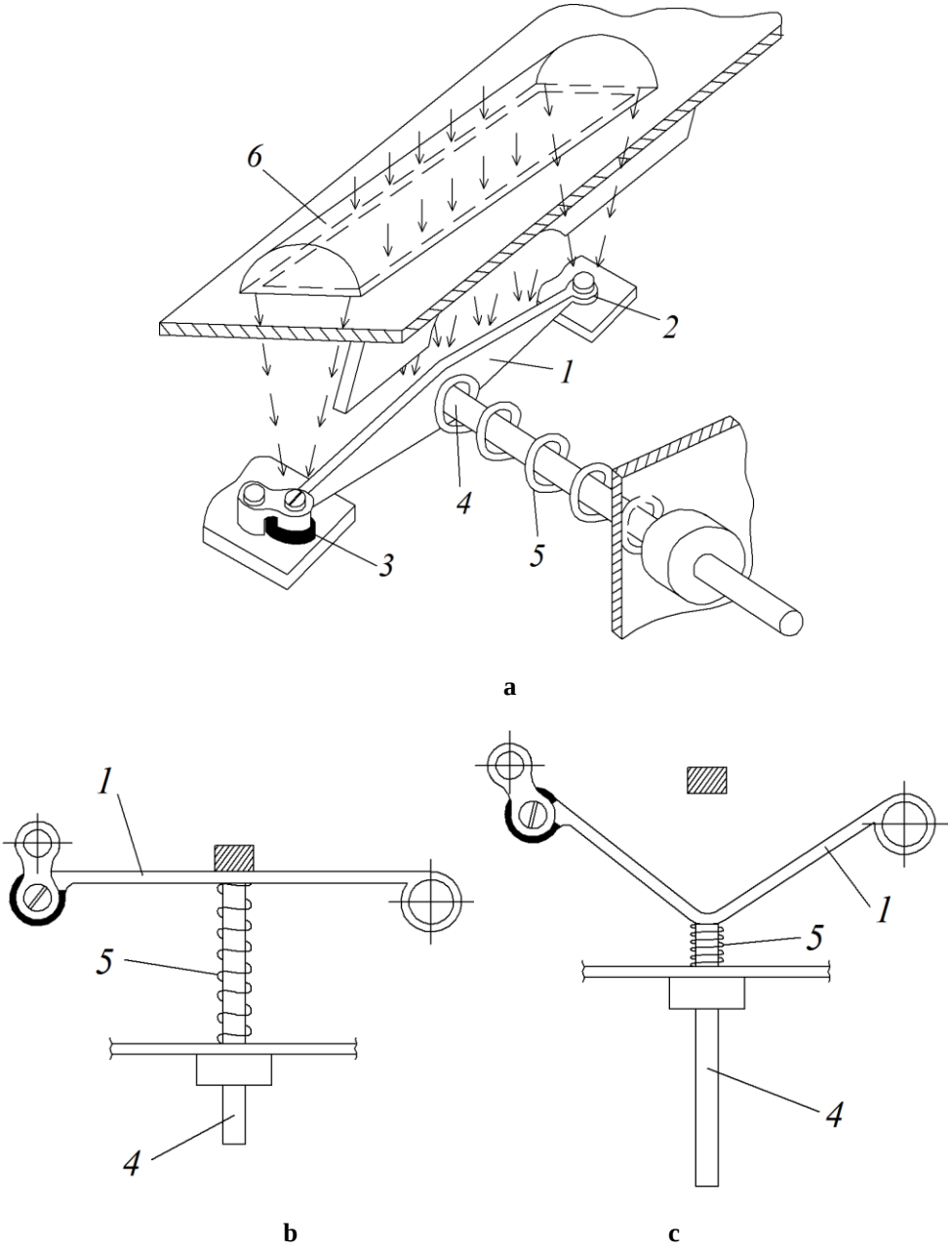

Figure 8. Heliodrive:
a – general view; b – power section in its initial state; c – power section after triggering; 1 – power element made from SME material; 2,3 – joint nodes for power element; 4 – rod; 5 – spring; 6 – lens.

Conclusions

1. The construction of the critical temperature increase indicator for machine's casing is marked by high manufacturability and reliability. The indicator does not lose its properties even when a machine is damaged. High corrosion resistance of nitinol ensures a service life of 30 years. Requirements of the heat-sensitive material are insignificant – one indicator needs several grams of the material. That's why additional costs can be paid off in one year
2. At many factories there is a need to utilize heat energy with a relatively small temperature difference. These requirements correspond to the design of the heat pump. The stable operation of this pump will be at a temperature difference in the range of 20...30°C, which is practically not realized in other known thermodynamic cycles. The temperature control can be carried out by any heat transferring fluid.
3. Power elements based on SME alloys have significant advantages: less mass, they can work in a wide range of temperatures, small dimensions, smooth movement of working elements, lower cost
4. Heat-sensitive elements with SME in the range of operating temperatures 290–320 °K have increased sensitivity in 200...400 times, comparatively to traditional materials.
5. Drives based on heat-sensitive elements with SME are effective in solar power plants.

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Comparison of price elasticity of demand for eggs in Lithuania and Ukraine

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Abstract

Introduction. Elasticity is a measure that shows how strongly buyers and sellers respond to changes in market conditions. Price elasticity of demand for eggs in Lithuania and Ukraine is presented in this work.

Materials and methods. While measuring price elasticity of demand for eggs in Lithuania and Ukraine, statistical data from 2003–2018 gathered by Statistics Lithuania and State Statistics Service of Ukraine was used. Data analysis, comparison and generalization were among the methods used. The annual coefficient of price elasticity of demand for eggs was calculated using the midpoint formula. An average, multi-annual coefficient of price elasticity of demand for eggs was calculated using the median. To demonstrate the results visually, the graphs below were used.

Results and discussion. It was established that in 2003–2018, fluctuation in the retail prices of eggs occurred both in Lithuania and Ukraine. In Ukraine it was clearer. During the period under investigation, the tendency to an increase of retail prices prevailed. To compare 2018 to 2003, the retail price of eggs in Lithuania increased by 1,9 times, and in Ukraine by 4,5 times. Despite a rapid increase in price, in 2003–2018 eggs were cheaper in the Ukrainian retail market.

The analysis of demand for eggs in Lithuania and Ukraine showed that customers reacted to the fluctuation in prices for just a short period of time. When the price of eggs increased, the consumption of eggs decreased; later, however, despite a further increase in price, usage was to return to the previous level.

Based on the data showing prices and usage, the coefficients of price elasticity of demand for eggs in Lithuania (0,28) and Ukraine (0,35) were calculated.

Conclusions. The study shows the hypothesis, that in Lithuania and Ukraine the demand for eggs is price inelastic, to be true.

Introduction

Market conditions are unstable. As they change, so does the demand for, and supply of, goods. The elasticity index is used to measure these changes. Elasticity is a measure that shows how strongly buyers and sellers respond to changes in market conditions.

When the demand for a product changes due to its price, it is called price elasticity of demand. This index indicates how the degree of demand, measured as a percentage, changes in response to a one percent change in price. Depending on the ratio of change in demand (%) to change in price (%), this elasticity can be of several kinds. Absolute elasticity is when a tiny price change (%) precipitates a big change in the amount of demand (%). In this case, the coefficient of elasticity is infinite. Absolute inelasticity is when the change in price does not affect the change in the amount of demand. In this case the coefficient of elasticity equals zero. Cross-price elasticity shows the strength of connection between the change in price (%) of one good and the change in quantity (%) of another good. Relational elasticity is when the prices change by a smaller amount (%) than the amount of change in demand (%). The coefficient of elasticity is then higher than one. Relational inelasticity is when the change in price (%) is higher than the amount of change in demand (%). In this case the coefficient of elasticity is smaller than one.

Price elasticity of demand is determined by a multitude of factors: availability of substitutes, household income, consumer preferences, the expected duration of the price change, and the product's share of a household's income [11]. Multiple factors work collectively to shape goods demand including traditional economic determinants as well as non–traditional determinants such as health, nutrition, and food safety information; changing product characteristics and new product developments; and shifts in consumer demographics and lifestyles [16].

A variety of economic studies in foreign countries has shown that the demand for victuals is prices inelastic. R. Pomboza and M. Mbaga [12] analyse enquiries into elasticity of demand for victuals conducted in Canada in 20 years. The authors they mention have performed multiple enquiries into elasticity of demand for victuals; these have unanimously shown demand for victuals to be inelastic.

In 2010, scientists at Yale University [1] carried out a study in which they reviewed 160 existing studies about price elasticity of demand for main food products. Having summed up the examined data, they presented the average level of price elasticity of demand for various food products in the US between 1938 and 2007. This study also affirmed that demand for food products is inelastic. In their list, the smallest price elasticity of demand (the coefficient of 0,27) was assigned to eggs.

Small price elasticity of demand for victuals is also mentioned in the works of C.A. Gallet [5, 6], and also R. Green et al. [7], where the authors drew their estimates of own–price elasticities for food from 136 studies in 162 countries.

The abundance of scientific studies in foreign countries about this topic affirms that observation of demand is important. Even when indicators are established, it is useful to renew the calculations, as the market does not stand still. Over time, new dimensions of demand may arise and the relative importance of previously examined determinants may adjust in response to new information and economic conditions. An on-going demand estimation is important for informed decision-making by industry stakeholders and policy makers [9]. Food demand elasticities are important criteria often used to analyse long-term projections in order to assess the effects of political reforms or to shed light on a variety of issues.

Very few studies have been conducted to investigate the price elasticity of demand for food products in Lithuania and Ukraine. In addition, these studies have been conducted for a long time ago and are of little relevance to this day. For example, the price elasticity of demand for food products in Lithuania has been examined in 2013 (eggs in the period 2003–2012) [13]. The price elasticity of demand for food products in Ukraine was examined in several works in 2005 (chocolate in the period 2001–2004) [3] and 2013 (fish in 2005) [12].

Due to such scarce research and old information this research was aimed at determining the elasticity of demand for eggs in relation to the changes in price of eggs in Lithuania and Ukraine. To achieve this aim, (1) a review of the literature on estimates for elasticity of food demand was conducted, (2) a review of prices and consumption of eggs was performed and (3) price elasticity of the demand for eggs in Lithuania and Ukraine was calculated.

Eggs were chosen for the study because they are relatively cheap in comparison with other livestock products. They are easily available on the market and easy to process, so eggs are always considered an important commodity to many consumers.

Materials and methods

To discover what results other scientists obtained while researching the elasticity of victuals, the works of other authors were examined, applying the methods of theoretical analysis, data interpretation, synthesis, logical comparison, systematization and generalization. While calculating price elasticity of demand in Lithuania and Ukraine, the statistical data from 2003–2018 collected by Statistics Lithuania and State Statistics Service of Ukraine was used. The monthly data is aggregated into yearly frequency using average values. The methods of statistical data analysis, comparison and generalization were applied. The coefficient of price elasticity of demand can be calculated by several methods:

* The Percentage Method. This method measures price elasticities of demand on the basis of a demand schedule and computes the percentage change in the quantity of a commodity demanded resulting from a given percentage change in its price [18].

* Point-price elasticity of demand. The point elasticity of demand method is used to identify change in demand within the same demand curve. However, this formula is inappropriate when price and quantity changes are large.

* Arc elasticity or Midpoint formula. The advantage of the midpoint method is that one get the same elasticity between two price points, there is no matter a price increase or decrease. It is because the formula uses the same base for both cases [23]. However, the greater the arch of the actual demand curve is over that range, the worse this estimation of its elasticity will be, because this formula implicitly presumes the part of the demand curve between those points is linear.

* The Total Outlay Method. This method compares the total expenses of a consumer both before and after the change in price. In this way, it is find out whether price elasticity of demand for a good is elastic, unity or less elastic. [18].

The coefficient of price elasticity of demand for eggs was calculated referring to various scientists [2, 3, 4, 8, 10, 13, 14] who offer the midpoint formula:

$$|E_d| = \frac{\frac{Q_d}{(Q_{d1} + Q_{d2})/2}}{\frac{\Delta P}{(P_1 + P_2)/2}}$$

where Ed is the coefficient of price elasticity of demand for eggs, Q_d is the amount of eggs consumed, ΔQ_d is the change in amount, P is the eggs price, ΔP is the change in price.

As the annual elasticity indices for each of the countries under study had some unusual deviations, the average multi-annual coefficient of price elasticity of demand for eggs was calculated using a median. When the curve of demand has a negative slope, the value of elasticity is negative. Economists agree that the further the coefficient of elasticity is from zero, the more elastic the demand is. Thus, in this article, the absolute size of elasticity was used. The significance for this study was chosen at 5 % level.

To demonstrate the results clearly, the graphs below were used. Our conclusions were offered using the method of generalization.

Results and discussion

Tendencies of price and consumption

The review of literature has shown that scientific research about price elasticity of demand for victuals is abundant. Price elasticity of the demand for individual victuals, however, was little researched in Lithuania and Ukraine. Theoretically, it is plausible that demand for eggs in both countries is price inelastic, yet indicators of elasticity had not been calculated in recent years. This work used the indicators of retail price and consumption of eggs in Lithuania and Ukraine. To avoid the derogations due to big seasonal fluctuations (which are especially relevant to egg price), and to avoid distortions (which could be produced during a short period of investigation when the users adapt to new conditions), annual indicators were taken and the period of 16 years was chosen.

Statistical data [18] indicates that the retail price of eggs in Lithuania in 2003–2018 increased by 1,9 times on average (Figure 1). The highest price recorded during this period was greater than the lowest by more than 3 times.

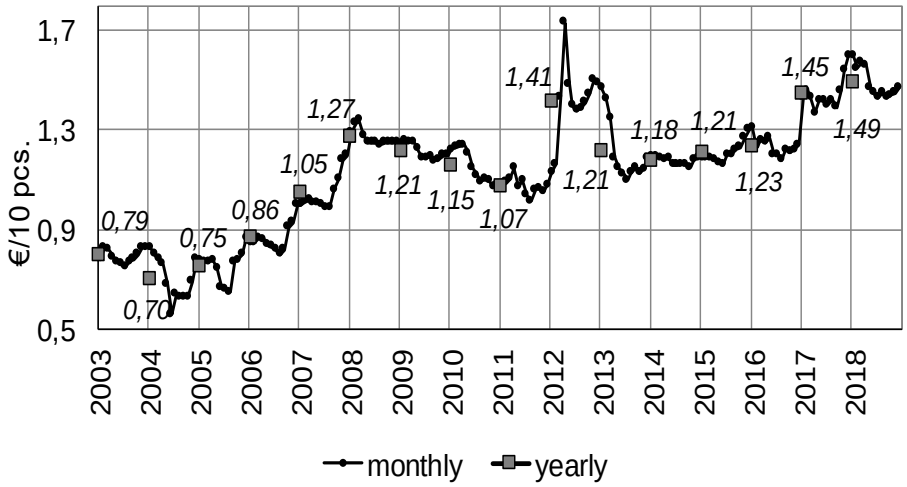

Figure 1. Retail price of eggs in Lithuania in 2003–2018

In Lithuania in 2003–2018, the retail price of eggs grew in three stages. The first began in 2004 and continued until 2008. Over three years and nine months, the price increased by 2,4 times. Then, the retail price of eggs decreased for several years. In August 2011, it reached its lowest level at almost 24 per cent below March 2008. Straight after that, however, the second, rapid, stage of increasing prices began. Over eight months, the retail price of eggs in Lithuania increased by more than 1,7 times. These changes in the retail price of eggs were not unexpected. The reasons for this growth were twofold. First, the price increased (just as every year) due to seasonality. The other reason was the change made by the European Union to its requirements for the keeping of laying hens, starting in 2012. The latter condition had the biggest influence on the unusual increase in price. Finally, in 2012, after Easter, the retail price of eggs in Lithuania decreased; yet it was higher than in the corresponding period of previous years. On average in 2012, the retail price of eggs was higher by almost a third than in 2011 and exceeded by more than a tenth its previous high point in 2008. In 2013 the retail price of eggs decreased until July. Later, there came a gradual growth in price that continued until the beginning of 2018. Then, over four years and seven months, the retail price of eggs increased by 45 per cent.

During the period under investigation, 2003–2018, the annual consumption of eggs per capita in Lithuania increased by 33 per cent (Figure 2) [21].

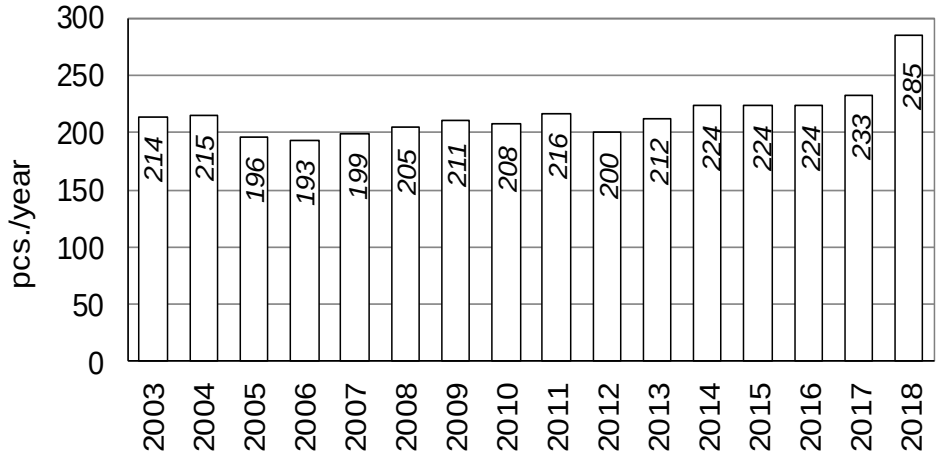

Figure 2. Consumption of eggs per capita in Lithuania in 2003–2018

A more detailed analysis reveals that each change in the price of eggs exerted only a brief influence. When the price increased or decreased, the demand for eggs was deflected to the opposite side. Yet when consumers got used to the changes in price, the demand for eggs would subsequently begin to grow.

In 2005 and 2006 the price of eggs in comparison to the previous year increased 7 per cent and 15 per cent. At that time, demand decreased by 9 and 2 per cent. Later, the price grew further; when users did not find suitable substitutes for eggs - despite their growing price - their demand also grew until it reached a level similar to that prevailing before the growth in price. A similar sequence occurred in 2012. When price grew by 32 per cent, the consumption of eggs in Lithuania decreased by 7 per cent.

Retail price of eggs in Ukraine in 2003–2018 was on average 16 per cent lower than in Lithuania (Figure 3) [17, 19, 20].

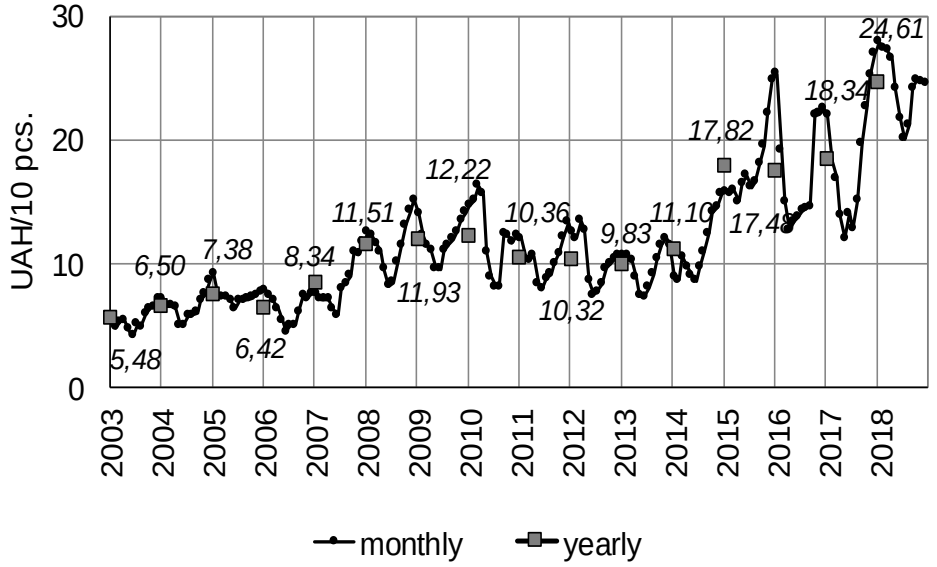

Figure 3. Retail price of eggs in Ukraine in 2003–2018

In Ukraine the retail price of eggs was marked by clearer seasonal fluctuations than in Lithuania. During the period under investigation, the difference of retail price of eggs in the summer-winter season was 17 per cent in Lithuania, then in Ukraine this indicator was as much as 63 per cent.

In 2003–2018 the retail price of eggs in Ukraine, just as in Lithuania, grew, but by significantly more, 4,5 times. The difference between the lowest and the highest price in this period was on 6,7 times.

In Ukraine, in 2003–2018, the retail price of eggs grew in two stages. The first continued from the middle of 2003 until the beginning of 2010. Then, over six years and ten months the price increased by 3,9 times. Later, the retail price of eggs decreased for several years. In June of 2013, it reached its lowest level, 2,2 times below March 2010. Then, the second stage of price growth began, which lasted until the beginning of 2018. Retail price of eggs in Ukraine grew by more than 3,8 times over four years and eight months. In comparison to Lithuania, all the fluctuations in egg price in Ukraine were markedly higher. In Ukraine they were influenced by seasonal fluctuations, global egg price tendencies and inflation in the country.

During the period under investigation in 2003–2018, the annual consumption of eggs per capita increased by 28 per cent (Figure 2) [15]. But the biggest leap in consumption in comparison to 2003 happened in 2011 and 2014, when it was 45 per cent. After 2014 somewhat fewer eggs were used in the country.

Figure 4. Consumption of eggs per capita in Ukraine in 2003–2018

In Ukraine, just as in Lithuania, the consumption of eggs depends little on trends in price. In this country in 2003–2010 when the retail price of eggs increased, the consumption of these products simply increased. Somewhat fewer eggs were used in Ukraine just after 2014, when the price of the eggs was to increase significantly over a relatively short time. In Lithuania, a similar situation took place in 2012. Yet experience was to show that the consumption of eggs would quickly return to previous level. Therefore, it is plausible that in Ukraine, too, the consumption of these products will go back to the level of 2011–2014.

Price elasticity of demand

These changes in the consumption of eggs and in their retail prices allows one to suppose that in both Lithuania and Ukraine, just as in those countries where the above-mentioned scientists conducted their research, there was a price inelasticity of demand for eggs. To confirm such a hypothesis, calculations based on statistical data were conducted, based on the formula shown above. They showed that, in the long term, and in both countries, the demand for eggs is price inelastic and statistically significant ($p = 0,00 < 0,05$).

The results obtained show that, in spite of the fact that the indicator of elasticity in the course of separate years fluctuated from one side to the other, the multiannual tendency in Lithuania was, the demand for eggs to be relatively price inelastic (0,28). Its inelasticity level was similar to that in the case of the USA (0,27), where scientists examined the experience of almost 70 years [1]. In Ukraine price elasticity of the demand for eggs in 2003–2018 was just a little higher (0,35) than in Lithuania. Yet in this country the demand for eggs was price inelastic too.

The results allow us to suppose that, despite changes in the price of eggs, their consumption, taking the long view, would not be significantly altered unless other conditions were also to change. The situation could be changed by innovations in science and the food industry, which would allow other nutritional products for humans to be substituted for eggs. There are scarcely any natural substitutes for eggs and, at this point, the various mixtures consisting of several elements of vegetable or animal origin cannot be substituted for eggs.

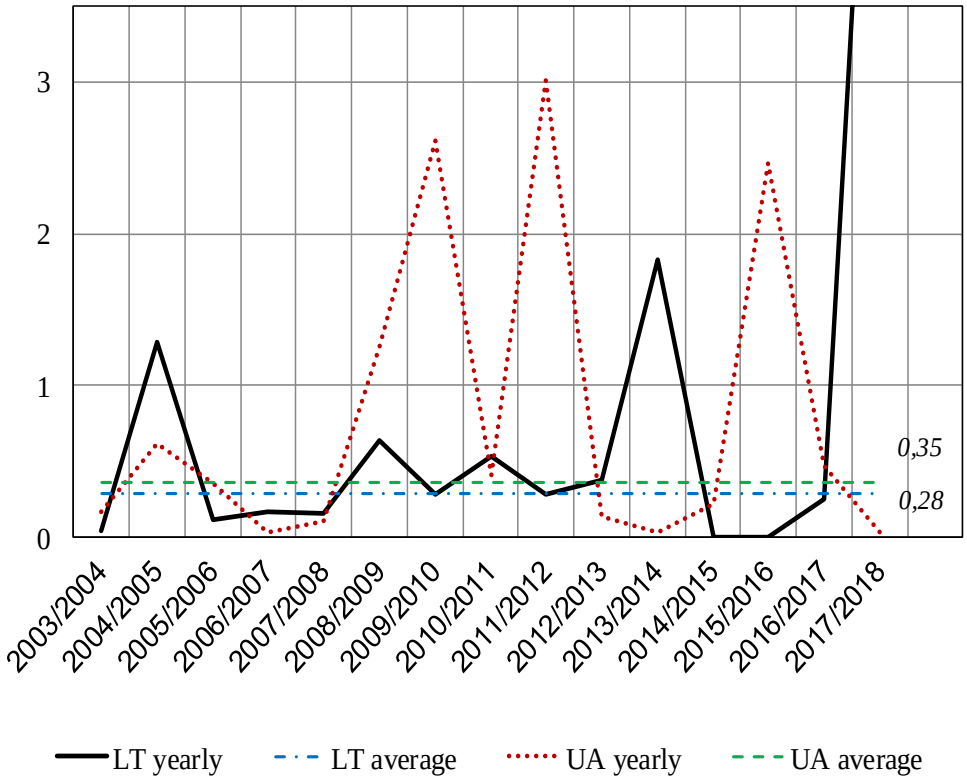

Figure 5. Price elasticity of demand for eggs in Lithuania and Ukraine in 2003–2018

There are no studys that provides consistent observation of price elasticity of demand for food in the Lithuania and Ukraine. This study set out to address this gap by estimating price elasticity of demand for egg. The results obtained here are recommended for the use of manufacturers. If producer want successfully compete on a market, he have to have relevant information. Talking about marketing, it is impossible to conduct an effective policy, to plan production and other processes without exact knowledge about the demand for the product ant its determinants. The price elasticity of demand is the most important thing that a producer should know. Knowledge of elasticities allow to gain a sense of how markets and the consumers react to price changes. It allow producers to make the most effective production, pricing and advertising decisions targeting either sales or profit magnification.

The results might also be useful to the government sector in making various decisions, carrying out calculations and forecasting. To increase the efficiency of the tax system, tax authorities should know price elasticity for each product and service in the market, also regularly estimate elasticity after the change of consumer priority or after the new products entreance in the market, because they can affect elasticity of demand for existing products.

Knowledge of price elasticity of demand for food allow the government sector to estimate the market conditions, to make informed decisions in the context of food assistance programmes, to ensure that the vulnerable segments of the population have access to food and which food stuff to target in food aid programmes.

Alas, price elasticity of demand for eggs is not favourable to consumers. They are, however, the ones whose actions produce the phenomenon; therefore, by being better informed and by showing more initiative, consumers could change the situation to their own advantage by always searching out new substitutes for eggs.

The regular need for knowledge of the price elasticity of demand suggests that periodic calculations of this indicator should be carried out in the future, not only for eggs but also for all other important food products. This information could be used by both the private and public sectors to make important decisions.

Conclusion

While analysing the retail price of eggs in Lithuania, it was established that over the period 2003–2018 it increased by 1,9 times. This growth in price occurred in several stages. From 2004 to 2008, the retail price of eggs increased by 2,4 times. After a small decrease in 2011–2012, a rapid and significant second leap in price occurred; over eight months the price increased more than 70 per cent. After a period of decreasing prices in 2013, the third growth period in the retail price of eggs began. It went on until 2018 and during that period the price increased by 45 per cent.

In Ukraine the retail price of eggs during the period under investigation was lower than in Lithuania; nevertheless, the fluctuations were more pronounced. In 2003–2018, the retail price of eggs increased by 4,5 times. This growth of price happened in several stages. In 2003–2010, the retail price of eggs increased by 3,9 times. Until the middle of 2013, a decrease in price ensued, and later the second stage of price growth began, which continued until 2018. During that period, retail price grew by 3,8 times.

The analysis of egg demand in Lithuania and Ukraine shows that consumers reacted to changes in price for just a short time. When the price grew, consumption of eggs was to decrease somewhat, but, despite the fact that the price was then to grow further, consumption would return to the previous level.

Using data for price and consumption over 16 years, the coefficients of price elasticity of demand for eggs in Lithuania and Ukraine were calculated. These calculations showed that demand for eggs in both countries was price inelastic. The average coefficient of elasticity during the period under investigation in Lithuania was 0,28 and in Ukraine it was 0,35.

The results obtained here are recommended for use by the production and government sectors in planning their activities and in forecasting future results. Consumers who want to change the situation into one more favourable to themselves, should find substitutes for eggs.

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Impact of insurance and inflation on economic growth and food market security

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Abstract

Introduction. The objective of this research is to investigate the impact of insurance and inflation on economic growth and food market security. Altogether, the most crucial task of this paper is related to estimation the interconnection between consumer prices, total gross insurance premiums and gross domestic product, food exports and food imports.

Materials and methods. The research model was developed by reviewing the previous studies and applying the correlation-regression analysis for defining the impact of insurance and inflation on economic growth and food market security. Thus, it was calculated the coefficient of pair correlation or Pearson correlation coefficient (r) and coefficient of determination (r^2), Significance **F**, as whole, **P**-value for regression coefficient and one-factor regression equations that have a liner form.

Results and discussion. The research findings of this study indicate that by the level of relationship and by statistical significance of impact of insurance and inflation on economic growth and food market security all our 17 research countries were divided into four groups. Group 1 – strong uphill (downhill) linear relationship where coefficient $0.700 \leq \mathbf{r} < 0.900$ ($-0.900 < \mathbf{r} \leq -0.700$). For example, this type of interconnection describes the impact of inflation on gross domestic product in Turkey, Italy, Spain and Denmark; or impact of insurance on food export in Australia, Iceland, Netherlands, France, Turkey and Belgium. Group 2 – a moderate uphill (downhill) relationship where $0.500 \leq \mathbf{r} < 0.700$ ($-0.700 < \mathbf{r} \leq -0.500$). For instance, this type of interconnection indicates the impact of inflation on food export in France and Turkey; or impact of insurance on food import in France, Switzerland, United Kingdom, Netherlands and Spain. Group 3 – a weak uphill (downhill) linear relationship where $0.300 \leq \mathbf{r} < 0.500$ ($-0.500 < \mathbf{r} \leq -0.300$). For example, this type of interconnection describes the impact of inflation on food import in Denmark, France, Finland, Turkey, Switzerland and Belgium; or impact of insurance on food import in Australia, Finland, Japan and Denmark. Group 4 – no linear relationship: $0.000 \leq \mathbf{r} < 0.300$ ($-0.300 < \mathbf{r} \leq 0.000$). It indicates the impact of insurance and inflation on economic growth and food market security in all other countries and cases except as described groups 1, 2, and 3.

Conclusions. Our paper has provided new evidence of impact of insurance and inflation on economic growth and food market security which could help to increase regulation approaches for financial market and food market security in the world level.

Introduction

The economic growth and food market security is one of the key points of the national development of countries. In addition, currently a lot of factors influence these indicators, and that's why it is important to understand the nature of its. In our research study we focus on the inflation and insurance as the factor variables and gross domestic product (GDP) and food export and import as target functions (dependent variables).

The critical literature review of foreign experience shows that insurance has significant effect on food market security. According to Isaboke et al. (2016) it was analyzed the impact of weather index based micro-insurance on food security status of smallholders. These study results show the positive effect of index insurance on food security [1]. In addition, Mârzaa et al. (2015) argued that insurance alone cannot provide food security [2]. Furthermore, based on the Agricultural Insurance Conference (2014) agricultural insurance should be seen as one component of the ACS and it is related to food security [3]. Altogether, the effect of agricultural insurance scheme on agricultural production in Ondo state (Nigeria) was studied by Akinrinola O.O. and Okunola A.M. (2014). The results show that there may be an increase in the level of investment of farms after participating in insurance [4].

In general, Kim Y., Pendell D.L. and Yu J. (2018) suggest that one of the key study points of the influence of insurance on food market security were focused on the effects of crop insurance on farm disinvestment and exit decisions [5]; besides, according to Zhao Y. and Preckel P. (2016) an empirical analysis of the effect of crop insurance on farmers' income [6]; the effects of subsidized crop insurance on crop choices [7]; risk management in the ACS with special attention to insurance [8; 9].

It was also analyzed the literature review on the interconnection between insurance and economic growth. Outreville (2011) noted that influence of the insurance on the macroeconomic activity can be described from two viewpoints as follows: first, in providing indemnification; and, second, its role as an institutional investor [10]. In addition, according to Njegomir & Stojić (2010), Stojaković & Jeremić (2016) and others the positive impact of life insurance on economic growth can be based on the effects of financial stability, competitiveness of trade and commerce, increases liquidity [11–15]; the loss reduction [16]; increasing of new capital [10; 17]; risk management and financial management [18-20].

Furthermore, based on the research results of Nwani & Omankhanlen (2019), Pradhan et al. (2017), Satrovic (2019) it was found that the life premium was positively insignificant to economic growth and the non-life premium – negatively, while the insurance investment – positively [15; 21; 22]. However, Pradhan et al. (2017) noted that in the long run, insurance have had a significant impact on the economic growth, and in the short term – the inter-relationships differ by countries [22].

Studying the factors of food inflation Qayyum and Sultana (2018) analyzed the GDP, food exports, food imports, taxes and money supply as the independent determinants. As a result of this research it was recommended that special attention has to be paid on food exports and food imports along with excess money supply [23]. Also, according to Islam (2013), there is a positive correlation between domestic inflation and import [24]. In addition, Muktadir-Al-Mukit D., Shafiullah A.Z.M. and Ahmed R. (2013) noted that there is a a stable, positive and significant relationship between inflation and import [25]. Besides, significant research results about the analysis of relationship between import, export and inflation were obtained by Kiganda, Obange and Adhiambo (2017), Ahmed, Ghauri, Vveinhardt, Streimikiene (2018), which studied the cases of Kenya [26] and Pakistan [27]. Furthermore, in the worldwide level, food market security, food prices or food inflation was studied by Gazdar and Mallah (2013), Løvendal, Jakobsen and Jacque (2007), Huppé, Shaw, Dion,

Voora (2013). It was presented their research results of a qualitative study of food security among rural and urban households to better understand the perceptions, behavior etc. [28]; the development of retail food prices, its causes, the potential impact thereof in terms of food security [29]; the assessment of Morocco's food security strategy and trade policy and important detailed analysis in the context of the current global economic situation [30].

Next significant part of our research describes the impact of inflation on economic growth. The critical literature review shows a lot of world recognized scientists has used different approaches and has obtained its own evidence base conclusions. Mukoka (2018) has argued that controlling the rise in the overall price level is necessary but not necessary for the Zimbabwean economy. This study based on the Dickie Fuller Test (ADF), cointegration analysis, Jacques-Behr test. The hypothesis underpinning this research is that inflation is negatively related to the economic surge [31].

Another significant result studying the influence of inflation on economic growth were obtained by Švigir and Miloš (2017). The group of scientists deals with the assessment of the impact of rising prices on the economy through an imperial analysis. It was analyzed the data collected cover more than 100 countries from 1960 to 1990. A system of regression equations was used to analyze the impact of inflation on economic recovery [32]. In addition, according by Ruzima and Veerachamy (2016) the theoretical and empirical studies of the effects of inflation on economic growth were examined. The results stated that there is no consensus on the relationship between inflation and economic growth in both theoretical and empirical studies [33].

Furthermore, Mishchenko et al. (2018) has studied the impact of inflation on economic growth and argued the main directions of increasing the effectiveness of central bank anti-inflation policy. It was concluded that rising inflation significantly slows down economic growth [34]. Akinsola & Odhiambo (2017) states that impact of inflation on economic recovery varies by country, and negatively correlated, most notably in advanced economies [35].

Materials and methods

Materials

The source of the statistical data for the research study was the information materials based on the World Bank Open Data (gross domestic product (GDP), inflation (consumer prices), food export, food import) [36] and OECD Insurance Statistics (total gross insurance premiums by countries) [37]

Studying the role and impact of the insurance and inflation on economic growth and food market security more than 100 articles and research papers were analyzed from the Google Scholar, ResearchGate, ScienceDirect, Academia.edu and other resources with various permutations of the following keywords: "food security", "market", "inflation", "insurance", "food export", "food import". The results of literature review show that more than forty research studies most directly associated with the influence of insurance and inflation on economic growth and food market security. This list of publications was the theoretical background for this research study.

Methods

Key research indicators

The analysis of the impact of insurance and inflation on economic growth and food market security was performed based on the economic indicator as follows:

1) inflation, consumer prices (annual %);
2) total gross insurance premiums (US Dollar, billions);
3) GDP – gross domestic product (US Dollar, billions);
4) food exports (% of merchandise exports);
5) food imports (% of merchandise imports).

In this list the indicators number 4 and 5 are indexes of food market security because they explain of merchandise export and imports structure. And these circumstances are very important for providing the food market security in every country.

These research indicators were collected and processed for the study period 1960-2018 for the following 17 countries: Australia, Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Spain, Turkey, Switzerland and United Kingdom (UK).

Correlation-regression analysis

The study of the relationship and interconnection between the insurance, inflation, economic growth and food market security was performed based on the coefficient of pair correlation or Pearson correlation coefficient (r) and coefficient of determination (r^2).

The assessment of the impact of insurance and inflation on economic growth and food market security was conducted based on the correlation-regression analysis according to the available data. The regression equations are used in linear type (one-factor and multivariate regression equations). This economic-statistical analysis was conducted using the Microsoft Office software packages. For this analysis we determined three target research functions Y_1, Y_2, Y_3; and two factor variables X_1 and X_2 (table 1).

Table 1

Macroeconomic target functions and factors for the regression analysis

Marking	Explanation	Unit of measure
Target functions Y_n (Y_1, Y_2, Y_3)		
Y_1	**GDP** (Gross domestic product)	US Dollar, billions
Y_2	**EX** (Food exports)	% of merchandise exports
Y_3	**IM** (Food import)	% of merchandise import
Factor variables X_n (X_1, X_2)		
X_1	**INF** (Inflation, consumer prices)	annual %
X_2	**INP** (Total gross insurance premiums)	US Dollar, billions

Source: Elaboration of authors.

According to the research procedure, for each correlation-regression dependence it is planned to calculate Pearson correlation coefficient (**r**), determination coefficient (**r^2**), Significance **F** for regression equations as whole (Sign. **F**), **P**-value for Y_0 and one-factor regression equations that have a liner form:

$$Y_n = Y_0 + f(X_n) = Y_0 + a_n X_n \quad (1)$$

where Y_0 is the free coefficient; a_n, is correlation coefficient. In addition, based on the Significance **F** for regression (Sign. **F**) and **P**-value for Y_0 we can describe the significance of each correlation-regression dependence. For example, when **P**-value is less than 5.0% (0.05) – the coefficient is statistically significant (reliability = 95%). In this case we can include this indicator in regression model. But when **P**-value is greater than 5.0% (0.05) – the coefficient is statistically insignificant with a reliability of 95% – here it doesn't allow to include Y_0 in regression equations [38]. In the same way we can characterize the values of Significance **F** for regression model.

Results and discussion

Ranking of countries

Based on the Pearson correlation coefficient (**r**) we have ranked all 17 countries in four groups by statistical significance of impact of insurance and inflation on economic growth and food market security. Thus, these groups are listed below:

Group 1, where between target functions Y_n (Y_1, Y_2, Y_3) and factor variables X_n (X_1, X_2) there is a strong uphill (downhill) linear relationship because here we have $0.700 \leq \mathbf{r} < 0.900$ ($-0.900 < \mathbf{r} \leq -0.700$). These calculations are presented in *Table 2*;

Group 2 – a moderate uphill (downhill) relationship (*Table 3*), where Pearson correlation coefficient $0.500 \leq \mathbf{r} < 0.700$ ($-0.700 < \mathbf{r} \leq -0.500$);

Group 3 – a weak uphill (downhill) linear relationship (*Table 4*), where correlation coefficient $0.300 \leq \mathbf{r} < 0.500$ ($-0.500 < \mathbf{r} \leq -0.300$);

Group 4 – no linear relationship: $0.000 \leq \mathbf{r} < 0.300$ ($-0.300 < \mathbf{r} \leq 0.000$). It is related to the all our countries and cases of relationships except as described in Tables 2, 3 and 4. Also, it is important to notice that there is not any cases of relationship between target functions and factor variables where we have a perfect uphill (downhill) linear relationship: $0.900 \leq \mathbf{r} \leq 1.000$ ($-1.000 \leq \mathbf{r} \leq -0.900$).

Our analysis starts with a presentation of correlation-regression statistics the estimates the impact of inflation and insurance on economic growth and food market security. Thus, Table 2 describes the list of top-countries where correlation coefficients show the a strong uphill (downhill) linear relationship between these economic indicators. In addition, based on the values of Pearson correlation coefficient (**r**) almost in every case we can see the downhill linear relationship, because $-0.900 < \mathbf{r} \leq -0.700$. It shows the inversely proportional dependence between the inflation, insurance and economic growth and food market security. Here, we have only two exceptions of directly proportional relationship as follows: interconnection between inflation and food exports (% of merchandise exports) in Denmark where $\mathbf{r} = 0.707$; and between total gross insurance premiums and food import (% of merchandise import): $\mathbf{r} = 0.757$.

Looking at Table 3 figures, we can see a list of countries where the interconnection between insurance, inflation and economic growth and food market security has a moderate uphill (downhill) linear relationship because of where Pearson correlation coefficient $0.500 \leq \mathbf{r} < 0.700$ ($-0.700 < \mathbf{r} \leq -0.500$).

Table 2

List of countries where inflation (X_1) and insurance (X_2) have a strong uphill (downhill) linear relationship with economic growth (Y_1) and food market security (Y_2, Y_3)

Country	r	r^2	Regression equations	Sign. F	P-value for Y_0
Impact of X_1 on Y_1					
Turkey	-0.778	0.605	724.872-8.083·$\mathbf{X_1}$	0.000	0.000
Italy	-0.763	0.582	1990.885-142.363·$\mathbf{X_1}$	0.000	0.000
Spain	-0.740	0.548	1300.874-113.453·$\mathbf{X_1}$	0.000	0.000
Denmark	-0.706	0.498	265.547-23.471·$\mathbf{X_1}$	0.000	0.000
Impact of X_1 on Y_2					
Portugal	-0.737	0.543	9.348-0.033·$\mathbf{X_1}$	0.535	0.000
Denmark	0.707	0.500	19.414+1.669·$\mathbf{X_1}$	0.000	0.000
The impact of X_1 on Y_3 – no this type of linear relationship					
Impact of X_2 on Y_2					
Australia	-0.896	0.803	26.844-0.167·$\mathbf{X_2}$	0.000	0.000
Iceland	-0.760	0.578	86.270-77.309·$\mathbf{X_2}$	0.000	0.000
Netherlands	-0.737	0.543	21.464-0.109·$\mathbf{X_2}$	0.000	0.000
France	-0.732	0.536	16.066-0.015·$\mathbf{X_2}$	0.000	0.000
Turkey	-0.723	0.523	22.660-1.176·$\mathbf{X_2}$	0.000	0.000
Belgium	-0.720	0.518	10.631-0.045·$\mathbf{X_2}$	0.000	0.000
Impact of X_2 on Y_3					
Belgium	-0.865	0.748	11.752-0.088·$\mathbf{X_2}$	0.000	0.000
Germany	-0.829	0.687	12.188-0.016·$\mathbf{X_2}$	0.000	0.000
Italy	-0.760	0.578	13.328-0.025·$\mathbf{X_2}$	0.000	0.000
Norway	0.757	0.573	5.970+0.114·$\mathbf{X_2}$	0.000	0.000

The correlation-regression results in Table 3 indicate, that a moderate downhill linear relationship is related to almost every case of interconnection between X_n and Y_n. Its conditions display the inversely proportional dependence ($-0.700 < \mathbf{r} \leq -0.500$) between the inflation (consumer prices), insurance (total gross insurance premiums) and economic growth (gross domestic product) and food market security (food exports – % of merchandise exports; food import) – % of merchandise import).

Table 4 shows the number and list of countries where inflation and total gross insurance premiums have a weak uphill (downhill) linear relationship with GDP and food market security indicators (food exports and food import).

Consequently, a weak uphill (downhill) linear relationship between inflation, insurance and economic growth and food market security indicators is associated to the list of countries in Table 4. Besides, correlation-regression statistics indicate a week directly ($0.300 \leq \mathbf{r} < 0.500$) and inversely ($-0.500 < \mathbf{r} \leq -0.300$) proportional dependence between X_n and Y_n values.

Furthermore, the research results indicate group 4, that includes list of countries where inflation (X_1) and insurance (X_2) have not linear relationship (negligible correlation) with economic growth (Y_1) and food market security (Y_2, Y_3) and meets the following criteria: $0.000 \leq \mathbf{r} < 0.300$ ($-0.300 < \mathbf{r} \leq 0.000$).

Table 3

List of countries where inflation (X_1) and insurance (X_2) have a moderate uphill (downhill) linear relationship with economic growth (Y_1) and food market security (Y_2, Y_3)

Country	r	r^2	Regression equations	Sign. F	P-value for Y_0
Impact of X_1 on Y_1					
France	-0.632	0.399	1910.309-157.911·$\mathbf{X_1}$	0.000	0.000
Switzerland	-0.607	0.368	492.251-73.822·$\mathbf{X_1}$	0.000	0.000
UK	-0.550	0.303	2641.153-252.696·$\mathbf{X_1}$	0.001	0.000
Japan	-0.529	0.280	4589.123-566.657·$\mathbf{X_1}$	0.001	0.000
Finland	-0.519	0.269	181.728-13.506·$\mathbf{X_1}$	0.000	0.000
Portugal	-0.514	0.264	200.732-8.830·$\mathbf{X_1}$	0.000	0.000
Impact of X_1 on Y_2					
France	0.604	0.365	13.014+0.357·$\mathbf{X_1}$	0.000	0.000
Turkey	0.559	0.312	11.337+0.140·$\mathbf{X_1}$	0.000	0.000
Impact of X_1 on Y_3					
Italy	0.676	0.457	9.466+0.445·$\mathbf{X_1}$	0.000	0.000
Ireland	-0.637	0.406	10.178-0.033·$\mathbf{X_1}$	0.803	0.000
Portugal	-0.577	0.333	13.133+0.042·$\mathbf{X_1}$	0.250	0.000
UK	0.506	0.256	8.700+0.333·$\mathbf{X_1}$	0.002	0.000
Impact of X_2 on Y_2					
UK	-0.674	0.454	7.488-0.004·$\mathbf{X_2}$	0.000	0.000
Switzerland	0.615	0.378	2.454+0.017·$\mathbf{X_2}$	0.000	0.000
Italy	0.608	0.370	6.337+0.009·$\mathbf{X_2}$	0.000	0.000
Impact of X_2 on Y_3					
France	-0.682	0.465	11.001-0.008·$\mathbf{X_2}$	0.000	0.000
Switzerland	-0.682	0.465	7.528-0.028·$\mathbf{X_2}$	0.000	0.000
UK	-0.670	0.449	10.910-0.005·$\mathbf{X_2}$	0.000	0.000
Netherlands	-0.577	0.333	14.810-0.061·$\mathbf{X_2}$	0.000	0.000
Spain	-0.512	0.262	12.106-0.023·$\mathbf{X_2}$	0.001	0.000

Thus, it was found that negligible correlation (not linear relationship) is associated with following interconnection between Y_n and X_n for research countries:

1. Interconnection between inflation or consumer prices (X_1) and gross domestic product (Y_1) in Germany, Ireland and Netherlands;
2. Interconnection between inflation or consumer prices (X_1) and food exports (Y_2) in Iceland, Japan, Norway, Belgium, Germany, Netherlands, Ireland and Spain;
3. Interconnection between inflation or consumer prices (X_1) and food import (Y_3) in Norway, Spain, Japan, Germany, Australia, Netherlands and Iceland;
4. Interconnection between insurance or total gross insurance premiums (X_2) and food exports (Y_2) in Finland, Spain, Germany and Norway;
5. Interconnection between insurance or total gross insurance premiums (X_2) and food import (Y_3) in Ireland, Iceland, Turkey and Portugal.

Table 4

List of countries where inflation (X_1) and insurance (X_2) have a weak uphill (downhill) linear relationship with economic growth (Y_1) and food market security (Y_2, Y_3)

Country	r		Regression equations	Sign. F	P-value for Y_0
Impact of X_1 on Y_1					
Iceland	-0.475	0.226	13.234-0.203·$\mathbf{X_1}$	0.000	0.000
Australia	-0.474	0.225	-39.573+16.58·$\mathbf{X_1}$	0.000	0.000
Belgium	-0.400	0.160	338.361-32.52·$\mathbf{X_1}$	0.000	0.000
Norway	-0.365	0.133	381.487-42.74·$\mathbf{X_1}$	0.043	0.000
Impact of X_1 on Y_2					
UK	0.425	0.181	5.863+0.220·$\mathbf{X_1}$	0.012	0.000
Australia	0.399	0.159	20.381+0.963·$\mathbf{X_1}$	0.001	0.000
Italy	-0.381	0.145	7.501-0.108·$\mathbf{X_1}$	0.022	0.000
Switzerland	-0.362	0.131	3.325-0.116·$\mathbf{X_1}$	0.030	0.000
Finland	0.336	0.113	2.441+0.110·$\mathbf{X_1}$	0.000	0.000
Impact of X_1 on Y_3					
Denmark	-0.481	0.231	12.837-0.122·$\mathbf{X_1}$	0.001	0.000
France	0.461	0.213	10.573+0.233·$\mathbf{X_1}$	0.067	0.000
Finland	-0.460	0.212	6.887+0.113·$\mathbf{X_1}$	0.081	0.000
Turkey	0.456	0.208	4.101+0.020·$\mathbf{X_1}$	0.005	0.000
Switzerland	0.416	0.173	6.035+0.205·$\mathbf{X_1}$	0.012	0.000
Belgium	0.324	0.105	9.758+0.329·$\mathbf{X_1}$	0.000	0.000
Impact of X_2 on Y_2					
Portugal	0.445	0.198	7.727+0.156·$\mathbf{X_2}$	0.001	0.000
Japan	-0.408	0.166	0.822-0.001·$\mathbf{X_2}$	0.013	0.000
Ireland	0.403	0.162	8.279+0.028·$\mathbf{X_2}$	0.121	0.000
Denmark	-0.397	0.158	23.811-0.050·$\mathbf{X_2}$	0.020	0.000
Impact of X_2 on Y_3					
Australia	0.486	0.236	4.896+0.011·$\mathbf{X_2}$	0.003	0.000
Finland	0.451	0.203	5.350+0.149·$\mathbf{X_2}$	0.006	0.000
Japan	-0.435	0.189	16.925-0.012·$\mathbf{X_2}$	0.008	0.000
Denmark	0.401	0.226	12.269+0.009·$\mathbf{X_2}$	0.019	0.000

Comparisons with previous studies

The critical literature review of previous studies on interconnection and impact of insurance and inflation on economic growth and food market security shows that it is very important research direction and it still need more analysis and research. Comparing with previous studies it was found that Spörri, Baráth, Bokusheva and Fertö (2012) described the negative impact of insurance on economic indicators (economic profit, productivity of labor and productivity of land) [39]. According by Juan et al. (2016) it was proposed the model that counts several features of the insurance program based on the empirical parameter of

interest [40]. Ul Din et al. (2017) stated that for developed countries there is a significant relationship between life insurance, net written premiums and density [41]. Additionally, Cristeaa et al. (2014) have determined that there is a high correlation between insurance penetration, density and economic growth, measured using GDP per capita [42]. However, Wang & Li (2019) argued that development of China's foreign capital insurance market has not promoted China's economic growth [43].

The research results of the Mamo & Lin (2012) stated that inflation is negatively and significantly related to economic growth. Inflation and real GDP per capita tend to be the opposite. Therefore, inflation can be used to forecast economic growth for all the sample countries, and economic growth can also be used to forecast inflation for the two sample countries [44]. In addition, Shirinyan and Arych (2019) have studied the Impact of the insurance costs on the competitiveness of food industry enterprises of Ukraine in the context of the food market security [45]. According by Naseri & Zada (2013) was confirmed that there are negative links between inflation and economic growth in the context of Malaysia. But, applying the OLS method to annual data from 1970 to 2011, the study found a statistically significant positive relationship between inflation and Malaysia's economic growth [46].

Conclusions

This research study develops a new model by identifying the type of influence of inflation (consumer prices in annual %) and insurance (total gross insurance premiums in US Dollar) on economic growth (gross domestic product in US Dollar) and food market security (two indicators: food exports in % of merchandise exports and food import in % of merchandise import). The results indicate four groups by level of interconnection between these economic indicators as follow below.

1. A strong uphill (downhill) linear relationship that related to the following: to impact of inflation on GDP in Turkey, Italy, Spain and Denmark; to impact of inflation on food export in Portugal and Denmark; to impact of insurance on food export in Australia, Iceland, Netherlands, France, Turkey and Belgium; to impact of insurance on food import in Belgium, Germany, Italy and Norway.
2. A moderate uphill (downhill) linear relationship that related to the following: to impact of inflation on GDP in France, Switzerland, United Kingdom, Japan, Finland and Portugal; to impact of inflation on food export in France and Turkey; to impact of inflation on food import in Italy, Ireland, Portugal and United Kingdom; to impact of insurance on food export in United Kingdom, Switzerland and Italy; to impact of insurance on food import in France, Switzerland, United Kingdom, Netherlands and Spain.
3. A weak uphill (downhill) linear relationship that related to the following: to impact of inflation on GDP in Iceland, Australia, Belgium and Norway; to impact of inflation on food export in United Kingdom, Australia, Italy, Switzerland and Finland; to impact of inflation on food import in Denmark, France, Finland, Turkey, Switzerland and Belgium; to impact of insurance on food export in Portugal, Japan, Ireland and Denmark; to impact of insurance on food import in Australia, Finland, Japan and Denmark.

In addition, the fourth group include a list of all other countries in cases where between Y_n and X_n there is negligible correlation (not linear relationship).

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Analysis of consumer preferences when choosing wine

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Abstract

Introduction. The peculiarities of consumer behavior when choosing wine were investigated in current work, that had been dictated by the need to identify preferences for the implementation of effective product policy.

Materials and methods. The research is based on information of a survey conducted using the questionnaire, which consisted of two parts: the personality questions about participants, including their gender, age, income level, social status, and directly the questions about choice of a wine bottle with answer options. The conjunction tables and the $\chi 2$ criterion were used to determine statistical correlations between factor and result parameters.

Results and discussion. Taking into account the various characteristics of the wine, including its economic, technological, ampelographic components, as well as the appearance of the bottle and the beverage label, significantly influence the consumers of different social statuses. Thus, women and men with diverse family status differ in the choice of wine, given the grape variety from which it was made, while other quality characteristics of wine is not critically influential. Therefore, consumers with various income levels choose wines of different price categories, the organoleptic properties of which they consider unique. However, the price of wine and its gastronomic attributes are statistically significant for people aged from 18 to 50 that prove the difference among preferences of generations. Also women aged from 25 to 35 with income level higher than 200 American dollars ready to buy souvenir wine bottle.

In addition regardless of marital status, survey participants buy wines at all proposed places of sale, but ones who have higher level of income prefer wine specialized stores. However, married people largely choose wines for holidays, gastronomic pleasure or for medicinal purposes, because wine is enriched by antioxidants, vitamins and has relatively low calorie content. Respondents aged more 35 are also buy wine at the aforementioned shops or directly from the wineries, which may be related to greater experience when choosing alcoholic beverages. Most respondents choose wines whose label is simple and understandable, especially with the image of the winery, a grape cluster, because it demonstrates the production of wine, its place of origin. Moreover, most consumers prefer to add information on the label about the combination of wine with certain products and tend to buy wine, the bottle of which is standard 0,75 dm^3.

Conclusions. The criteria of choosing a wine, its quality properties and the choice of purchase place differs among consumers with different personal characteristics, which has the practical importance in order to develop the effective marketing, taking into account the preferences of the population.

Introduction

Nowadays the choice of wine for most consumers is the whole philosophy: from aesthetics to taste. After all, the modern consumer wants to buy not only the item of goods, but also a product evoking positive emotions, which depend on the taste properties of wine as well as visual images.

In recent years in Ukraine much attention has been paid to the aesthetic properties of packaging, including design and information expressiveness. This fact is related to not only with cultural development, but also with increasing of the export potential of wines to the European countries. The visual attributes form the wine brand and product sales culture: inform about a value, national and family traditions, current fashion, style trends and others.

Many scientists, including Verneau F. [1], Shane E. [2], A. Sobchak [3], O. Teletov [4], O. Ganotska [5], who had studied the factors influencing the consumer's choice of wine and determined the importance of visual perception of bottle design and expressive labels, color solutions and decoration, their influence on consumer emotions. The goal factors that mostly impact on consumer choice had been defined by researchers. Among them are the region of wine origin [6–10], the brightness of the label, brand and grape variety [11–17]. It should be noted that the trend of "competent consumer" and the role of informativeness of goods including its sufficiency, reliability and accessibility develop today. Also scientists have established the importance of demographic factors affecting the choice of consumers, specifically, age characteristics, income and employment, consumption needs [11, 13, 18-26].

The national factor and mentality cannot be ignored, as each country has its own rules and traditions for choosing wine. Aspasia Vlachwei in her work [27] has analyzed data (surveys of respondents) from different countries of the world and the main factors influencing the behavior of consumers of wines. Based on the results of the surveys, it can be stated that opinions differ significantly among countries [28–35]. In our view, this fact can be only explained by culture, traditions and national characteristics.

Taking in consideration the above, the aim of article was to determine the consumer preferences of Ukrainians lived in Odessa and to identify the main factors that influence the choice of wine.

Materials and methods

The objects of research were the peculiarities of consumer behavior when choosing wine in Ukrainian city – Odesa. Should be noted that today Odesa region possesses the biggest areas of vineyards in Ukraine that’s why the determination of consumer preferences have the practical significance for wine producers, technologists, marketers.

Methodology. The survey was attended by 61 people aged 18 to 55 (50 and more), including 18 male and 43 female lived in Odessa, Ukraine in the end of March 2020. The time of this research has been chosen not by chance to exclude other influencing factors when choosing a wine, including the nearest holidays or celebrations.

To determine the preferences of consumers when choosing a wine bottle, a questionnaire was created, which was conditionally divided into two parts: questions about gender, age, family status, and the rate of respondent wages, and directly a question regarding the choice of a wine bottle with answer variants. Factors influencing consumer wine choice and offered reasons of a wine purchase, general places of a wine buying were proposed to answer in our questionnaire. The another part of our survey consisted of questions related to design, appearance of label and forms of a wine bottle in order to determine the significant

level of its impact on consumer preferences. In order to characterize the exact consumer preference of label we offered the six different pictures of existing wine label: 1. Men on black-and-white paper; 2. Picture in the baroque style with golden lines; 3. An extraordinary label with black lines; 4. Classical wine label with winery and grapes; 5. Wine label with fillwords (Hungarian crosswords); 6. All information about wine was on packing paper.

The correlation between factor and result attributes was calculated using the conjugation tables and the $\chi 2$ criterion. Two-way ANOVA was utilized to determine influence of gender, age, family status and average wage per month on separate questions that also play role when choosing of a wine bottle.

Figures were created using Microsoft Excel, the questionnaire was developed by *Google forms*.

The average ratio of the exchange rate of 1 American dollar to the Ukrainian national currency was 27,6 Ukrainian hryvnia at the time of research conducting and article writing.

Results and discussion

General factors influencing consumer wine choice

Results of four factors including gender, age, family status and average wage per month of consumers show that they quite significantly differ towards wine choice taking into account its diverse characteristics (Table 1).

Table 1

Significance level of factors influencing consumer wine choice

Answer variants/Factors	Gender		Age		Family status		Average wage per month	
	p	$\chi 2$	*p*	$\chi 2$	*p*	$\chi 2$	*p*	$\chi 2$
Grape variety, producer country	**	10,370	n/s	4.040	**	9.993	n/s	6.423
Organoleptic properties	n/s	0.126	n/s	5.417	*	8.736	*	12.239
Aesthetic properties of the bottle design	n/s	0.146	**	11.876	n/s	2.691	n/s	1.743
Price, sales	n/s	0.329	**	37.225	**	21.763	**	15.412
Gastronomic preferences	n/s	1.792	**	17.184	n/s	3.104	n/s	6,020
Advertising	-	-	-	-	-	-	-	-

Note: n/s – not significant; * - significant at p <0,05; ** - significant at p <0,01

According to information published in previous studies [8, 11, 13] sensory properties of wine are the main factors that impact on consumer preference. Wine organoleptic attributes were counted practically equally between genders and ages of Ukrainian consumers in our study. But depending on family status and average wage per month respondents divided with significance level of p <0,05 that perhaps due to various social status, influence and inheritance of habits from other members of family. Also such

fact can be explained by no ordinary wine choices for married and unmarried people with average wage per month more than 250 American dollars. The price is substantially affected on consumer purchase [3] and proved by our observations. Significance level of p <0,01was indicted between wine price situation and age, family status and average wage per month of respondents without taking account gender.

It is remarkable that correlation between genders of different consumers towards grape variety are statistically significant (p <0, 01). In accordance with our investigations, most women buy a wine depending on the grape variety and country of production, which in turn proves that female reads the information on a wine bottle label more carefully [3]. People with various average wages per month and ages are not significantly different among themselves when they purchase wines produced from the exact grape variety or wine country that unfortunately means the low wine culture and interest for Ukrainians. The age of respondents was determined statistically significant towards the aesthetic properties of the bottle design and gastronomic preferences that is correct for none typical points of views related to shape, label colours of wine bottles, as well as pairs of wine and food between people aged from 18 to 50 and more (p <0, 01). Advertising was proposed as one of answer variants which can influence consumer wine choice. But none of survey participants chose the advertising that means wine is not popular beverage in Ukrainian community or perhaps the promotion is not needed for it.

Place of a wine purchase. Nowadays a place to buying wine plays one of main role due to improving of wine culture worldwide [17, 20]. Besides general locations people can purchase a wine at different wine festivals or trade fairs and remotely using home delivery. According to results presented in Table 2, Ukrainians shop basically in supermarkets and wine boutiques, and rarely - directly from the winery or make wine by own way.

Table 2

Significance level of factors influencing a place of a wine purchase

Answer variants /Factors	**Gender**		**Age**		**Family status**		**Average wage per month**	
	p	**χ^2**	***p***	**χ^2**	***p***	**χ^2**	***p***	**χ^2**
Supermarket	*	5,428	n/s	6,750	n/s	5,390	n/s	8,368
Wine shop, wine boutique	n/s	0,283	**	14,432	n/s	4,982	*	11,638
Directly from the winery	n/s	1,127	**	12,850	n/s	4,201	n/s	4,170
Own production	n/s	0,417	n/s	0,617	n/s	4,325	n/s	5,621

Note: n/s – not significant; * - significant at p <0,05; ** - significant at p <0,01

The proposed answer variants were detected unimportant for respondents with different family status. But such factor as average wage per month of consumers influence choice of a wine place namely wine specialized shops and boutiques that can be explained by various rates of wages and willingness to buy a wine with different price categories. Also the correlation between survey participants with various ages and abovementioned wine places were indicated significant clarifying human education and perhaps experience in a wine choice likewise buying of wine directly from the winery. Based on previous research [20], women may shop spontaneously and men purposefully procure goods in supermarkets that obtained results were showed.

Factors influencing offered reasons of a wine purchase

Noteworthy is that the antecedent analysis identified no significance between people with different family status and their choice of a wine place of purchase, but in accordance with Table 3 this factor influences reasons of a wine purchase. It appears probable that family traditions and holidays, as well as feast are the reasons to buy a wine for people with different civil status [27]. Also consumers aged from 18 to 50 differed in case of a wine purchase for holidays and respondents with diverse rates of wages – for gastronomic pleasure. No significance was detected between participants of different gender when they buy a wine according to proposed reasons.

Table 3

Significance level of factors influencing offered reasons of a wine purchase

Answer variants /Factors	Gender		Age		Family status		Average wage per month	
	p	$\chi 2$	*p*	$\chi 2$	*p*	$\chi 2$	*p*	$\chi 2$
Gastronomic pleasure	n/s	1.641	n/s	3.438	*	7.579	**	16.716
Holidays	n/s	0.212	**	13.195	**	9.556	n/s	3.741
Therapeutic goals	n/s	0,240	n/s	3.998	*	6.456	n/s	2,019
No matter	n/s	0,116	n/s	2,573	n/s	4,020	n/s	3,554

Note: n/s – not significant; * - significant at p <0,05; ** - significant at p <0,01

Results of ANOVA analysis proved that people of different gender, age and average wage per month are differentiated towards a wine buying taking into account its label (table 4).

Table 4

Significance of a wine label

Answer variants /Factors	Gender	Age	Family status	Average wage per month
Buying a wine I read its label	*	*	n/s	*

Note: n/s – not significant; * - significant at p <0,05; ** - significant at p <0,01

Among the proposed answers in the questionnaire, most respondents chose the answer that they always read the information on a wine label, but especially women aged 25-35 are more attentive to the text. Moreover, people who earn more than 280 American dollars choose a wine according to label and also require consistency between quality of wine and its price. Most people between the ages of 18 and 25 years old were found who never or rarely read the information on the wine label which indicates non-acquaintance of wine culture. Family status of respondents was determined insignificant in the context of a label reading.

Label design

Consumers were proposed to answer which label design they prefer [36, 37]. Based on Figure 1, survey participants ready to buy a wine with light label design which is understandable and clear for them. However, the second big percent of answers was defined belonged to group who has never thought about it, meaning a label design is not remarkable.

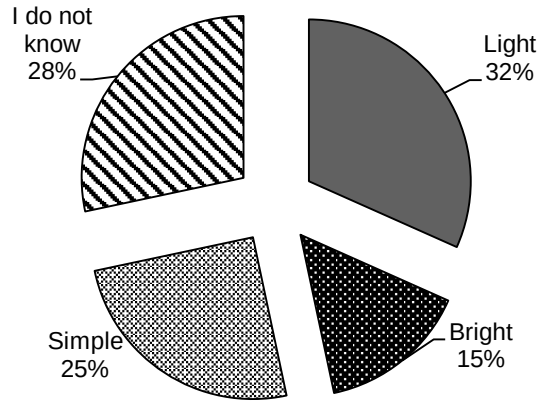

Figure 1. Consumer preference on label design

Analysis of label pictures acknowledged that the most of respondents would rather a simple label with image of winery and grapes. Such fact may also explain subconscious choice of consumers when they see things associable with wine [15]. The labels which illustrated men on black-and-white paper, picture in the baroque style with golden lines and one where all information about wine has been written on packing paper were chosen by the same number of survey participants. The label pictures with fillwords (Hungarian crosswords) and black lines obtained the lowest percent of choice – 5 and 2 % of total number of interviewed that perhaps demonstrates about consumer mind towards uselessness of an unusual label design for a quality wine.

Evaluating the label influence on wine choice included the question about adding of other information to the existing one on the label. 59 % of respondents were unanimous in adding of information on the combination of wine with various products. Therefore, consumers were interested in processes of wine technology and indicators forming the wine price. Honest wine composition was written by 2 respondents of survey on line «Add your answer» that can be sign of their incredulity regarding winemaking.

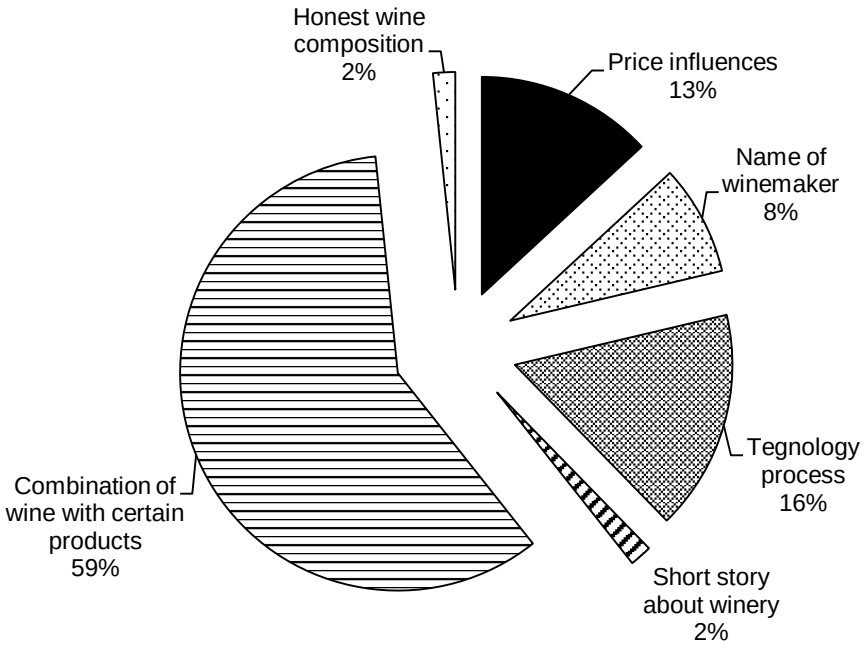

Figure 2. Consumer desired information to add

Wine bottle

Souvenir wine bottle can be present for any celebrating and thing of art. For this reason, many wine producers present the own alcoholic beverages bottling in untypical tares [30, 31]. According to data in table 5, correlation between age and family status of consumers and their readiness to buy souvenir wine bottle were not identified significant. But gender of respondents and their average wage per month showed discrepancy among its groups. It is no wonder that most women choose souvenir bottles who have average wage per month of 200–300 American dollars.

Table 5

Significance of a wine bottle

Answer variants /Factors	**Gender**	**Age**	**Family status**	**Average wage per month**
Ready to buy souvenir wine bottle	*	n/s	n/s	*

Note: n/s – not significant; * - significant at p <0,05; ** - significant at p <0,01

71 % of Ukrainian who took part in our questionnaire preferred the typical volume of wine bottle – 0, 75 dm^3, 18 and 15 % – 0, 5 and 1 dm^3 respectively (Figure 3).

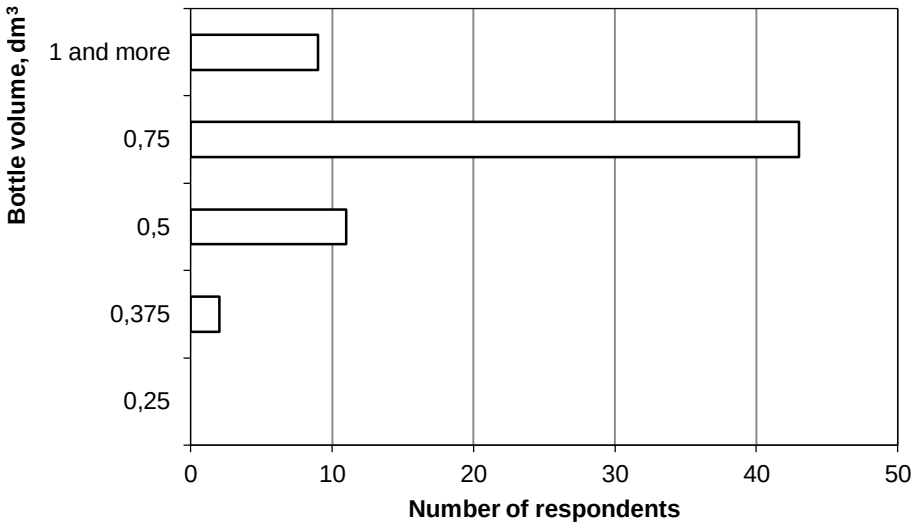

Figure 3. Consumer preference of a wine bottle volume

As a rule, the bigger the volume of a wine bottle, the more expensive it is. Nevertheless, quality wines including premium are poured into bottles of 0, 25 and 0, 375 dm^3 for hotel and catering business that cost more. On the supposition that with due regard for wine price abovementioned bottle volumes are not popular among majority of people.

Conclusion

Summarizing the results of our research, it can be concluded that today the culture of wine consumption is developed rapidly in Ukraine. And the consumer tends to awareness the product with history and old traditions, because wine plays an important role in the life of the modern man: for some it is tradition and holidays, for others it is special moments of life.

According to results wine and its packaging are considered a unified whole by the consumer, inasmuch as the appearance of the packaging plays an extremely important role in the consumer belief process.

Particular attention needs to be paid to exploring elements such as the design and label of the wine, because namely they encourage the undecided consumer to buy the product.

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Анотації

Харчові технології

Відновна здатність настоїв з відходів пряно-ароматичної сировини у технології алкогольних напоїв

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Вступ. Метою дослідження є вивчення відновної здатності водно-спиртових настоїв з відходів пряно-ароматичної сировини у технології алкогольних напоїв.

Матеріали і методи. Відновну здатність настоїв з відходів пряно-ароматичної сировини (*Perilla frutescens, Elsholtzia stauntonii Benth, Artemisia abrotanum, Monarda didyma, Agastache foeniculum, Satureja hortensis, Ruta graveolens, Nepeta transcaucasica Grossch)* визначали за методом редоксметрії та *pH*-метрії, сенсорні показники – за експертним методом.

Результати і обговорення. Відходи рослинної пряно-ароматичної сировини, які утворюються після мацерації, при подальшій підготовці можуть використовуватися повторно у технології алкогольних напоїв.

Щодо контролю (7,80 од. pH) настої мають значення водневого показника від 6,73 од. *pH* (*Agastache foeniculum*) до 7,35 од. *pH* (*Satureja hortensis*), що, відповідно, на 13,72% та 5,77% менше за контроль. Значення мінімального теоретичного окисно-відновного потенціалу для водно-спиртових настоїв Eh_{min} – від 219,0 мВ (*Satureja hortensis*) до 256,2 мВ (*Agastache foeniculum*), що на 14,06% та 33,44% перевищують контрольні (Eh_{min} 192 мВ). Значення фактично виміряного окисно-відновного потенціалу для водно-спиртових настоїв Eh_{act} – від 94,0 мВ (*Monarda didyma*) до 141,0 мВ (*Ruta graveolens*), що більше, відповідно, на 2,17% та 53,26% за контроль (Eh_{act} 92 мВ).

Водно-спиртові настої з відходів пряно-ароматичної сировини мають величину відновної здатності (енергію відновлення) *RE* від 101,4 мВ (*Ruta graveolens*) до 153,2 мВ (*Monarda didyma*), яка перевищує контроль (водно-спиртова суміш) *RE* 100 мВ на 1,40% та 53,20% відповідно.

Водно-спиртові настої з відходів пряно-ароматичної сировини мають значення сенсорних показників *S.e.* від 9,47 до 9,68 бала, тоді як контроль *S.e.* – 9,21 бала. Найбільше значення *S.e.* (9,68 бала) характерне для водно-спиртового настою з *Agastache foeniculum*: колір – ясно-бурштиновий (1,98 бала); смак – яскравий ефірний, трав'яний, запашний (3,98 бала); аромат – кисло-гіркий, терпкий (3,72 бала).

Висновки. Застосування відходів з пряно-ароматичної сировини *Monarda didyma* у водно-спиртових настоях призводить до підвищення відновних характеристик настоїв *RE* на 53,20 % і позитивних сенсорних показників *S.e.* – 9,51 бала за 10-бальною шкалою.

Ключові слова: *пряно-ароматичний, відходи, алкоголь, напій, антиоксидант, окисно-відновний потенціал, настій.*

Визначення ароматичних і летючих ароматичних сполук та органолептичних властивостей йогуртів з непорушеним згустком, збагачених незрілим зерном пшениці

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Вступ. Мета дослідження – визначити вплив збагачення йогурту незрілим зерном пшениці (IWG) на його аромат, летючі сполуки та органолептичні властивості.

Матеріали і методи. IWG збирали у дві різні стадії – молочної і тістової до фази повного дозрівання. Зразки йогурту збагачувались зерном (MSF) та борошном із тістового зерна (DSF) на різних рівнях (0, 1, 2 і 3%), щоб отримати перевагу від їхніх пребіотичних і функціональних властивостей. Вміст ароматичних і летючих сполук у зразках йогурту було визначено методом твердофазної мікроекстракції (SPME) на 1, 14 та 28-й день зберігання.

Результати і обговорення. Кількість ацетальдегіду, характерного ароматизатора йогурту, мала вищу концентрацію в йогурті, збагаченому MSF. Вміст ацетальдегіду зменшився з 14,87 до 7,54 проміле у пробах зі збільшенням періоду зберігання. Збільшення кількості етилового спирту спостерігалось у контрольних та інших збагачених зразках йогурту відповідно до зменшення кількості ацетальдегіду під час зберігання. В збагачених зразках йогурту виявлені такі летючі кислоти, як масляна, октанова, оцтова, гексанова, які поліпшували смак і аромат. Ізобутил 2-метилвалерат, який викликав смак і запах у зернових, визначали у зразках йогурту, збагачених MSF та DSF. Вміст цього складного ефіру збільшувався залежно від коефіцієнтів збагачення, і це призводило до інтенсивного зернового смаку в йогуртах із коефіцієнтом збагачення 3%. Зі збільшенням вмісту борошна IWG аромат зернових у йогурті переважає, що знижує оцінку споживачів.

Висновок. Використання IWG борошна у виробництві йогурту впливає на ароматичні та летючі смакові сполуки зразків йогурту. У цьому контексті ароматизатори можуть бути використані для маскування зернових ароматів і смаку, які домінують через збільшенню концентрації MSF та DSF у йогуртах.

Ключові слова: *йогурт, збагачення, пшениця, органолептика.*

Функціонально-технологічні властивості харчової нанодобавки на основі подвійного оксиду дво- та тривалентного заліза

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Вступ. Досліджено водо- і жироутримувальну здатності харчової нанодобавки на основі подвійного оксиду дво- та тривалентного заліза “Магнетофуд”(Fe_3O_4).

Матеріали і методи. Модельні системи: «крохмаль+магнетофуд», «яєчний білок+магнетофуд», «жир+магнетофуд». Водо- і жироутримувальну здатності досліджували за допомогою енергодисперсійної рентгенівської (EDX) та ІЧ-Фур'є спектроскопії (FTIR). Масову частку зв’язаної та вільної вологі визначали індикаторним методом (ІМ) та диференційно-термічним аналізом (ДТА).

Результати і обговорення. Відзначено здатність наночастинок харчової добавки Fe_3O_4 утворювати з високомолекулярними сполуками харчових систем (білками, вуглеводами, ліпідами) електростатичні комплекси – достатньо стійкі структури типу «кластерів», «клатратів», «кавітатів», «супрамолекулярних асоціатів», що сприяє зв'язуванню та утриманню води й жиру. Гідрофільні контакти сольватованих наночастинок Fe_3O_4 з диполями води, молекулами білків і полісахаридів (вуглеводів) підвищують стабільність поліфазних систем.

Зсунення в ІЧ-спектрах максимуму поглинання зв'язку Fe–O у високочастотну область на (57±2) $см^{-1}$ порівняно з дослідним зразком чистої харчової добавки «Магнетофуд» – Fe_3O_4 (ХДМ) свідчить про хімічну взаємодію катіонів феруму ХДМ з молекулами високомолекулярних сполук (крохмалю, яєчного білка, жиру).

Завдяки енергодисперсійним рентгенівським дослідженням встановлено хімічний склад модельних систем високомолекулярних сполук з (ХДМ): для частинок чистої ХДМ – Fe 75,5%; O 24,5%; для частинок добавки, покритих яєчним білком, – Fe 44,7%; O 26, 9%; C 21,4%; N 5,9%; S 1,1%; для частинок добавки, покритих крохмалем, – Fe 41,7%; O 35,7%; C 22,6%; для частинок добавки, покритих лінолевою кислотою, – Fe 45,6%; O 34, 7%; C 19,7%; для частинок добавки, покритих соняшникової олією, – Fe 39,7%; O 36,7%; C 23,67%.

Співвідношення зв'язаної та вільної вологи в сольватованій ХДМ: 50,5–51,6% води припадає на зв'язану вологу і 48,4–49,5% – на вільну, осмотичну (вода набухання) і фізико-механічну від загальної кількості води.

Висновки. Вперше запропоновано моделі взаємодії наночастинок Fe_3O_4 з водою, білками, жирами, вуглеводами для обґрунтування механізмів водо- і жироутримання наночастинками харчової добавки на основі подвійного оксиду дво- та тривалентного заліза.

Ключові слова: *водоутроутримання, жироутримання, оксид заліза, наноасоціат.*

Вплив кокосового молока на фізико-хімічні, мікробіологічні та органолептичні характеристики молочного продукту «Дахі»

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Вступ. Замінники молока на рослинній основі або безмолочні продукти – поширена тенденція розвитку нових харчових продуктів. Тому це дослідження було проведене з метою вивчення якості та потенціалу продукту «Дахі», приготованого з коров'ячого молока і кокосового молока.

Матеріали та методи. Отримані рецептури A (Контроль), B і C готували шляхом змішування коров'ячого молока і кокосового молока в трьох різних пропоріях (100:0, 50:50, 0:100). Склад, фізико-хімічні, сенсорні та мікробні властивості були визначені для оцінки якості зразків «Дахі».

Результати і обговорення. Результати фізико-хімічного аналізу показали зростання значень pH (4,05–4,33), TSS (14,05–14,90) та індексу солодкості (10,60–20,13) під час заміни коров'ячого молока кокосовим молоком. Також було помітне збільшення вологості (82,75–85,20%), жирності (1,57–3,06%) і зольності (0,71–2,94%).

Результати підказують, що додавання кокосового молока призводить до значного збільшення вмісту мінеральних речовин, а також ненасичених жирних кислот, що може сприяти користі для здоров'я. Кількість бактерій у всіх зразках становила (4,51–5,34)×10^5 cfu/ml, що відповідає прийнятим стандартам для кисломолочних продуктів. Результати цього дослідження також показали, що додавання кокосового молока значно покращило аромат і консистенцію «Дахі». В цілому прийнятність збагаченого кокосовим молоком «Дахі» була схожа з контрольним зразком (100% коров'ячого молока).

Висновок. «Дахі» з кокосового молока може бути відповідним замінником звичайних молочних продуктів «Дахі», що може бути цінним для осіб з непереносимістю лактози.

Ключові слова: *"Дахі", кокос, молоко, корова, якість.*

Вплив температури води та приросту вологи на температуру пшениці під час зволожування

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Вступ. Метою дослідження є розроблення спрощеної залежності для визначення температури зерна пшениці при його зволожуванні з урахуванням коефіцієнтів теплоємності, яка зв'язує температуру зерна пшениці після зволожування з його початковою температурою, температурою води та кількістю води, якою зволожується зерно.

Матеріали і методи. Дослідження проводились на основі математичного моделювання з урахуванням теплопровідності зерна та води. Обробку дослідних даних здійснювали за допомогою методу найменших квадратів. Перевірку адекватності отриманої залежності здійснювали за допомогою F-критерію Фішера.

Результати і обговорення. При зволожуванні зерна пшениці, температура якого збільшується від -10 °С до 50 °С водою, температура якої збільшується від 5 °С до 60 °С, температура зерна збільшується за лінійною залежністю. Це надало можливість розробити лінійну залежність температури зерна пшениці після зволожування, яка враховує початкову температури зерна і початкову температуру води при незмінній кількості води, яку додано до зерна.

З метою введення до отриманої залежності показника, який враховує кількість води, проведено дослідження зміни температури зерна пшениці, зважаючи на його початкову температуру, різну кількість води і незміну температуру, яка становила 20 °С. Аналіз отриманих результатів показав, що температура зерна пшениці лінійно збільшується при збільшенні його температури та збільшенні кількості води, яку введено у зернову масу. Виявлено, що лінійні прямі змінюють кут нахилу відносно точки, яка дорівнює температурі 10 °С. Це дало ввести у лінійну залежності добуток, який враховує кількість доданої до зернової маси води.

Перевірка адекватності отриманої лінійної залежності підтвердила, що рівняння адекватне. Аналіз отриманих даних показав, що відхилення температури зерна, розраховане за лінійним рівнянням та фізичною моделлю, коливається в межах 1,0 °С за абсолютним значенням.

Висновки. У результаті дослідження зміни температури зерна при його зволожуванні підігрітою водою отримано узагальнену залежність, в якій враховано коефіцієнти теплопровідності. Отриману залежність можна рекомендувати для аналізу температури зерна пшениці в процесі його зволожування.

Ключові слова*: пшениця, температура, вологість, вода*

Вплив знакозмінних імпульсів тиску на сенсорні характеристики та дегустаційне оцінювання води, асоційованих водних систем і розчинів

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Вступ. Метою дослідження є визначення впливу знакозмінних імпульсів тиску на сенсорні характеристики та дегустаційне оцінювання води, асоційованих водних систем і розчинів.

Матеріали і методи. Предметом дослідження є зміна фізичних і хімічних параметрів та властивостей водних систем і розчинів під час оброблення в умовах знакозмінних імпульсів тиску. Використані загальнонаукові та спеціальні методи досліджень, зокрема електрохімічні. Окрім цього, використано метод сенсорного аналізу зразків води та розчинів.

Результати і обговорення. Встановлено, що значна кількість методів оброблення водних систем, які широко застосовуються у різних галузях харчової промисловості, є недостатньо вивченою.

Фізичні та хімічні властивості і параметри води, водних систем і розчинів такі як окисно-відновний потенціал, водневий показник, кількість розчиненого кисню тощо, можуть змінюватись завдяки застосуванню методів фізичного впливу.

Дегустаційні випробування води, одержаної за технологією підприємства, та води, обробленої в умовах знакозмінних імпульсів тиску, з різним часом оброблення піддавались порівняльному аналізу.

У результаті порівняльного аналізу встановлено, що вода, оброблена в умовах знакозмінних імпульсів тиску, протягом 1 с має покращений зовнішній вигляд, забарвлення, аромат, смак. Дегустаційний бал підвищився на 12,12%, якщо порівняти з контрольними зразками, що є досить вагомим показником якості води. Оброблення води знакозмінними імпульсами тиску протягом 30 с сприяє покращенню смаку. Слід зауважити, що дегустаційний бал підвищився на 3%. В результаті оброблення води протягом 60 с відбувається підвищення загального дегустаційного балу майже на 9%, при цьому покращується смак. Оброблення протягом 90 с призводить до покращення аромату води. Загальний бал при цьому підвищився майже на 9%.

Висновки. Загальний бал зразків води та водних розчинів, які були оброблені в умовах знакозмінних імпульсів тиску, мав підвищені показники якості порівняно з контрольними зразками. Це позитивним чином впливає на якість готового продукту на основі обробленої води та водних розчинів.

Ключові слова: *сенсорний, аналіз, рідкий, оброблення, тиск.*

Використання молочної сироватки у технології молочних десертів

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Вступ. У світі інтенсивно ведуться дослідження з модифікації складу та властивостей молочної сироватки, метою яких є регулювання характеристик для застосування в різних галузях промисловості, зокрема створення якісно нових продуктів харчування спеціального призначення.

Матеріали і методи. Об'єкт дослідження – молочна сироватка як сировина при виробництві молочних десертів.

Результати і обговорення. Реалізація методів повного циклу переробки молочної сироватки шляхом виділення, концентрування, модифікації її властивостей та розроблення інноваційних технологій її використання для харчових продуктів, зокрема цільового призначення, має визначену ресурсозберігаючу спрямованість. Це дасть змогу ефективно використовувати технологічні властивості наповнювачів, їхні синергічні взаємодії між собою та з молочною сироваткою, покращити функціонально-технологічні характеристики молочної сироватки, розширити можливості використання в технологіях виробництва харчових продуктів на основі молочної сироватки.

Вченими проводяться дослідження зі створення технологій подальшого використання молочної сироватки у молочній промисловості для виробництва напівфабрикатів, технологічних сумішей і функціональних продуктів для отримання повноцінних харчових продуктів цільового призначення та забезпечення в такий спосіб населення білками та нутрієнтами в біодоступній формі.

Запровадження ресурсозберігаючих технологій і виготовлення якісної та безпечної продукції з високими споживчими властивостями сприяє вирішенню проблеми білкового дефіциту, а також забезпечення населення різних соціальних груп та умов проживання повноцінними, збалансованими за біодоступним мікронутрієнтним складом комбінованими і багатокомпонентними харчовими продуктами цільового призначення.

Висновки. Поєднання молочних компонентів і плодово-ягідних наповнювачів забезпечить бажаний технологічний ефект та оригінальні органолептичні характеристики нових видів молочних десертів.

Ключові слова: *молочна сироватка, десерти, плодово-ягідні наповнювачі.*

Процеси, обладнання і системи контролю

Моделювання процесу агрегації наночастинок в гетерогенних дисперсних системах

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Вступ. Дослідження агрегації частинок актуально і досліджується в хімічних технологіях, біофізиці при вирішенні проблем очищення від аерозольних або колоїдних забруднень.

Матеріали та методи. Розглядається вплив наночастинок на кінетику агрегації дисперсних фаз у суспензії. Використовуються моделі, що засновані на модифікаціях методу динаміки частинок з урахуванням сил Ван-дер-Ваальса, гравітації, Броунівських і Стоксових сил на основі напівемпіричних залежностей для швидкостей агрегації і дезагрегації при зіткненнях.

Результати та обговорення. На основі аналізу рівняння Смолуховського, молекулярно-кінетичної та локально-ізотропної турбулентності Колмогорова теорій досліджено динаміку одночасного турбулентного та броунівського перенесення на процес «швидкої коагуляції» та запропоновано механізм впливу наночастинок на їх агрегатоутворюючу здатність у колоїдних гетерогенних дисперсних системах.

Розроблені рівняння для швидкості дисипації кінетичної енергії в суспензії дозволяють визначити дисперсність часток, при яких в механізмі коагуляції переважає броунівська дифузії часток. Тобто, чим інтенсивніший процес перемішування суспензії, тим більшу роль в процесі коагуляції, седиментації та фільтруванні відіграють частинки нанорозмірного діапазону, які включаються в турбулентний вихоровий рух. Наведені результати корисні для практичного застосування при керуванні інтенсивністю процесів коагуляції в апаратах змішувального типу.

Висновки. Запропоновано механізм впливу наночастинок на їх агрегатоутворюючу здатність у колоїдних гетерогенних дисперсних системах.

Ключові слова: *коагуляція, агрегація, наночастинка, дифузія, швидкість дисипації.*

Синтез інтелектуальної системи управління електропостачанням процесів виробництва харчових продуктів з прогнозуванням споживання електроенергії

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Вступ. Дослідження проведено з метою обґрунтування методів інтелектуальної системи управління електропостачанням процесів виробництва харчових продуктів (ПВХП) для підвищення ефективності використання електроенергії.

Матеріали і методи. Дослідження базується на інтелектуальних методах управління, алгоритмі прогнозування споживання електроенергії з використанням штучних нейронних мереж та активному методі ідентифікації статичних характеристик навантаження.

Результати і обговорення. На основі системного аналізу управління ПВХП визначаються критерії та функції управління. Для реалізації функцій управління в інтелектуальній системі управління електропостачанням ПВХП використовується модель прогнозування споживання електроенергії, алгоритми прийняття рішень управління електропостачанням, процедура формування оптимального переліку споживачів-регуляторів та обчислення раціональних режимів споживання електроенергії.

Для прогнозування споживання електроенергії на харчовому виробництві вибрано багатошаровий перцептрон із набору архітектур штучних нейронних мереж.

Показано, що оптимальна конфігурація нейронної мережі – це тришаровий перцептрон із прихованим шаром, де кількість елементів дорівнює половині суми елементів вхідного та вихідного шарів. Навчання перцептрону здійснюється комбінованим машинним методом зворотного поширення помилки / машини Коші. Обчислювальний експеримент з прогнозуванням споживання енергії на виробництво продуктів харчування на рік вперед має помилку в навчанні в межах 0,05–0,06.

Алгоритм визначення оптимальної напруги, що забезпечує енергоефективні режими роботи енергосистеми, використовує статичні характеристики напруги навантаження. Для підвищення точності та ефективності алгоритму обґрунтовано використання процедури ідентифікації статичних характеристик навантаження в інтерактивному режимі для основних режимів технологічного процесу з урахуванням стану споживачів-регуляторів та ступеня компенсації реактивної потужності з використанням трансформатора, оснащеного електронним вимикачем.

Висновки. Алгоритми інтелектуальної системи управління електропостачанням ПВХП стають більш ефективними і точними завдяки застосуванню процедур прогнозування споживання енергії та ідентифікації статичних характеристик навантаження.

Ключові слова: *електроенергія, управління, інтелектуальний, перцептрон.*

Аналіз роботи апаратів харчової промисловості при застосуванні сплавів з ефектом пам'яті форми

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Вступ. Метою дослідження є проведення комплексного аналізу інноваційних пристроїв на основі сплавів з ефектом пам'яті форми (ЕПФ) для застосування в апаратах харчових технологій.

Матеріали і методи. Використовувались фізичне та математичне моделювання процесів, положення теорії автоматичного керування, теорія нечіткої логіки.

Результати і обговорення. Проведений комплексний аналіз пристроїв на основі матеріалів з ефектом пам'яті форми (ЕПФ), які можуть бути застосовані в апаратах харчової промисловості. Зокрема, проаналізована конструкція та принцип дії термоклапанів, що вирізняються простотою конструкції і надійністю; індикатора критичного підвищення температури корпусу апарата та гайки сигналізатора аварійного перегрівання роз'ємного корпусу технологічної установки, які підвищують надійність роботи апаратів; термоприводу, який може бути ефективно використаний на підприємствах, де виникає потреба утилізувати низькотемпературну теплову енергію, та геліоприводу.

Конструкція індикатора критичного підвищення температури роз'ємного корпусу технологічної установки відзначається високою технологічністю та надійністю.

На багатьох підприємствах виникає потреба утилізувати теплову енергію при порівняно невеликому перепаді температур. Цим вимогам відповідає конструкція термонасоса.

Силові елементи на основі сплавів з ЕПФ мають суттєві переваги: меншу масу, робота в широкому діапазоні температур, незначні габарити, плавне переміщення робочих органів, меншу вартість, високу чутливість.

Приводи на основі термочутливих елементів з ЕПФ ефективні в сонячних енергоустановках.

Ключові слова: *апарат, пам'ять, форма, термопривід, температура, термоклапан, геліопривід.*

Економіка

Порівняння цінової еластичності попиту на яйця в Литві та Україні

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Вступ. Еластичність – це міра, яка показує, наскільки сильно реагують покупці та продавці на зміни ринкових умов. У статті досліджена цінова еластичність попиту на яйця в Литві та Україні.

Матеріали і методи. Під час вимірювання еластичності попиту на яйця в Литві та Україні використовувались статистичні дані 2003–2018 рр. відповідно до даних Служби статистики Литви та Державної служби статистики України. Як інструменти дослідження було застосовано методи аналізу даних, порівняння та узагальнення. Річний коефіцієнт цінової еластичності попиту на яйця розраховувався за формулою середньозваженої величини. Також було використано медіану для визначення середнього та багаторічного коефіцієнта еластичності попиту на яйця. З метою наочної демонстрації результатів дослідження були використані графічні методи.

Результати і обговорення. Встановлено, що в 2003–2018 рр. коливання роздрібних цін на яйця було характерним і для Литви, і для Україні. При цьому більш об'єктивнішою ситуація була в Україні. У досліджуваний період переважала тенденція до зростання роздрібних цін. Якщо порівнювати кінець періоду дослідження (2018 р. із 2003 р.), то роздрібні ціни на яйця в Литві зросли в 1,9 раза, а в Україні – у 4,5 раза. Крім цього, незважаючи на стрімке зростання цін, у 2003–2018 рр. яйця на українському роздрібному ринку дешевшали.

Аналіз попиту на яйця в Литві та Україні показав, що клієнти реагували на коливання цін лише протягом короткого проміжку часу. Коли ціна на яйця зросла, споживання яєць зменшувалося; пізніше, однак, незважаючи на подальше зростання цін, споживання цього харчового продукту поверталося до попереднього рівня.

Також на основі даних, що показують ціни та споживання яєць, розраховані коефіцієнти цінової еластичності попиту на яйця в Литві (0,28) та Україні (0,35).

Висновки. Проведене дослідження підтверджує гіпотезу про те, що в Литві та Україні попит на яйця є нееластичним.

Ключові слова: *яйце, попит, ціна, еластичність, Литва, Україна.*

Вплив страхування та інфляції на економічний розвиток і безпеку продовольчого ринку

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Вступ. Метою дослідження є аналіз впливу страхування та інфляції на економічний розвиток та безпеку продовольчого ринку. Крім того, одним із ключових завдань статті є оцінка взаємозв'язку між споживчими цінами, валовими страховими преміями та валовим страховим продуктом, експортом та імпортом продуктів харчування.

Матеріали і методи. Модель наукової роботи обґрунтована на основі літературного огляду попередніх досліджень у цьому напрямі. Для визначення впливу страхування та інфляції на економічний розвиток і безпеку продовольчого ринку використовувався кореляційно-регресійний аналіз. Також розраховано коефіцієнт парної кореляції Пірсона (r), коефіцієнт детермінації (r^2), статистична значущість F, P-значення для коефіцієнта регресії та однофакторні лінійні рівняння регресії.

Результати і обговорення. Відповідно до результатів цього дослідження всі сімнадцять досліджуваних країн було поділено на чотири групи залежно від рівня взаємозв'язку і статистичної значимості впливу страхування та інфляції на економічний розвиток і безпеку продовольчого ринку. Група 1 – сильна прямо пропорційна (обернено пропорційна) лінійна регресія, де коефіцієнт кореляції $0{,}700 \leq \mathbf{r} < 0{,}900$ ($-0{,}900 < \mathbf{r} \leq -0{,}700$). Так, наприклад, цей тип взаємозв'язку описує вплив інфляції на валовий внутрішній продукт у Туреччині, Італії, Іспанії та Данії або вплив страхування на структуру продовольчого експорту в Австралії, Ісландії, Нідерландах, Франції, Туреччині та Бельгії. Група 2 – середній прямо пропорційний (обернено пропорційний) взаємозв'язок, де коефіцієнт кореляції $0{,}500 \leq \mathbf{r} < 0{,}700$ ($-0{,}700 < \mathbf{r} \leq -0{,}500$). Наприклад, цей тип взаємозв'язку описує вплив інфляції на структуру продовольчого експорту у Франції та Туреччині або вплив страхування на структуру продовольчого імпорту у Швейцарії, Франції, Великій Британії, Нідерландах та Іспанії. Група 3 – слабка прямо пропорційна (обернено пропорційна) лінійна регресія з коефіцієнтом кореляції $0{,}300 \leq \mathbf{r} < 0{,}500$ ($-0.500 < \mathbf{r} \leq -0.300$). Цей тип взаємозв'язку описує вплив інфляції та структуру продовольчого імпорту в Данії, Франції, Фінляндії, Туреччині, Швейцарії та Бельгії або вплив страхування на цей же показник безпеки продовольчого ринку в Австралії, Фінляндії, Японії та Данії. Група 4 – характерна для країн, де між досліджуваними показника інфляції, страхування та індикаторами безпеки продовольчого ринку немає лінійного взаємозв'язку, тобто коефіцієнт кореляції $0{,}000 \leq \mathbf{r} < 0{,}300$ ($-0{,}300 < \mathbf{r} \leq 0{,}000$).

Висновки. У статті обґрунтовано вплив страхування та інфляції на безпеку продовольчого ринку, на основі чого стане можливим підвищення ефективності регулювання як фінансового ринку, так і підвищення безпеки продовольчого ринку на міжнародному рівні.

Ключові слова: *страхування, інфляція, безпека, продовольство, експорт, імпорт, ВВП.*

Аналіз споживчих переваг при виборі вина

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Вступ. Досліджено особливості поведінки споживачів при виборі вина, що продиктовано необхідністю виявлення уподобань для впровадження ефективної товарної політики.

Матеріали і методи. Дослідження базуються на даних соціологічного опитування, яке проводилось на основі анкети, що складалася з двох частин: питання стосовно особистості, зокрема стать, вік, рівень доходу, соціальний статус, і безпосередньо питання щодо вибору пляшки вина з варіантами відповідей. Таблиці спряженості і критерій $\chi 2$ були використані для встановлення статистичних взаємозв'язків між факторними і результативними ознаками.

Результати і обговорення. Різні характеристики вина, включаючи його економічні, технологічні, ампелографічні складові, а також зовнішній вигляд пляшки та етикетки напою, суттєво впливають на споживачів різних соціальних статусів. Так, жінки і чоловіки з різним сімейним статусом відрізняються у виборі вина, враховуючи саме сорт винограду, з якого воно виготовлено, при цьому інші якісні ознаки вина критично не впливові. Крім того, споживачі з різним рівнем доходу обирають вина різних цінових категорій, органолептичні якості яких вважають відмінними. Проте ціна вина та його гастрономічні властивості є статистично значущими для осіб різних вікових категорій від 18 до 50 років, що підтверджує різницю між уподобаннями поколінь. Також саме жінки віком від 25 до 35 років із доходом, вищим за 200 доларів США, схильні купувати сувенірні пляшки вина.

Незалежно від сімейного стану учасники анкетування купують вина в усіх запропонованих місцях його продажу, проте ті, хто має вищий рівень доходу, віддають перевагу винним спеціалізованим магазинам. Особи, які перебувають у шлюбі, обирають вина до свят, з лікувальною метою або для гастрономічного задоволення, оскільки вино збагачене антиоксидантами, вітамінами і має порівняно низьку калорійність. Респонденти, вік яких перевищує 35 років, також більш схильні купувати вино у вищезгаданих крамницях або безпосередньо з винних підприємств, що можливо пов'язано з більшим досвідом у виборі алкогольних напоїв. Більшість респондентів обирають вина, етикетка яких є простою і зрозумілою, особливо, із зображенням виноробні, грона винограду, оскільки демонструє виробництво вина, його місце походження. Також більша частина споживачів воліють додати інформацію на етикетці про поєднання вина з певними продуктами і схильні купувати вино, пляшка якого є стандартною – 0,75 дм^3.

Висновки. Критерії вибору вина, його якісні властивості та вибір місця придбання відрізняється між споживачами з різними особистісними характеристиками, що має практичне значення для побудови ефективного товаропросування, враховуючи уподобання населення.

Ключові слова: *вино, споживач, уподобання, етикетка, вибір.*

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Автори (рік видання), Назва статті, *Назва журналу (курсивом)*, том (номер), сторінки.

Всі елементи після року видання розділяються **комами**.

Приклади:

1. Yannick Fayolle, Sylvie Gillot, Arnaud Cockx, Laetitia Bensimhon, Michel Roustan, Alain Heduit (2010), In situ characterization of local hydrodynamic parameters in closed-loop aeration tanks, *Chemical Engineering Journal*, 158(2), pp. 207–212.
2. Carlo Tocchi, Ermanno Federici, Laura Fidati, Rodolfo Manzi, Vittorio Vincigurerra, Maurizio Petruccioli (2012), Aerobic treatment of dairy wastewater in an industrial three-reactor plant: Effect of aeration regime on performances and on protozoan and bacterial communities, *Water Research*, 46(10), pp. 3334–3344.

Приклад оформлення статті, оригінал якої українською мовою:

1. Pyroh T.P., Konon A.D., Skochko A.B. (2011), Vykorystannia mikrobnykh poverkhnevo-aktyvnykh rechovyn u biolohii ta medytsyni, *Biotekhnolohiia*, 4(2), pp. 24–38.

За бажання після транслітерованої назви статті або журналу в {фігурних дужках можна дати переклад англійською мовою}.

Посилання на книгу

Автори (рік), *Назва книги (курсивом)*, Видавництво, Місто.

Всі елементи після року видання розділяються комами.

Приклади:

1. Harris L. (1991), *Money theory*, McGraw-Hill Companies, Hardcover
2. Rob Steele (2004), *Understanding and measuring the shelf-life of food*, CRC Press.

Приклад оформлення статті, оригінал якої українською або російською мовою:

1. Kirianova H.A. (2008), Udoskonalennia tekhnolohii termostabilnykh zheleinykh nachynok shliakhom ratsionalnoho vykorystannia hidrokoloidiv roslynnoho ta mikrobnoho pokhodzhennia: PhD tethis, NUHT, Kyiv.
2. Zalutskyi I.R., Tsymbaliuk V.M., Shevchenko C. H. (2009), Planuvannia i diahnostyka diialnosti pidpryiemstva, Novyi svit, Lviv.

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Приклад посилання на статтю із електронного видання:

1. Barbara Chmielewska. (2012), Differentiation of the standard of living of families in countries of the European Union, *Ukrainian Food Journal*, 2(2), pp. 230–241, available at: http://ufj.ho.ua/Archiv/UKRAINIAN%20FOOD%20JOURNAL%202013%20V.2%20Is.2.pdf
2. (2013), *Svitovi naukovometrychni bazy*, available at: http://www1.nas.gov.ua/publications/q_a/Pages/scopus.aspx

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